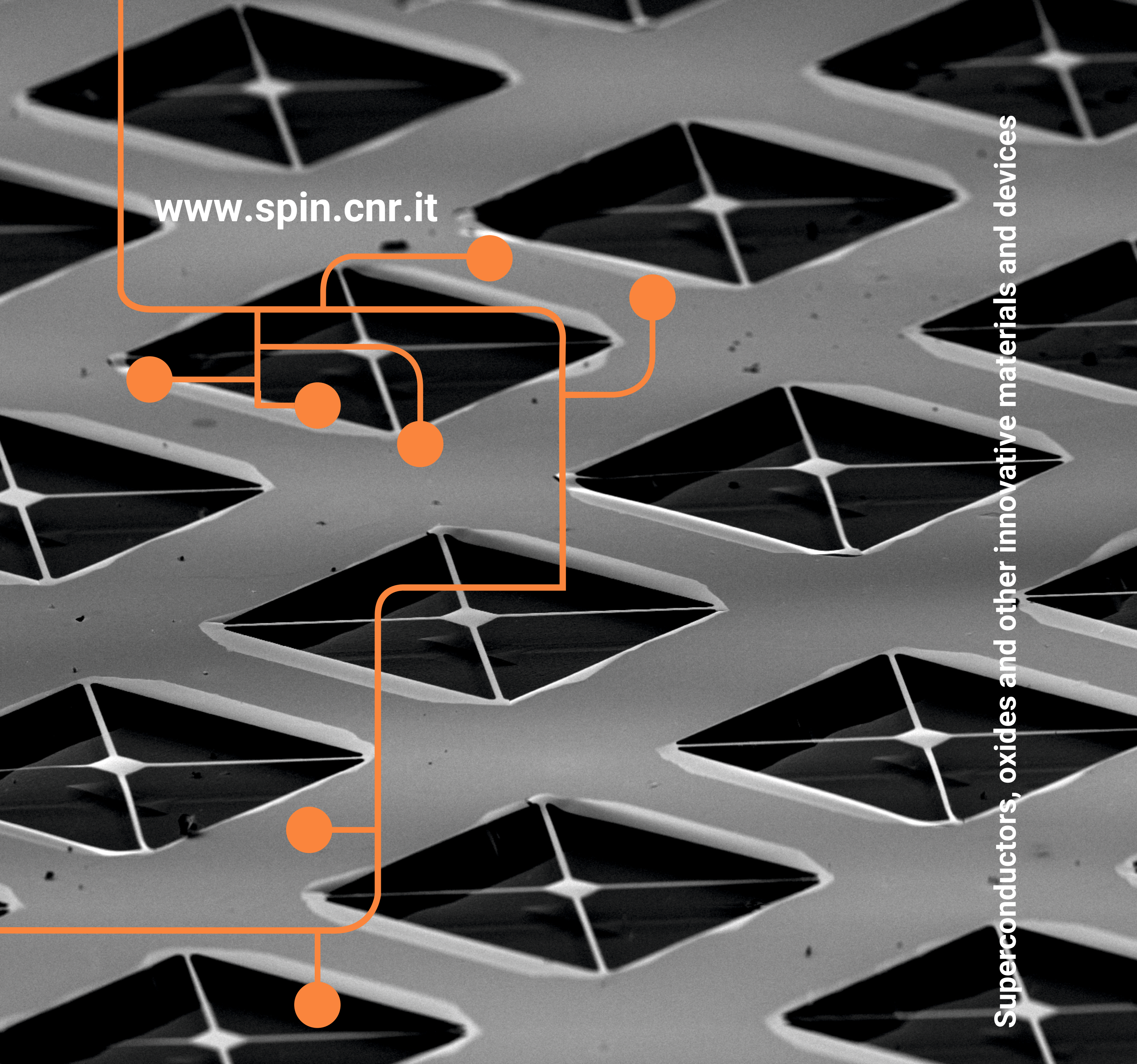


www.spin.cnr.it

Superconductors, oxides and other innovative materials and devices

Scientific Report 2020-2021

Consiglio Nazionale delle Ricerche

SPIN

Editorial Project by
SPIN - CNR

Project and editorial coordination
Paolo Barone, Valeria Braccini, Gaia Grimaldi, Daniele Marré

Graphical and editorial design
Daniela Gaggero, Cnr - Communication Unit

Editors of scientific contents
Fabio Miletto Granozio with contributions from all SPIN Researchers

Cover Image
Array of trampolines made of a magnetic oxide thin film, by C. Bernini and N. Manca

Thanks to
Barbara Cagnana, Roberta De Donatis, Marco Raimondo for the support

www.spin.cnr.it

Consiglio Nazionale delle Ricerche

SPIN

Scientific Report 2020-2021

Summary

90
Life and events

102
Publications

25
Research activities with Highlights

Activity A
Novel superconducting and functional materials for energy and environment

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

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

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

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

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

Foreword

Foreword

The SPIN (SuPerconducting and other INnovative materials and devices) Institute is part of the National Research Council (CNR), which, in turn, is the largest public organization pursuing research and innovation in Italy. SPIN belongs to the CNR Department of Physical Sciences and Technologies of Matter (DSFTM).
This document is the SPIN biennial report for the years 2020-2021. It is the sixth report since the Institute was founded.
Year 2021 had been a quite complex year for the SPIN Institute, not only because of the effects of the SARS-CoV-2 pandemic that affected the whole biennium. In this year, three Directors followed one another at the head of the Institute. Dr. Carlo Ferdeghini, who retired at the end of his second mandate on March 31st; dr. Silvia Picozzi, as Acting Director, until June 31st; the current Director, Dr. Fabio Miletto Granozio, who started his mandate on July 1st.
In the course of the 2020-2021 biennium, SPIN has been 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. Such scientific organization is being revised in year 2022.
SPIN competed successfully in these two year both on the National and International field for the acquisition of funding on many different calls, in the domains of Superconductivity, Oxides, Nanomaterials and Quantum Technologies. A list and a description of the most significant can be found in the Report.
The collection of highlights, as well as the final publication list, allow the reader to appreciate the variety and the very high scientific level of the research carried out in SPIN. The section dedicated to the communication and dissemination of science, both among scientists and towards the general public demonstrate our very strong engagement in the field.
I wish to thank the working group that supervised the preparation of the report (Paolo Barone, Valeria Braccini, Gaia Grimaldi and Daniele Marré) and Daniela Gaggero for editing the document.
Sincere thanks to Barbara Cagnana, Roberta De Donatis, Diletta Miceli, Maria Paola Osteria, Daniela Pollio, Marco Raimondo, to the activity leaders and to the whole SPIN community for providing the relevant information.

The CNR-SPIN Director

Fabio Miletto Granozio

Management

Management

2020-2021

Fabio
Miletto Granozio

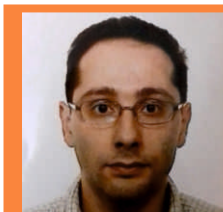
The Director and the Executive Board are the management bodies of the Institute.

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

Paolo
Barone

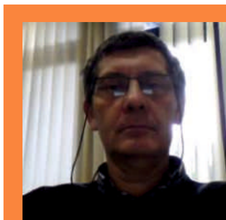
Roberto
Felici



Andrea
Gerbi

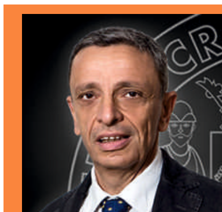
Gaia
Grimaldi

Alberto
Porzio

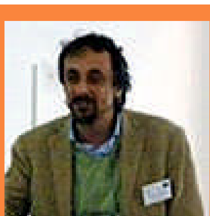


Ettore
Sarnelli

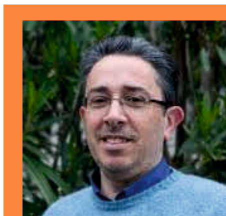
Alberto
Martinelli



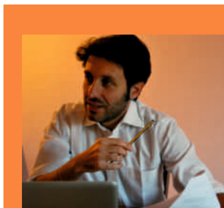
Carmine
Attanasio



Vittorio
Cataudella

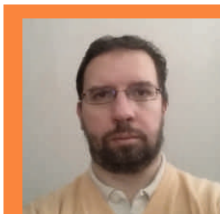


Daniele
Marré



Gianni
Profeta

Salvatore
Abate



Marco
Raimondo

Community

Community

Researchers

Carmela Aruta (RM)
Paolo Barone (RM)
Mario Barra (NA)
Emilio Bellingeri (GE)
Cristina Bernini (GE)
Francesco Bisio (GE)
Valeria Braccini (GE)
Renato Buzio (GE)
Federico Caglieris (GE)
Barbara Cagnana (GE)
Carlo Camerlingo (NA)
Giovanni Cantele (NA)
Matteo Carrega (GE)
Fabio Chiarella (NA)
Alessandro Ciattoni (AQ)
Carla Cirillo (SA)
Roberto Cristiano (NA)
Mario Cuoco (SA)
Mikkel Ejrnaes (NA)
Martina Esposito (NA)
Roberto Felici (RM)
Carlo Ferdeghini (GE)
Annalisa Fierro (NA)
Rosalba Fittipaldi (SA)
Vittorio Foglietti (RM)
Filomena Forte (SA)
Paola Gentile (SA)
Andrea Gerbi (GE)
Filippo Giubileo (SA)
Gaia Grimaldi (SA)
Gianrico Lamura (GE)
Mariateresa Lettieri (SA)
Alessandro Leveratto (GE)
Mikhail Lisitskiy (NA)
Procolo Lucignano (NA)
Andrea Malagoli (GE)
Nicola Manca (GE)
Alberto Martinelli (GE)
Nadia Martucciello (SA)
Fabio Miletto Granozio (NA)
Riccardo Moroni (GE)
Pasquale Orgiani (SA)
Ilaria Pallecchi (GE)
Luca Pellegrino (GE)
Massimo Pica Ciamarra (NA)
Silvia Picozzi (AQ)
Alberto Porzio (NA)
Carlo Rizza (AQ)
Marco Salluzzo (NA)
Alessia Sambri (NA)
Ettore Sarnelli (NA)
Alessandro Stroppa (AQ)
Cesare Tresca (AQ)
Andrei Varlamov (RM)
Antonio Vecchione (SA)
Maurizio Vignolo (GE)
Xuan Wang (NA)

Research Associates

Amoruso Salvatore (NA)
Andreone Antonello (NA)
Attanasio Carmine (SA)
Ausanio Giovanni (NA)
Avella Adolfo (SA)
Balestrino Giuseppe (RM)
Bobba Fabrizio (SA)
Bruzzese Riccardo (NA)
Canepa Fabio Michele (GE)
Carapella Giovanni (SA)
Cassinese Antonio (NA)
Cataudella Vittorio (NA)
Citro Roberta (SA)
Cristiano Roberto (NA)
De Candia Antonio (NA)
De Filippis Giulio (NA)
De Lisio Corrado (NA)
Di Capua Roberto (NA)
Di Castro Daniele (RM)
Ferretti Maurizio (GE)
Ghiringhelli Giacomo Claudio (NA)
Iannotti Vincenzo (NA)
Manfrinetti Pietro (GE)
Maritato Luigi (SA)
Marré Daniele (GE)
Massone Anna Maria (GE)
Nigro Angela (SA)
Ninno Domenico (NA)
Noce Canio (SA)
Nucara Alessandro (RM)
Ottaviano Luca (AQ)
Pagano Sergio (SA)
Pani Marcella (GE)
Parlato Loredana (NA)
Pepe Giovanni Piero (NA)
Perroni Carmine Antonio (NA)
Piana Michele (GE)
Polichetti Massimiliano (SA)
Profeta Gianni (AQ)
Putti Marina (GE)
Romano Alfonso (SA)
Romano Paola (SA)
Sassetti Maura (GE)
Tafuri Francesco (NA)
Tebano Antonello (RM)
Vaglio Ruggero (NA)

Affiliated Fellowships

Ahmad Halima Giovanna (NA)
Alecci Marcello (AQ)
Aloisio Alberto (NA)
Autieri Carmine (SA)
Avallone Guerino (SA)
Barone Carlo (SA)
Capra Marco (GE)
Caruso Roberta (NA)
Cavaliere Fabio (GE)
Chao Liu (URT CH)
Chianese Federico (NA)
Cialone Matteo (GE)
Conte Felice (NA)
Crescente Alba (GE)
D'Antuono Maria (NA)
De Luca Gabriella Maria (NA)
Della Penna Stefania (URT CH)
Di Bartolomeo Antonio (SA)
Di Gennaro Emiliano (NA)
Faella Enver (SA)
Ferraro Dario (GE)
Galante Angelo (AQ)
Galluzzi Armando (SA)
Giovannini Mauro (GE)
Giuliano Domenico (NA)
Granata Veronica (SA)
Grillo Alessandro (SA)
Iebole Michela (GE)
Iemmo Laura (SA)
Khan Massod Rauf (SA)
Leo Antonio (SA)
Marini Giovanni (AQ)
Massarotti Davide (NA)
Meinero Martina (GE)
Nicodemi Mario (NA)
Papari Gian Paolo (NA)
Passacantando Maurizio (AQ)
Passarelli Gianluca (NA)
Pelella Aniello (SA)
Plaza Alejandro Enrique (GE)
Rebora Giacomo (GE)
Rizza Carlo (AQ)
Saba Aisha (GE)
Salvoni Daniela (NA)
Sanna Simone (RM)
Schott Marine (GE)
Serdaroglu Goncagul (AQ)
Siviello Ciro (NA)
Sorrentino Alberto (GE)
Stornaiuolo Daniela (NA)
Sylva Giulia (GE)
Traverso Andrea (GE)
Traverso Ziani Niccolò (GE)
Urban Francesca (SA)
Wang Hongbo (AQ/CH)
Yerin Yuriy (RM)

Administrative staff

Arnone Alberto (GE)
Calvisi Vincenza (AQ)
Camauli Enrico (GE)
Dalla Libera Monica (GE)
Di Lello Piero (GE)
Distefano Fabio (GE)
Garbarino Maria Carla (GE)
Gatti Maria Antonietta (AQ)
Iannotta Carmela (NA)
Loffredo Antonia (SA)
Morra Sonia (NA)
Osteria Maria Paola (NA)
Parisi Cristina (NA)
Poggi Sabrina (GE)
Pollio Daniela (GE)
Punginelli Marco (GE)
Sacco Rosalia (SA)
Santroni Adriana (GE)
Scotto Stefania (GE)
Talamo Valeria (GE)

Technical staff

Abate Salvatore (SA)
Ciocia Paolo (GE)
Loria Federico (GE)
Nunziata Immacolata
Raimondo Marco (GE)
Robustelli Chiara (GE)
Scotto di Vettimo Paolo (NA)
Taurino Francesco M. (NA)

Struttura comune di supporto agli Istituti IOM, NANO e SPIN

Coordinatore
Marco Campani (CNR-IOM)

Unità organizzativa gare e appalti, amministrazione e servizi generali del comprensorio
Referente Danilo Imperatore Antonucci (CNR-IOM)
Alberto Arnone (CNR-SPIN), Marco Punginelli (CNR-SPIN)
Enrico Camauli (CNR-SPIN), Paolo Ciocia (CNR-SPIN)
Monica Dalla Libera (CNR-SPIN), Josè Carlos De Almeida Nunes Manganaro (CNR-IOM), Piero Di Lello (CNR-SPIN)

Unità organizzativa supporto al reclutamento del personale a tempo determinato e assimilato e supporto giuridico fiscale
Matilde Bolla (CNR-IOM), Enrico Camauli (CNR-SPIN), Fabio Distefano (CNR-SPIN), Giuseppe Genovese (CNR-NANO), Liliana Sciaccaluga (fino al 30 aprlie 2020), Simone Spinozzi (CNR-NANO), Marco Punginelli (CNR-SPIN)

Unità organizzativa supporto alla progettualità e al reperimento di fondi esterni - Area 1 - progetti regionali, nazionali, europei ed internazionali
Referente Barbara Cagnana (CNR-SPIN)
Francesca Fortunati (CNR-IOM), Paola Corezzola (CNR-NANO)

Unità organizzativa supporto alla progettualità e al reperimento di fondi esterni - Area 2 - collaborazioni industriali e istituzionali
Monica Dalla Libera (CNR-SPIN), Diletta Miceli (CNR-IOM)
Elisabetta Narducci (CNR-IOM)

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

Genova

Headquarter
Corso F.M.Perrone, 24 16152 Genova - Italy
Ph. +39 010 6598 750
E-mail segreteria@spin.cnr.it
PEC protocollo.spin@pec.cnr.it
Director Fabio Miletto Granozio
Deputy director Andrea Malagoli

Napoli with Pozzuoli

Research Unit
c/o University of Napoli "Federico II",
Department of Physics
via Cintia, I-80126 Napoli
and Area di Ricerca 3 Via Campi Flegrei 34,
80078 Pozzuoli
Ph. +39 089 676233
Deputy director Ettore Sarnelli

Roma

Research Unit
c/o Tor Vergata University of Rome
Department of Civil Engineering
and Computer Science
Via del Politecnico 1, 00133 Roma
Ph. +39 06 4993 4392
Deputy director Paolo Barone

L'Aquila with Chieti

Research Unit
c/o University of L'Aquila, Department of Physics
Via Vetoio, 67010 Coppito (AQ)
and DNI Università Chieti - Pescara
"Gabriele D'Annunzio"
Via dei Vestini 31, 66100 Chieti
Ph. +39 0862 433 759
Deputy director Alessandro Stroppa

Salerno

Research Unit
c/o University of Salerno, Department of Physics
Via Giovanni Paolo II 132, 84084 Fisciano (SA)
Ph. +39 089 969 328
Deputy director Mario Cuoco

Projects and grants

Projects and grants

Running projects 2020/2021

Source: European

Type	Coordinator	Title	SPIN Leader	Duration	SPIN Unit involved
ERANET COFUND QUANTERA	CNR SPIN	QUANtum Technologies with 2D-OXides	Marco Salluzzo	Feb 2018 - Feb 2022	Napoli
ERANET COFUND QUANTERA	CNR-INO	ShoQC – Short-range optical Quantum Connections	Alberto Porzio	Dec 2019 - Nov 2023	Napoli
ERANET COFUND FLAG ERA	CNR SPIN	Scoprire le potenzialità dei dicalcogenuri di metalli di transizione per applicazioni termoelettriche sfruttando gli effetti della nano-strutturazione e del confinamento - Melodica	Ilaria Pallecchi	Apr 2018 - Oct 2021	Genova
EU - H-2020	CERN	European Advanced Superconductivity Innovation and Training _EASITrain	Emilio Bellingeri, Marina Putti	Oct 2017 - Oct 2021	Genova
EU - H-2020	CNR SPIN	Highly sensitive detection of single microwave photons with coherent quantum network of superconducting qubits for searching galactic axions - SUPERGALAX	Mikhail Lisitskiy	Jan 2020 - Dec 2023	Napoli
EU - H-2020	CNR SPIN	OXIDE NANOELECTROMECHANICAL SYSTEMS FOR ULTRASENSITIVE AND ROBUST SENSING OF BIOMAGNETIC FIELDS - OXiNEMS	Luca Pellegrino	May 2019 - Apr 2023	Genova
EU - H-2020	Universitat Autònoma de Barcelona (UAB)	Magnetoelectrics Beyond 2020: A Training Programme on Energy-Efficient Magnetoelectric Nanomaterials for Advanced Information and Healthcare Technologies - BeMAGIC	Silvia Picozzi	Sep 2019 - Feb 2024	L'Aquila/Chieti
EU - H-2020	UNIVERSITAT KONSTANZ	Gate Tuneable Superconducting Quantum Electronics - SUPERGATES	Mario Cuoco	Mar 2021 - Aug 2024	Salerno
EU - H-2020 Ageement as Third Party	UNIVERSITAT WIEN	MOmentum and position REsolved mapping Transmission Electron energy loss Microscope' — 'MORE-TEM' - partecipazione come terza parte dell'Università degli studi di Roma La Sapienza	Paolo Barone	May 2021 - Apr 2027	Roma

Source: National

Type	Coordinator	Title	SPIN Leader	Duration	SPIN Unit involved
PRIN 2015	Partecipazione all'interno dell'unità ISM	NEWLI: NEW LIght on transient states in condensed matter by advanced photon - electron spectroscopies (modello A Prot. 2015CL3APH)	Francesco Bisio	feb 2017 - feb 2020	Genova
PRIN 2017	CNR ICCOM	Novel Multilayered and Micro-Machined Electrode Nano-Architectures for Electrocatalytic Applications (Fuel Cells and Electrolyzers) Codice PRIN 2017YH9MRK	Roberto Felici	Jun 2019 - Dec 2022	Roma
PRIN 2017	CNR SPIN	TWEET: ToWards fErroElectricity in Two-dimensions Codice PRIN 2017YCTB59	Silvia Picozzi	Aug 2019 - Feb 2023	L'Aquila/Chieti - Napoli
PRIN 2017	Università di Roma La Sapienza	Tuning and understanding Quantum phases in 2D materials - Quantum2D Codice PRIN 2017Z8TS5B	Paolo Barone	Aug 2019 - Feb 2023	L'Aquila/Chieti
PRIN 2017	Università di Genova	"HIBiSCUS - High performance-low cost Iron BaSed Coated condUctorS for high field magnets" Codice PRIN 201785KWLW	Valeria Braccini	Aug 2019 - Feb 2023	Genova - Salerno Napoli
PRIN 2017	CNR SPIN	TOPSPIN: Two-dimensional oxides Platform for SPIN-orbitronics nanotechnology" Codice PRIN 20177SL7HC	Marco Salluzzo	Aug 2019 - Feb 2023	Napoli
PRIN 2017	Università degli studi di Genova	Understanding and Tuning FRiction through nanOstructure Manipulation (UTFROM) Codice PRIN 20178PZCB5	Renato Buzio	Aug 2019 - Feb 2023	Genova
PRIN 2017	Università di Trento	Photonic Extreme Learning Machine: from neuromorphic computing to universal optical interpolant, strain gauge sensor and cancer morphodynamic monitor PELM Codice PRIN 2017PSCKT	Alessandro Ciattoni	Aug 2019 - Feb 2023	L'Aquila/Chieti
PON 2014-2020	CNR - DIITET	ARS01_00405 "OT4CLIMA - Tecnologie OT innovative per lo studio degli impatti del Cambiamento climatico sull'ambiente	Giampiero Pepe	Sep 2018 - Feb 2022	Napoli

Projects and grants

Running projects 2020/2021

Source: National

Type	Coordinator	Title	SPIN Leader	Duration	SPIN Unit involved
PON 2014-2020	CNR - DSFTM	PON Fotovoltaico BEST4U ARS01_00509	Fabio Miletto Granozio	Jan 2020 - Dec 2023	Napoli
PON 2014-2020	CNR -DSFTM	PON Quancom ARS01_00734	Coordinatore e referente Napoli G. Pepe - referente Salerno C. Cirillo	Mar 2021 - Aug 2024	Napoli Salerno
PON IR	INFN	II.B.S.Co. – PIR01_00011	Giovanni Cantele	Jun 2019 - Feb 2022	Napoli
“MISSION INNOVATION” POA 2021-2023	DSCTM	Progetto “MISSION INNOVATION” Piattaforma Italiana Accelerata per i Materiali per l’Energia (Italian Energy Materials Acceleration Platform - IEMAP)	Roberto Felici	May 2021 - May 2024	Roma
Accordo Progetto MISE	Comune di MATERA	Casa delle Tecnologie Emergenti di Matera CTEMT	Alberto Porzio	Aug 2020 - Nov 2022 (proroga da definire)	Napoli
MISE POA 2013	ASG Supercondutors	DRYSMES4GRID - Superconductive Energy Storage for Smart Electrical Greed	Maurizio Vignolo	Jun 2017 - Jun 2020	Genova
ENI research agreement	ENI	Sottoprogetto 4 - Sviluppo di superconduttività materiali e processi produttivi in particolare per alta Tc	Valeria Braccini	Mar 2019 - Mar 2024	Genova

Projects and grants

Running projects 2020/2021

Source: International

Type	Coordinator	Title	SPIN Leader	Duration	SPIN Unit involved
Bilateral Project	//	Accordo di cooperazione scientifica CNR - RSE (Scozia)	Andrea Gerbi	Jan 2019 - Dec 2020	Genova
Bilateral Project	//	Accordo di cooperazione scientifica CNR - BAS (Bulgaria)	Massimiliano Polichetti	Jan 2019 - Dec 2021	Salerno
Scientific Collaboration	CERN	Future Circular Collider (FCC) Study: EDMS	Alessandro Leveratto	Mar 2021 - Feb 2024	Genova

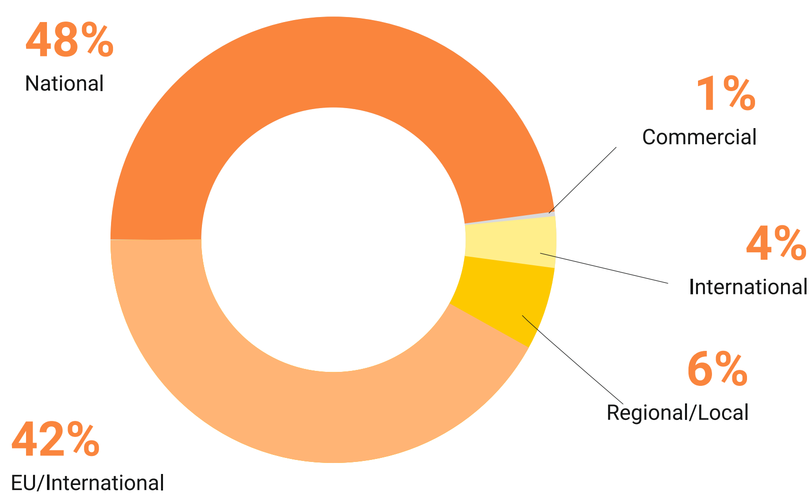
Source: Regional and local

Type	Coordinator	Title	SPIN Leader	Duration	SPIN Unit involved
Scientific Collaboration	University of Salerno	Osservazione tramite microscopio elettronico a scansione di campioni polimerici ottenuti per stampaggio ad iniezione ed elettrospinning	Rosalba Fittipaldi	Feb 2020 - Aug 2020	Salerno
POR FESR LIGURIA	CNR-SPIN	Facility per la qualifica di materiali superconduttori in alto campo magnetico	Andrea Malagoli	May 2020 - Sep 2022	Genova
Compagnia di San Paolo Foundation	CNR-SPIN	Microdevices for active photonics - MIDA	Emilio Bellingeri	Feb 2020 - Jun 2022	Genova

Source: Commercial projects

Type	Commissioner	Title	SPIN Leader	Duration	SPIN Unit involved
Commercial agreement	Piaggio Aeroindustries	Laboratory measurements and tests	Cristina Bernini	Nov 2020 - Dec 2020	Genova
Commercial agreement	ASG SUPERCONDUCTORS	Laboratory measurements and tests	Andrea Malagoli	Oct 2020 - Nov 2020	Genova
Commercial agreement	University of Naples Federico II	Consultancy on development of pressure sensors based on organic active channels	Mario Barra	Oct 2020 - Oct 2021	Napoli
Commercial agreement	COOPER STANDARD Automotive	Laboratory measurements and tests	Rosalba Fittipaldi	Apr 2020 - Apr 2020	Salerno
Commercial agreement	HYPERTAC SPA	Characterizations of materials	Renato Buzio	Feb 2020 - Feb 2020	Genova
Commercial agreement	Various	Sponsorships of SUPERFOX2020 conference and IBS2APP Workshop	Valeria Braccini	Feb 2020 - Feb 2020	Genova
Commercial agreement	Piaggio Aeroindustries	Laboratory measurements and tests	Cristina Bernini	May 2021 - Nov 2021	Genova

2020-2021 running projects total amount ~ 5.8 M€



Technology transfer

Technology transfer

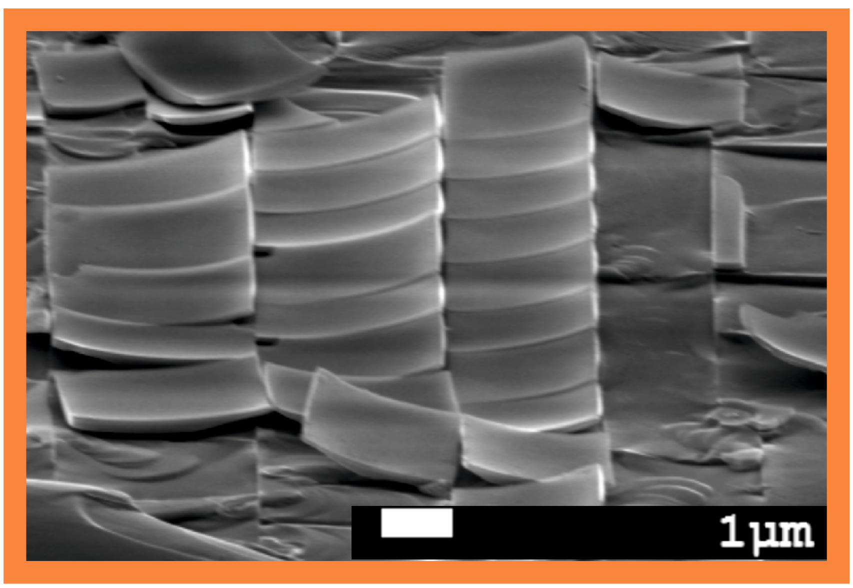
Exploiting its scientific results inventions and expertise for the benefit of the industrial production systme is one of SPIN strategic goals. SPIN scientists are routineley engaged in joint projects with industrial partners, carefully pursuing the protection of intellectual property rights.
In the framework of a Joint Research Agreement (JRA) between CNR and ENI, SPIN is actively involved in research conducted at the “Ettore Majorana” Fusion Centre in Gela for the development of skills and technological know-how for magnetic fusion. In particular, the Centre 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. SPIN's laboratory for the synthesis and characterisation of innovative materials (MAIN Lab in Genoa) is being upgraded. It will enable the best possible development of innovative superconducting materials, which require high magnetic field qualification for their industrial success.
The MaSTER Lab in the SPIN Research Unit of Salerno, equipped with a 16T Cryogen-Free Magnetic system, a dilution refrigerator, double-axis rotator, thermo-electric effects inserts, is also an important infrastructure for collaborations of industrial interest.
SPIN is actively engaged in several public-private partnerships targeted at fostering technology transfer for 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

Selection of SPIN's filed Patents

Title: Heterostructure membranes and process for fabricating heterostructure membranes
Inventors: Fabio Miletto Granozio, Alessia Sambri
Applicant: (patent application pending) Consiglio Nazionale delle Ricerche

Title: A device for sensing a magnetic field
Inventors: Luca Pellegrino, Nicola Manca, Daniele Marré, Federico Remaggi, Riccardo Bertacco, Federico Maspero, Warner J. Venstra, Stefania Della Penna, Ingo Hilschenz, Alexei Kalaboukhov, Floriana Lombardi
Applicant: Consiglio Nazionale delle Ricerche, Università degli Studi di Chieti Pescara, Quantified Air (NL)

Title: A magnetic field sensor
Inventors: Federico Maspero, Luca Pellegrino, Riccardo Bertacco, Simone Cuccurullo, Nicola Manca, Daniele Marré
Applicant: Consiglio Nazionale delle Ricerche

Title: Apparatus for nuclear magnetic resonance utilizing metamaterials or dielectric materials
Inventors: Carlo Rizza, Marcello Alecci, Angelo Galante, Marco Fantasia
Applicant: Consiglio Nazionale delle Ricerche, Università degli Studi dell'Aquila

Title: Stimolazione selettiva di fibre nervose piccole mediante elettrodi superficiali interdigitati micropatternati
Inventors: Luca Pellegrino, Massimo Leandri, Antonio Sergio Siri
Applicant: Consiglio Nazionale delle Ricerche, Università degli Studi di Genova

Title: Elastic backscattering and backreflection lidar device for the characterization of atmospheric particles
Inventors: Xuan Wang, Nicola Spinelli, Maria Grazia Frontoso
Applicant: Consiglio Nazionale delle Ricerche

Former Patents

Title: Metodo per aumentare il fattore di merito e il campo accelerante massimo in cavità superconduttrici, cavità superconduttrice realizzata secondo tale metodo e sistema per l'accelerazione di particelle utilizzante tale cavità
Inventors: Ruggero Vaglio, Vincenzo Palmieri, Mattia Checchin, Martina Martinello, Sergei Stark, Fabrizio Stivanello
Applicants: Consiglio Nazionale delle Ricerche, Istituto Nazionale per la Fisica Nucleare

Title: A process for producing optionally doped elemental Boron
Inventors: Maurizio Vignolo, Antonio Sergio Siri
Applicants: Consiglio Nazionale delle Ricerche, Antonio Sergio Siri

Title: Microelectromechanical thin film device of transition metal oxide, and manufacturing method thereof
Inventors: Luca Pellegrino, Michele Biasotti, Antonio Sergio Siri
Applicants: Consiglio Nazionale delle Ricerche

Activity B

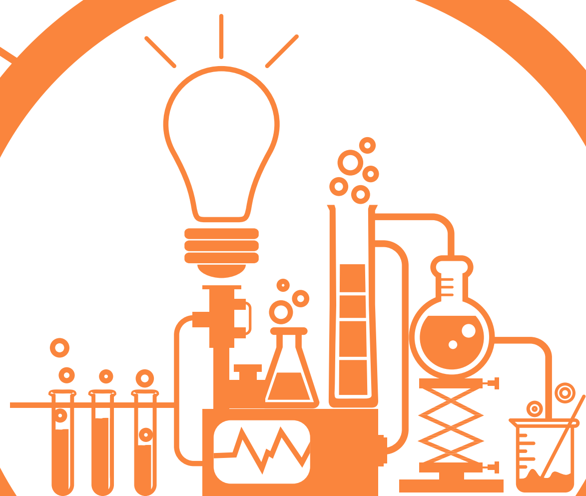
Superconducting and correlated low dimensional materials and devices for quantum electronics and spintronics

Activity A

Novel superconducting and functional materials for energy and environment

Activity C

Innovative materials with strong interplay of spin-orbital-charge and topological



Activity F

Electronic and thermal transport from the nanoscale to the macroscale

Activity D

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

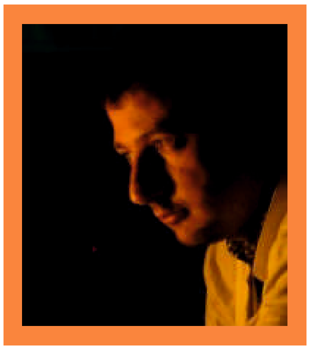
Activity E

Advanced materials and techniques for organic electronics, biomedical and sensing applications

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.

Amorphous ZnO/PbS quantum dots heterojunction for efficient responsivity broadband photodetectors

Xinyu Wang[1], Kaimin Xu[1], Xiaoyan Yan[1], Xiongbin Xiao[1], Carmela Aruta[2], Vittorio Foglietti[2], Zhijun Ning[1], and Nan Yang[1]

[1]School of Physical Science and Technology, ShanghaiTech University, Shanghai 201210, P. R. China
[2]CNR-SPIN Institute of Superconductors, Innovative Materials and Devices, UOS-Roma, 00133 Rome, Italy

ACS APPLIED MATERIALS & INTERFACES 12, 8403−8410 (2020)

The integration of lead sulfide quantum dots (QDs) with a high-conductivity material that is compatible with a scalable fabrication is an important route for the applications of QD-based photodetectors. We developed a broadband photodetector by combining amorphous ZnO and PbS QDs, forming a heterojunction structure. The photodetector showed detectivity up to 7.9 × 1012 and 4.1 × 1011 jones under 640 and 1310 nm illumination, respectively. The role of the oxygen background pressure in the electronic structure of ZnO films grown by pulsed laser deposition was found to play an important role in the conductivity associated with the variation of the oxygen vacancy concentration. By increasing the oxygen vacancy concentration, the electron mobility of amorphous ZnO layers dramatically increased and the work function decreased. Combining the energy band alignment with the device performance, we can conclude that the improved the photocurrent of ZnO/PbS heterojunction photodetector with ZnO grown at the lowest oxygen pressure is not only related to its higher carrier mobility but also benefits by the proper energy band alignment. This is a consequence of the upward shifting of the Fermi level due to the donor defects induced by a higher concentration of oxygen vacancies.

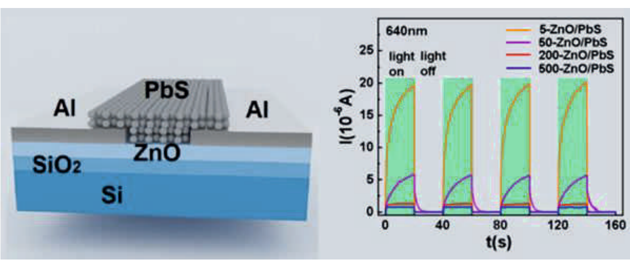


Fig. 1: Schematic structure of the photodetector based on the amorphous ZnO/PbS QD heterojunction (left). Current-time (I-t) curves under 640 nm illumination and at +20 V bias of 5, 50, 200, and 500-ZnO/PbS photodetectors, with ZnO grown at different oxygen pressure, namely 5, 50, 200, and 500 mTorr, respectively.

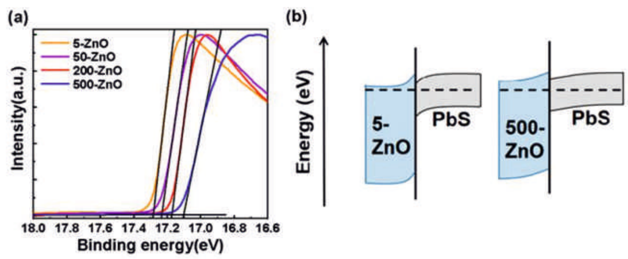


Fig. 2: (a) UPS spectra of 5, 50, 200, and 500-ZnO for high binding energy cut-off. (b) Energy band alignment sketch of the 5-ZnO/PbS (left) and 500-ZnO/PbS QD heterojunctions.

Improved Structural Properties in Homogeneously Doped $Sm_{0.4}Ce_{0.6}O_{2-\delta}$ Epitaxial Thin Films: High Doping Effect on the Electronic Bands

Nan Yang[1], Daniel Knez[2], Giovanni Vinai[2], Piero Torelli[2], Regina Ciancio[2], Pasquale Orgiani[2,3] and Carmela Aruta[4]

[1]School of Physical Science and Technology, ShanghaiTech University, 201210 Shanghai, China
[2]CNR-IOM, TASC National Laboratory, I-34149 Trieste, Italy
[3]CNR-SPIN Institute of Superconductors, Innovative Materials and Devices, UOS Salerno, I-84084 Fisciano, Italy
[4]CNR-SPIN Institute of Superconductors, Innovative Materials and Devices, UOS Roma, I-00133 Rome, Italy

ACS APPLIED MATERIALS & INTERFACES

The study of ionic materials on nanometer scale is of great relevance for efficient miniaturized devices for energy applications. The epitaxial growth of thin films can be a valid route to tune the properties of the materials and thus obtain new degrees of freedom in materials design. High crystal quality SmxCe$_{1-x}$O$_{2-\delta}$ (SDC) films were grown at a high doping level up to x = 0.4, thanks to the good lattice matching with the (110) oriented $NdGaO_3$ (NGO) substrate. Transmission electron microscopy measurements reported in Figure 1 demonstrate the ordered structural quality and absence of Sm segregation at the macroscopic and atomic level. Therefore, in epitaxial thin films, the homogeneous doping can be obtained even with the high dopant content not always approachable in bulk form, getting even an improvement of the structural properties. In situ spectroscopic measurements by X-ray photoemission and X-ray absorption show the O 2p band shift toward the Fermi level (see Figure 2), which can favor the oxygen exchange and vacancy formation on the surface when the Sm doping is increased to x = 0.4, in agreement with the results reported in Nan Yang et al. ACS Appl. Mater. Interfaces 2016, 8, 14613.

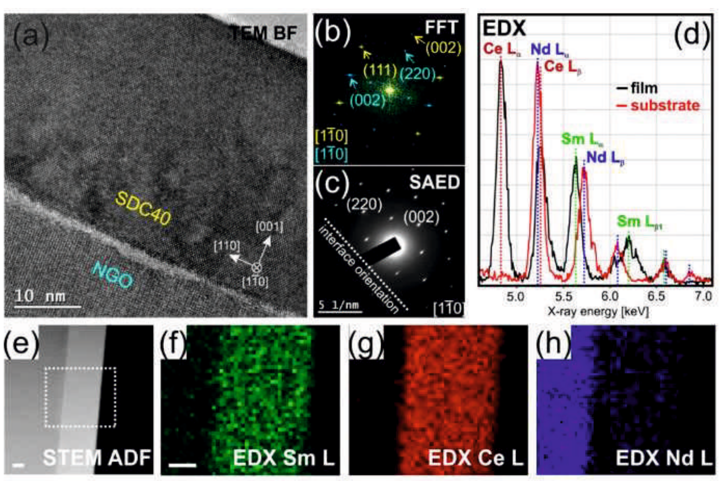


Fig. 1: HRTEM analysis of the Sm doped film with x = 0.4: (a) bright-field micrograph showing substrate and film. (b) FFT from the film (yellow) and substrate region (cyan). (c) SAED pattern of the film. (d) EDX analysis. (e) STEM ADF image, the rectangle marks the region chosen for EDX elemental mapping. (f–h) EDX elemental maps for Sm, Ce, and Nd. Scale bars in (e–h) are 10 nm.

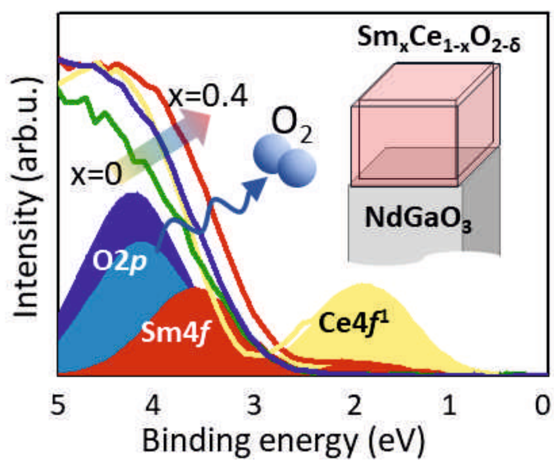


Fig. 2: Valence band spectra in situ measured with 495 eV photon excitation energy for undoped CeO2 and SDC with x = 0–0.4 in the energy range 0–5 eV. The colored regions point out the different contributions to the valence band obtained by fitting after subtracted a Shirley background. In the inset, sketch of the largest SDC40 crystallographic cell, almost unstrained when grown on the NGO

The role of texturing and thickness of oxide buffer layers in the superconducting properties of Fe(Se,Te) Coated Conductors

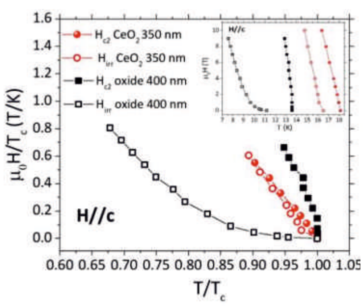
G. Sylva1,2, E. Bellingeri2, C. Bernini2, G. Celentano3, C. Ferdeghini2, A. Leveratto2, M. Lisitskiy4, A. Malagoli2, N. Manca2, A. Mancini3, P. Manfrinetti2,5, I. Pallecchi2, A. Provino2, M. Putti1, A. Vannozzi3 and V. Braccini2

1 Physics Department, University of Genova, via Dodecaneso 33, 16146 Genova, Italy
2 CNR-SPIN Genova, C.so F. M. Perrone, 24, 16152 Genova, Italy
3 ENEA Frascati Research Centre, Via E. Fermi 45, 00044 Frascati, Italy
4 CNR-SPIN Napoli, Via Campi Flegrei 34, 80078, Pozzuoli (NA), Italy
5 Chemistry Department, University of Genova, via Dodecaneso 33, 16146 Genova, Italy

SUPERCONDUCTOR SCIENCE AND TECHNOLOGY 33, 114002 (2020)

Fe(Se,Te) CC were realized with new templates developed to be simple, scalable, cost effective and to have a good chemical barrier against Ni diffusion and a suitable texturing. The goal of the work was gaining information on the roles of thickness and texturing of the oxide buffer layer. The results obtained employing a well textured NiW5% substrate with CeO_2 buffer layer of different thickness - 150 or 350nm - were compared to the results obtained using a randomly oriented Hastelloy substrate with native oxide of different thickness – i.e. 10, 130 or 400nm. Both kinds of substrates employ only one oxide buffer layer, significantly simplifying the realization of the CC, and the Hastelloy substrate would even employ a native oxide layer, which allows skipping the complex deposition of the oxide buffer. Regardless texturing, as long as the buffer layers are too thin they are not efficient in blocking the Ni diffusion from the substrate, causing the poisoning of the Fe(Se,Te) phase. Accordingly, bulk superconductivity with $T_{c,0}$ of 11.1K and 16.5K were observed respectively for films deposited on randomly oriented Hastelloy substrate covered with a 400nm native (not oriented) oxide and on 350nm thick very well textured CeO_2 buffer layer grown on biaxially textured NiW5% alloy. In Fig. 1 we report the H-T diagrams of the films on the two different systems, while in Fig. 2 the J_c behaviour in field which outlines how the J_c magnitude is strongly dependent on the texturing. Fe(Se,Te) thin film deposited on the untextured native oxide grown on Hastelloy are partially orientated along the c-axis, with both in plane and out of plane misalignment and they exhibited self-field Jc much lower than those obtained in epitaxial thin films, but still significant and the same as the one measured on thin films grown on bi-crystals with misalignment angles larger than 24°, suggesting that J_c in this film, is ultimately limited by high misalignment between grains, responsible for a weak link dominated scenario. From this study we concluded that the properties of Fe(Se,Te) CC are strongly related to the texturing and thickness of the buffer layers, which both contribute to the final superconducting properties of the phase. In particular, it has been shown that it is possible to fabricate superconducting CCs on templates consisting of randomly oriented substrates covered with native oxides.

Fig. 1: H-T diagrams of the 11 thin films deposited on the Hastelloy and on the RABiTS substrates with 350 nm of CeO_2 oxide (red). Hc_2 and H_{irr} were obtained using the criteria of 10% and the 90% of the normal state resistivity.



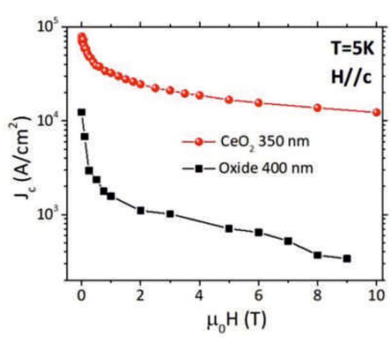


Fig. 2: J_c at 5 K vs applied magnetic field of the 11 thin films deposited on Hastelloy substrate with 400 nm of oxide (black) and on the RABiT substrate with a 350 nm thick CeO_2 buffer layer (red).

Transport and Point Contact Measurements on $Pr_{1-x}Ce_xPt_4Ge_{12}$ Superconducting Polycrystals

Paola Romano [1,2], Francesco Avitabile [1], Angela Nigro [3,4], Gaia Grimaldi [2] , Antonio Leo [3,4] , Lei Shu 5,6, Jian Zhang 5, Antonio Di Bartolomeo 2,3 and Filippo Giubileo 2

[1]Science and Technology Department, Via De Sanctis, University of Sannio, I-82100 Benevento, Italy
[2]CNR-SPIN Institute of Superconductors, Innovative Materials and Devices, Salerno, Italy
[3]Physics Department "E. R. Caianiello", University of Salerno, via Giovanni Paolo II n. 132, 84084 Fisciano, Italy
[4]NANO_MATES Research Center, Università degli Studi di Salerno, I-84084 Fisciano (SA), Italy
[5]State Key Laboratory of Surface Physics, Department of Physics, Fudan University, Shanghai 200433, China
[6]Shanghai Research Center for Quantum Sciences, Shanghai 201315, China

NANOMATERIALS 2020, 10, 1810

We performed a detailed investigation of the superconducting properties of polycrystalline $Pr_{1-x}Ce_xPt_4Ge_{12}$ pellets. We report the effect of Ce substitution, for x = 0.07, on magnetic field phase diagram H-T. We demonstrate that the upper critical field is well described by the Ginzburg–Landau model and that the irreversibility field line has a scaling behavior similar to cuprates. We also show that for magnetic fields lower than 0.4 T, the activation energy follows a power law of the type $H^{-1/2}$, suggesting a collective pinning regime with a quasi-2D character for the Ce-doped compound with x = 0.07. Furthermore, by means of a point contact Andreev reflection spectroscopy setup, we formed metal/superconductor nano-junctions as small as tens of nanometers on the $PrPt_4Ge_{12}$ parent compound (x = 0). Experimental results showed a wide variety of conductance features appearing in the dI/dV vs. V spectra, all explained in terms of a modified Blonder–Tinkham–Klapwijk model considering a superconducting order parameter with nodal directions as well as sign change in the momentum space for the sample with x = 0. The numerical simulations of the conductance spectra also demonstrate that s-wave pairing and anisotropic s-waves are unsuitable for reproducing experimental data obtained at low temperature on the un-doped compound. Interestingly, we show that the polycrystalline nature of the superconducting $PrPt_4Ge_{12}$ sample can favor the formation of an inter-grain Josephson junction in series with the point contact junction in this kind of experiments.

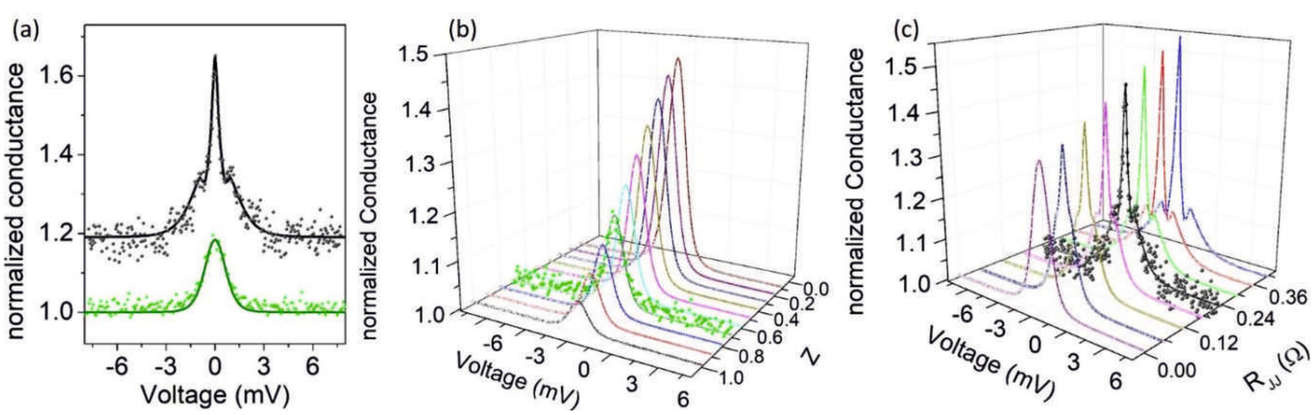


Fig.1(a) Conductance spectra measured (green data) soon after the tip approach on the surface. The upper (black)spectrum was measured after icreasing the tip pressure on the surface. (b) Evolution of conductance spectra calculated numerically for Δ = 0.55 meV and for 0 <Z < 1. (c) Evolution of conductance spectra calculated for Δ= 0.55 meV, Z= 0.39, α = 0.29, and 0<R_{JJ}<0.42 Ω

The uncollapsed $LaFe_2As_2$ phase: compensated, highly doped, electron-phonon coupled, iron-based superconductor

I. Pallecchi [1], A. Iyo [2], H. Ogino 2, M. Affronte [3], M. Putti [4,1]

1 CNR-SPIN, UOS-Genova, c/o Dipartimento di Fisica, via Dodecaneso 33, 16146 Genova, Italy
[2] National Institute of Advanced Industrial Science and Technology (AIST), 1-1-1 Umezono, Tsukuba, Ibaraki 305-8568, Japan
[3] Dipartimento di Scienze Fisiche, Informatiche e Matematiche, Università degli Studi di Modena e Reggio Emilia, and CNR-NANO, via G. Campi, 213/A, 41100 Modena, Italy
[4] Università di Genova, Dipartimento di Fisica, via Dodecaneso 33, 16146 Genova, Italy

PHYSICAL REVIEW MATERIALS 4, 114803 (2020)

The recently discovered $LaFe_2As_2$ superconducting compound, member of the 122 family of iron pnictide superconductors, becomes superconducting below $T_c \approx 13K$, yet its nominal doping apparently places it in the extreme overdoped limit, where superconductivity should be suppressed. In this work, we investigate the normal state of magneto- and thermo-electric transport and specific heat of this compound. The experimental data are consistent with the presence of highly compensated electron and hole bands, with ~0.42 electrons per unit cell just above T_c, and high effective masses ~$3m_0$. The temperature dependence of transport properties strongly resembles that of conventional superconductors, pointing to a key role of electron-phonon coupling. From these evidences, $LaFe_2As_2$ can be regarded as the connecting compound between unconventional and conventional superconductors.

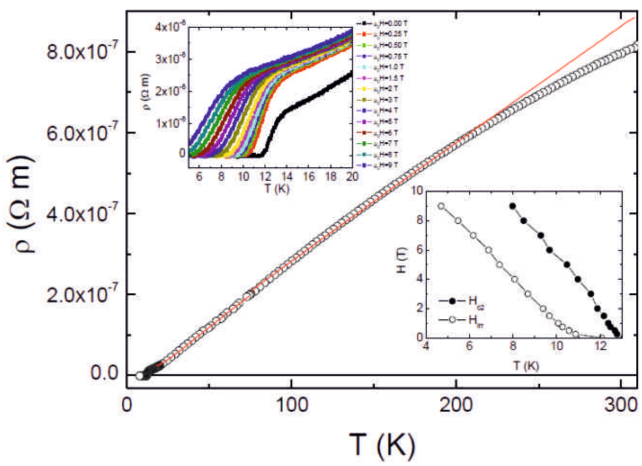


Fig. 1: Resistivity of $LaFe_2As_2$. The red line represents the fit with the generalized Bloch-Grüneisen law. The high temperature departure. Close to room temperature, the experimental curve bends with respect to the Bloch-Grüneisen law, as typical of metals with large electron-phonon coupling, when the mean free path decreases and approaches the lattice spacing. Upper left inset: resistivity curves in different magnetic fields up to 9 T. Lower right inset: Critical fields Hc_2 and H_{irr} extracted from the resistive transitions.

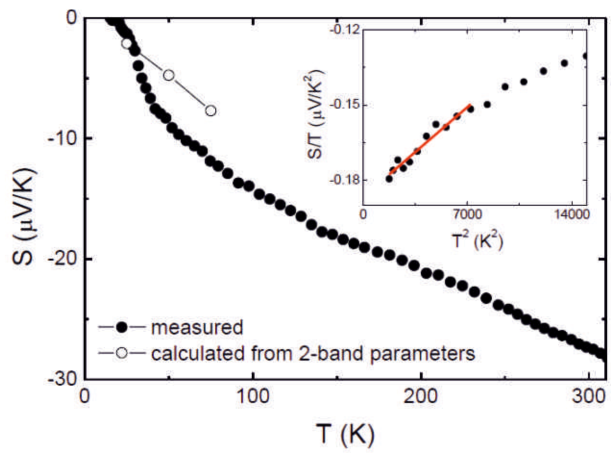


Fig. 2: Measured Seebeck coefficient of $LaFe_2As_2$ (filled symbols). The diffusive contribution to the Seebeck coefficient, calculated from the two-band parameters, is also shown in the main panel (open symbols). Inset: S/T versus T^2 plot, with a linear regime identified in correspondence of the temperature range 40-85K, which identifies the phonon drag Seebeck coefficient, related to the large electron-phonon coupling.

Hydrodynamical description for magneto-transport in the strange metal phase of Bi-2201

A. Amoretti[1,2], M. Meinero1,3, D. K. Brattan[2] , F. Caglieris[4], E. Giannini[5], M. Affronte[6], C. Hess[4,7] , B. Buechner[4,7], N. Magnoli[1,2], and M. Putti[1,3]

[1]Dipartimento di Fisica, Università di Genova, via Dodecaneso 33, I-16146, Genova, Italy
[2]INFN – Sezione di Genova, via Dodecaneso 33, I-16146, Genova, Italy
[3]CNR-SPIN Institute of Superconductors, Innovative Materials and Devices, Corso Perrone 24, 16152 Genova, Italy
4Leibniz IFW Dresden, Helmholtz str. 20, D-01069 Dresden, Germany
[5]Department of Quantum Matter Physics, University of Geneva, 24 Quai Ernest Ansermet, CH-1211 Geneva, Switzerland
[6]CNR Nano - Sezione S3 & Università di Modena e Reggio Emilia – Dipartimento di Scienze Fisiche, Informatiche e Matematiche, via G. Campi 213/A, 41125 Modena, Italy
[7]Faculty of Physics, Technische Universitat Dresden, D-01069 Dresden, Germany

PHYSICAL REVIEW RESEARCH 2, 023387 (2020)

High-temperature superconductors are strongly coupled systems which present a complicated phase diagram with many coexisting phases. This makes it difficult to understand the mechanism which generates their singular transport properties. Hydrodynamics, which mostly relies on the symmetries of the system without referring to any specific microscopic mechanism, constitutes a promising framework to analyze these materials. In this paper we show that, in the strange metal phase of the cuprates, a whole set of transport coefficients are described by a universal hydrodynamic framework once one accounts for the effects of quantum critical charge-density waves. We corroborate our theoretical prediction by measuring the DC transport properties (resistivity, magnetoresistance, Hall angle, transverse thermal conductivity and Nernst effect) of Bi-2201 close to optimal doping (Fig. 1). The identification of defined *T*-scaling laws, consistent with the hydrodynamic predictions, proves the validity of our approach (Fig. 1). Our argument can be used as a consistency check to understand the universality class governing the behavior of high-temperature cuprate superconductors.

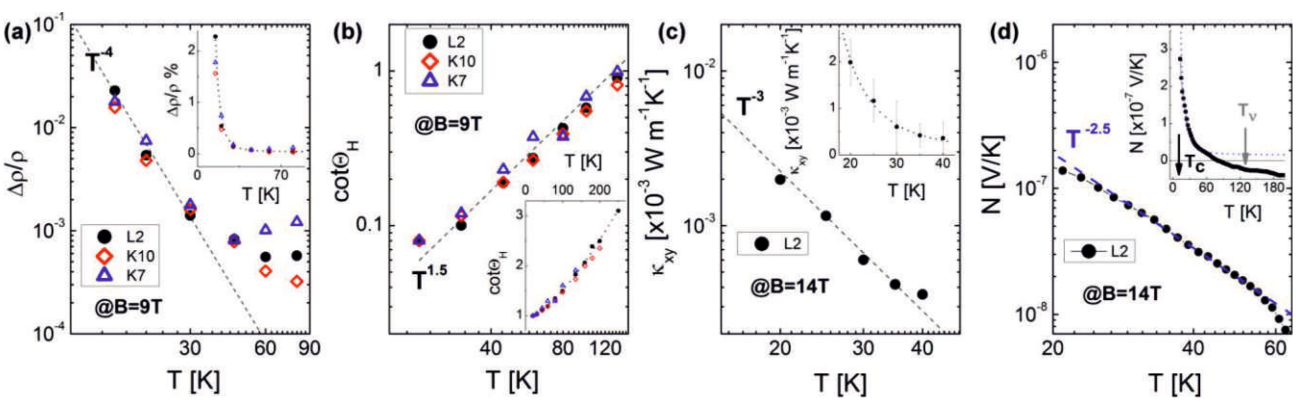


Fig. 1: Bi-logarithmic plot of (a) $\Delta\rho/\rho$ vs *T*, (b) cot ΘH vs *T*, (c) k_{xy} vs *T* and (d) *N* vs *T* for the Bi-2201 compounds. L2, K10 and K7 are three different samples. The dashed lines represent the different *T*-functions, which best reproduce the data in the temperature range 20 K < *T* < 60 K. The experimental scaling laws are consistent within the hydrodynamical model. Insets: linear plots of the data.

Defect engineering for tuning the photoresponse of ceria-based solid oxide photoelectrochemical cells

Yanuo Shi[1], Luyao Wang1, Ziyu Wang[2], Giovanni Vinai[3], Luca Braglia[3], Piero Torelli[3], Carmela Aruta[4], Enrico Traversa[5], Weimin Liu[2], Nan Yang[1]

[1]Electrochemical Thin Film Group, School of Physical Science and Technology, ShanghaiTech University, Shanghai, P.R. China
[2]School of Physical Science and Technology, ShanghaiTech University, Shanghai, P.R. China
[3]Istituto Officina dei Materiali (IOM) - CNR, Laboratorio TASC, Trieste I-34149, Italy
[4]CNR-SPIN, UOS Roma, Area della Ricerca di Tor Vergata, Via del Fosso del Cavaliere 100, 00133 Roma, Italy
[5]School of Materials and Energy, University of Electronic Science and Technology of China, Chengdu, Sichuan 611731, P.R. China

ACS APPLIED MATERIALS & INTERFACES 13 (2021) 541

Solid oxide photoelectrochemical cells (SOPECs) with inorganic ion-conducting electrolytes provide an alternative solution for light harvesting and conversion. Ceria-based thin films were newly explored as photoelectrodes for SOPEC applications. It was found that the photoresponse of ceria-based thin films can be tuned both by Sm doping-induced defects and by the heating temperature of SOPECs (Fig.1). The whole process was found to depend on the surface electrochemical redox reactions synergistically with the bulk photoelectric effect. Samarium doping level can selectively switch the open-circuit voltage polarity of SOPECs under illumination, thus shifting the potential of photoelectrodes and changing their photoresponse. In this work the role of defect chemical engineering in determining such a photoelectrochemical process was highlighted and explained.

Transient absorption and X-ray photoemission spectroscopies, together with the state-of-the-art in operando X-ray absorption spectroscopy, allowed us to provide a compelling explanation of the experimentally observed switching behavior on the basis of the surface reactions and successive charge balance in the bulk.

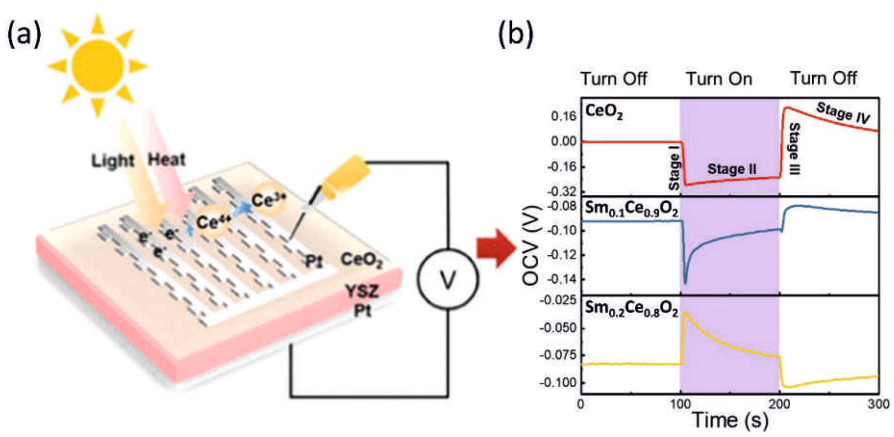


Fig. 1: (a) Sketch of working and measurement setup. (b) Open circuit voltage (OCV) dependence with time of the undoped ceria, 10% Sm and 20% Sm doped ceria based structures at 300°C in air. The whole OCV behavior is completely reversed for highest Sm doping content compared to the undoped one.

Nanoscale analysis of superconducting Fe (Se,Te) epitaxial thin films and relationship with pinning properties

Mario Scuderi[1], Ilaria Pallecchi[2], Antonio Leo[3,4], Angela Nigro[3,4], Gaia Grimaldi[3], Carlo Ferdeghini[2], Corrado Spinella[1], Marco Guidolin[5], Antonio Trotta[5], Valeria Braccini[2]

[1]CNR - IMM Catania Headquarter, Strada VIII n.5 Zona Industriale, 95121 Catania, Italy
[2]CNR-SPIN, Sede Genova, Area della Ricerca di Genova, C.so F. M. Perrone 24, 16152 Genova, Italy
[3]CNR-SPIN, UOS Salerno c/o Università di Salerno - Via Giovanni Paolo II 132, 84084 Fisciano (SA), Italy
[4]Dipartimento di Fisica "E.R. Caianiello", Università Di Salerno, Via Giovanni Paolo II n.132, 84084 Fisciano, (SA), Italy
[5]Eni Venezia, Via delle Industrie n.39, 30175 Marghera, Italy

SCIENTIFIC REPORTS 11 (2021) 20100

The process of developing superconducting materials for large scale applications is mainly oriented to optimize flux pinning and the current carrying capability. A powerful approach to investigate pinning properties is to combine high resolution imaging with transport measurements as a function of the magnetic field orientation, supported by a pinning modelling. We carry out Transmission Electron Microscopy, Electron Energy Loss Spectroscopy and critical current measurements in fields up to 16 T varying the angle between the field and c-axis of Fe(Se,Te) epitaxial thin films deposited on CaF2 substrates. We find evidence of nanoscale domains with different Te:Se stoichiometry and/or rotated and tilted axes, as well as of lattice distortions and two-dimensional defects at the grain boundaries. These elongated domains are tens of nm in size along the in-plane axes (Fig. 1). We establish a correlation between these observed microstructural features and the pinning properties, specifically strongly enhanced pinning for the magnetic field oriented in-plane and pinning emerging at higher fields for out-of-plane direction (Fig. 2). These features can be accounted for within a model where pinning centers are local variations of the critical temperature and local variations of the mean free path, respectively. The identification of all these growth induced defects acting as effective pinning centers may provide useful information for the optimization of Fe(Se,Te) coated conductors.

This work has been supported by the Joint Research Agreement Eni-CNR, and partially supported by the Italian MIUR projects: PRIN 'HiBiSCUS' Grant No. 201785KWLE, Beyond-Nano (PON a3_00363) and Nafassy (PON a3_00007).

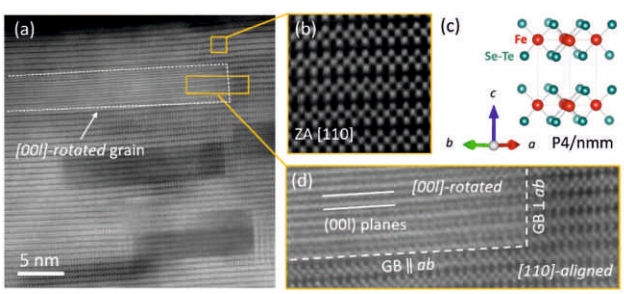


Fig. 1: Structure of the Fe(Se,Te) film at high-resolution. (a) High-resolution Z-contrast STEM image of the [110]-oriented $FeSe_{1-x}Te_{ex}$ film. (b) Enlarged view of the atomic lattice and corresponding 3D atomic model of the unit cell in (c). (d) Detail of GBs between a rotated grain and a not-rotated one.

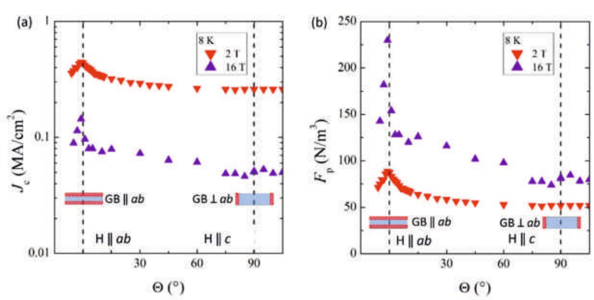


Fig. 2: Angular dependence Jc(θ) in semi-log scale (a) and pinning force (b), at 8 K and in fields of 2 and 16 T. The huge peak at H//ab is the signature of the pinning mechanism related to the 2D GB // ab defects. The small peak detectable at 16 T correlates with the 2D GB ⊥ ab observed defects, and indicates that c-axis correlated defects might become active as pinning centers at high fields.

Mn-induced Fermi-surface reconstruction in the SmFeAsO parent compound

M. Meinero[1,2], P. Bonfà[3]. I. J. Onuorah[3], S. Sanna[4], R. De Renzi[3], I. Eremin[5,6] , M. A. Müller[5], J.-C. Orain[7], A. Martinelli[2], A. Provino [2,8], P. Manfrinetti[2,9], M. Putti[1,2], T. Shiroka[7,10] G. Lamura[2]

[1]Dipartimento di Fisica, Università di Genova, via Dodecaneso 33, 16146 Genova, Italy.
[2]CNR-SPIN, Sede Genova, Area della Ricerca di Genova, C.so F. M. Perrone 24, 16152 Genova, Italy
[3]Dipartimento di Scienze Matematiche, Fisiche ed Informatiche, Università di Parma, Parco delle Scienze, 7a, 43124 Parma, Italy.
[4]Dipartimento di Fisica e Astronomia "A. Righi", Università di Bologna, Viale Berti Pichat 6/2, 40127 Bologna, Italy.
[5]Theoretische Physik III, Ruhr-Universität Bochum, 44801 Bochum, Germany.
[6]National University of Science and Technology MISiS, 119049 Moscow, Russian Federation.
[7]Laboratory for Muon-Spin Spectroscopy, Paul Scherrer Institut, 5232 Villigen PSI, Switzerland.
[8]Department of Physics and Astronomy, Rutgers, The State University of New Jersey, Piscataway, USA.
[9]Dipartimento di Chimica e Chimica Industriale, Università di Genova, via Dodecaneso 31, 16146 Genova, Italy.
[10]Laboratorium für Festkörperphysik, ETH-Hönggerberg, 8093 Zürich, Switzerland.

Scientific Reports 11 (2021) 14373

The electronic ground state of iron-based materials is unusually sensitive to electronic correlations. Among others, its delicate balance is profoundly affected by the insertion of magnetic impurities in the FeAs layers. Here, we address the effects of Fe -to-Mn substitution in the non-superconducting Sm-1111 pnictide parent compound via a comparative study of $SmFe_{1-x}Mn_xAsO$ samples with x(Mn)=0.05 and 0.10. Hall effect (Fig.1-a), dc magnetization (Fig.1-b) and muon-spin spectroscopy data provide a coherent picture (Fig.2) indicating a weakening of the commensurate Fe spin-density-wave (SDW) order, as shown by the lowering of the SDW transition temperature T_{SDW} with increasing Mn content and the unexpected appearance of another magnetic order, occurring at T* ≈10 and 20 K for x=0.05 and 0.10, respectively.
Despite a higher chemical pressure with respect to $LaFe_{1-x}Mn_xAsO$ system, expected to weaken the electronic correlations, in the $SmFe_{1-x}Mn_xAsO$ case, they are still sufficiently strong to sustain a Mn-Mn coupling via Ruderman–Kittel–Kasuya–Yosida (RKKY) interaction. Such magnetic coupling is able to pin the electronic charges locally, resulting in a full reorganization of the Fermi surface and the onset of an incommensurate antiferromagnetic (AF) order at T*, well inside the existing SDW phase (Fig. 1-2).

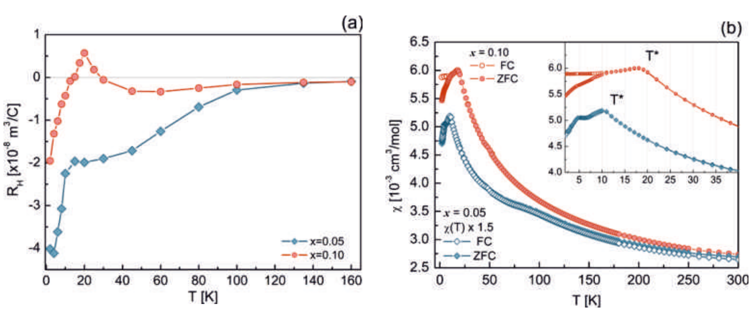


Fig. 1: (a) Hall coefficient R_H vs. T for the x=0.05 (blue) and 0.10 (red) cases. (b) DC magnetic susceptibility vs. temperature measured at 3 T in both zero-field-cooled (ZFC) and in field-cooled (FC) conditions. The full and open blue symbols refer to the x =0.05 case, while the red symbols to x = 0.10. To facilitate a comparison, the χ(T) data for x = 0.05 were multiplied by a factor of 1.5. The inset highlights the low-temperature features with the cusps at T* indicating the magnetic anomaly induced by the Mn substitution.

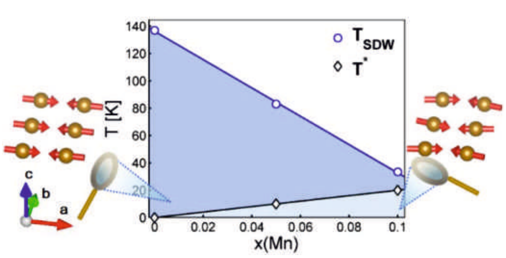


Fig. 2: Phase diagram of $SmFe_{1-x}Mn_xAsO$, showing the commensurate ordered phase (dark-blue area) and the Mn-induced incommensurate ordered phase (light-blue area). The collinear vs. tilted arrangement of Fe moments is also sketched.

Transport current and magnetization of Bi-2212 wires above liquid Helium temperature for cryogen-free applications

A. Leveratto[1], A. Angrisani Armenio[2], A. Traverso[1,3], G. De Marzi[2], G. Celentano[2], A. Malagoli[1]

[1]CNR-SPIN, Sede Genova, Area della Ricerca di Genova, C.so F. M. Perrone 24, 16152 Genova, Italy
[2]ENEA, Superconductivity Laboratory, Frascati Research Centre, Via E. Fermi, 45, 00044, Frascati, Italy

Scientific Reports 11 (2021) 11660

Since the discovery of high temperature superconductors, a possible cryogen-free scenario has always been wished. Nowadays, liquid Helium is running out, and it is likely that the cooling by will be a large part of the costs of any superconducting system. Bi-2212 wires at temperature higher than 4.2 K still show a very high irreversibility field and thus a deep investigation of their properties in such a range of temperature is very useful to assess its applicability. In the manuscript we reported electrical transport and magnetic properties characterization at variable temperature and magnetic field on our "GDG—processed" wires [1] together with a well-described original approach to calculate the irreversibility field H_{irr}; this characterization is useful to fill a gap in the literature on this superconductor. The paper can be summarized drawing the following conclusions: • Bi-2212 wire has been shown to be suitable for high magnetic field applications at 10 K, having good stability of J_c and an irreversibility field higher than 70 T. These properties open a wide window of applicability in the temperature—field diagram. Our original wires processed at 1 bar show at 10 K a J_E = 500 A/mm^2 at 7 T promising to be in line with the application requirements also at high field;

• The two main Bi-2212 powders used up to now to fabricate P.I.T. wires—Nexans and Engi-Mat—led to very different transport properties of the conductors, being J_c of Engi-Mat conductors about twice higher than Nexans ones. Our analysis finds no different pinning properties below 20 K and, therefore, the reasons for their different effect have to be found in other aspects such as connectivity and grain boundaries cleanliness; • An original and consistent approaching method has been proposed to calculate the Hirr which overcomes the approximation brought by the Kramer plot. We think that such a method might be used as a reference for future works and analysis.

[1] Leveratto, A., Supercond. Sci. Technol. 29, 4 (2016)

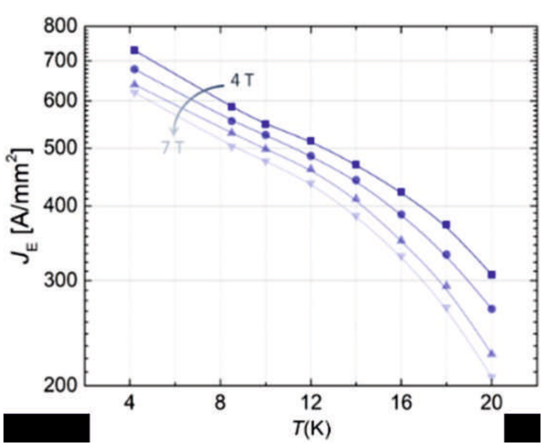


Fig. 1: J_E(T) SPIN36engimat at different magnetic fields.

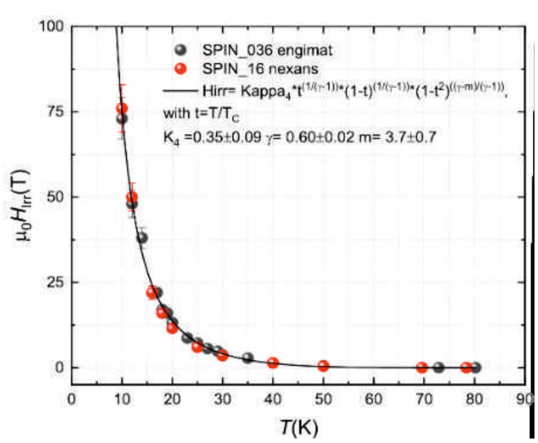


Fig. 2: H_{irr}(T) of both SPIN36engimat (black circles) and SPIN16nexans (red cycles).

Structural strain and competition between charge density wave and superconductivity in La(Fe,Mn)As($O_{0.89}F_{0.11}$) compounds

A. Martinelli[1], P. Carretta[2], M. Moroni[2], S. Sanna[3]

[1]CNR-SPIN, Sede Genova, Area della Ricerca di Genova, C.so F. M. Perrone 24, 16152 Genova, Italy
[2]Department of Physics, University of Pavia, Pavia, Italy
[3]Department of Physics and Astronomy "A. Righi", University of Bologna, University of Bologna, via Berti-Pichat 6-2, 40127 Bologna, Italy

PHYSICAL REVIEW B 103 (2021) 014518

Selected members of the La(Fe, Mn)As($O_{0.89}F_{0.11}$) system were analyzed using high-resolution synchrotron x-ray powder diffraction. The tetragonal to orthorhombic structural transition is progressively recovered in the optimally electron-doped La(Fe,Mn)As($O_{0.89}F_{0.11}$) phase by very light Mn substitution; at the same time, superconductivity is suppressed whereas magnetic ordering is restored. Distinct incommensurate satellite peaks develop within different thermal ranges and mark the occurrence of charge density waves characterized by distinct propagation wave vectors, as well as multiple incommensurate structural transitions. In particular, some of these peaks arise in conjunction with the structural transformation process, disappearing after the completion of the dissymmetrization, thus suggesting that the structural transformation is possibly driven by charge degrees of freedom. The thermal evolution of satellite reflections observed at Q ~ 1.93 Å−1 indicates a strong competition between the charge density waves and the superconductive state. A phase diagram of the La(Fe,Mn)As($O_{0.89}F_{0.11}$) system is drawn on the basis of the structural, magnetic, and electronic properties of the analyzed samples

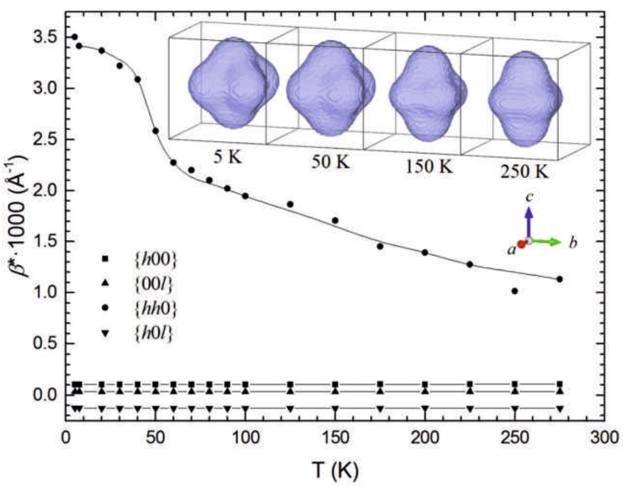


Fig. 1: Thermal evolution of the tetragonal anisotropic strain parameters obtained by Rietveld refinement; β represents the integral breadth of the diffraction line profile. The inset shows the corresponding tensor surfaces calculated at selected temperatures.

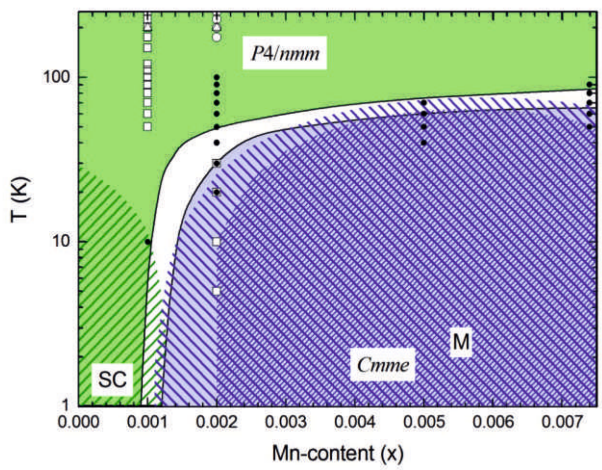


Fig. 2: Phase diagram of the La($Fe_{1-x}Mn_x$)As($O_{0.89}F_{0.11}$) system; the magnetic phase field is drawn for both a magnetic volume fraction equal to 50% (sparse pattern) and 100% (dense pattern); temperatures at which incommensurate peaks are observed are also indicated by points.

A precursor mechanism triggering the second magnetization peak phenomenon in superconducting materials

M. Polichetti[1,2], A. Galluzzi[1,2], K. Buchkov[3,4], V. Tomov[3], E. Nazarova[3], A. Leo[1,2], G. Grimaldi[2], S. Pace[1,2]

[1]Department of Physics "E.R. Caianiello", University of Salerno, Via Giovanni Paolo II, 132, 84084 Fisciano, (SA), Italy.

[2]CNR-SPIN, UOS Salerno c/o Università di Salerno - Via Giovanni Paolo II 132, 84084 Fisciano (SA), Italy

[3]Institute of Solid State Physics, Bulgarian Academy of Sciences, 72 Tzarigradsko Chaussee, 1784 Sofia, Bulgaria.

[4]Institute of Optical Materials and Technologies, Bulgarian Academy of Sciences, Acad. G. Bonchev Str. Bl. 109, 1113 Sofia, Bulgaria.

SCIENTIFIC REPORTS 11 (2021) 7247

The correlation in type-II superconductors between the creep rate S and the Second Magnetization Peak (SMP) phenomenon which produces an increase in J_c, as a function of the field (H), has been investigated at different temperatures by starting from the minimum in *S(H)* and the onset of the SMP phenomenon detected on a $FeSe_{0.5}Te_{0.5}$ sample. Then the analysis has been extended by considering the entire *S(H)* curves and comparing our results with those of many other superconducting materials reported in literature. In this way, we find evidence that the flux dynamic mechanisms behind the appearance of the SMP phenomenon in $J_c(H)$ are activated at fields well below those where the critical current starts effectively to increase. Moreover, the found universal relation between the minimum in the *S(H)* and the SMP phenomenon in $J_c(H)$ shows that both can be attributed to a sequential crossover between a less effective pinning (losing its effectiveness at low fields) to a more effective pinning (still acting at high fields), regardless of the type-II superconductor taken into consideration.

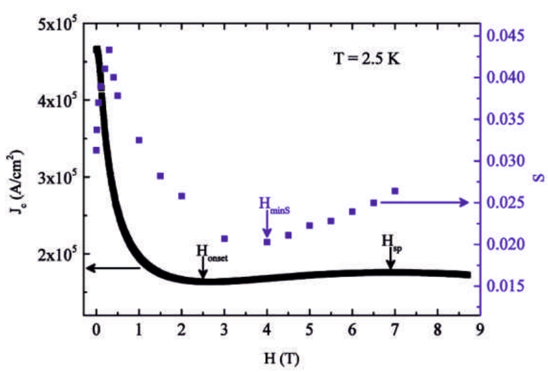


Fig. 1: The field dependence of relaxation rate *S* (blue closed squares, right scale) shown together with the *Jc(H)* curve (black closed squares, left scale) measured at the same temperature *T* = 2.5 K.

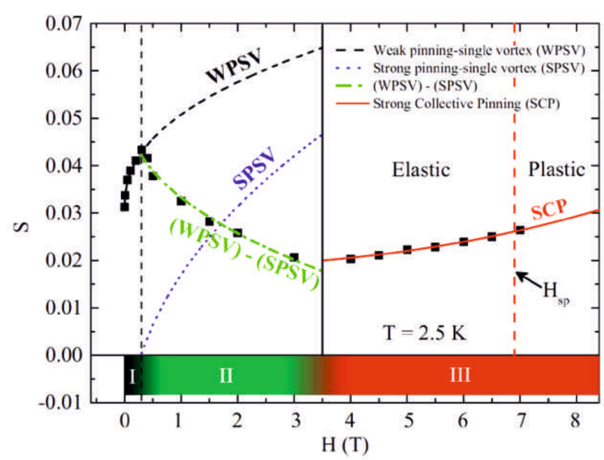


Fig. 2: *S* as a function of *H* at *T* = 2.5 K. The black dashed line is the fit of the first *S(H)* increase. The blue dotted line is the strong pinning single vortex behavior speculated for the vortices that enter in the twin boundaries. The green dashed-dotted line is the fit of the decreasing *S(H)* data by the subtraction of the black and blue line. The red solid line is the fit of the second *S(H)* increase. In the bottom of the figure, the field intervals relative to the three *S(H)* portions are identified with different colours. Finally, the black vertical solid line separates the single vortex state from the collective pinning state while the red vertical dashed line, individuated by the H_{sp} value, separates the elastic regime from the plastic regime in the framework of the collective pinning theory.

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.

Thermometric Calibration of the Ultrafast Relaxation Dynamics in Plasmonic Au Nanoparticles

Marzia Ferrera[1], Giuseppe Della Valle[2], Maria Sygletou1, Michele Magnozzi[1], Daniele Catone[3], Patrick O'Keeffe[3], Alessandra Paladini[3], Francesco Toschi[3], Lorenzo Mattera[1], Maurizio Canepa[1], and Francesco Bisio[4]

[1]OptMatLab, Dipartimento di Fisica, Universita` di Genova, I-16146 Genova, Italy
[2]Dipartimento di Fisica, IFN-CNR, Politecnico di Milano, I-20133 Milano, Italy
[3]CNR-ISM, Division of Ultrafast Processes in Materials (FLASHit), I-00133 Rome, Italy
[4]CNR-SPIN Institute of Superconductors, Innovative Materials and Devices, UOS-Genova, I-16152, Genova, Italy

ACS PHOTONICS 7, 959–966 (2020)

The impulsive excitation of matter by ultrashort laser pulses sets in motion a complex relaxation process, occurring on the femto-to-picosecond time scale, that involves the initial absorption of the electromagnetic energy by the system electrons, the gradual equilibration of the electron gas, and the subsequent release of energy to the ion-lattice, and to the environment. Thus, on the ultrafast time scale, the temperature of the electron gas (T_{el}), the ion lattice (T_L), and the environment (T_{bath}), differs (Fig.1, left), only to become equilibrated on the ps time scale. In order to have insights about these ultrafast processes, it is paramount to extract the dynamic evolution of the system temperature, yet such measurements are intrinsically complex. In this work, we report a measurement of the ultrafast dynamics of the ion-lattice temperature in Au nanoparticles following ultra-short-pulse excitation. To this end, we compared the ultrafast optical fingerprint of Au nanoparticles with their corresponding static optical spectra as a function of the increasing temperature of the thermodynamic bath (Fig.1, right). Evaluating the analogies and differences between the two sets of data allowed us to evaluate the experimental conditions upon which electrons and lattice are in thermal equilibrium, and henceforth extract the ultrafast temperature evolution of the plasmonic particles as a function of time (Fig.2).

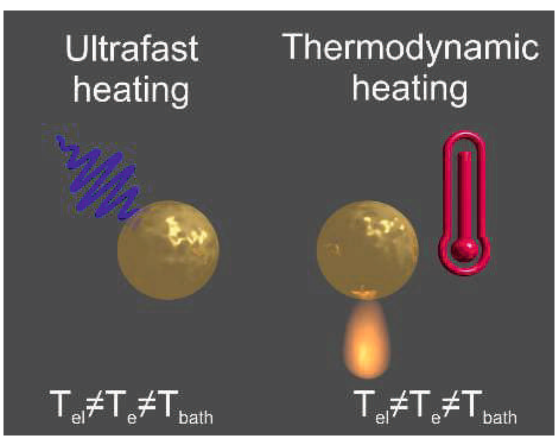


Fig. 1: The principle of the thermos-optical temperature calibration of impulsively excited plasmonic Au nanoparticles.

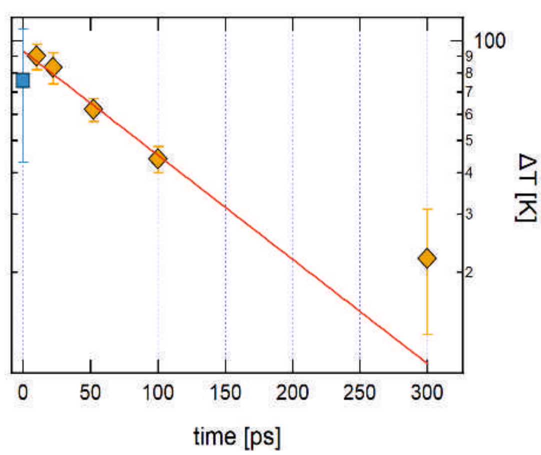


Fig. 2: Dependence of the ion-lattice temperature of Au nanoparticles as a function of the delay time elapsed since impulsive electromagnetic excitation, extracted by means of a static thermos-optical calibration method.

Electrodynamics of Highly Spin-Polarized Tunnel Josephson Junctions

H.G. Ahmad[1,2], R. Caruso[1,2,3], A. Pal[4,5], G. Rotoli[6], G.P. Pepe[1,2], M.G. Blamire[4], F. Tafuri[1,2], D. Massarotti[2,7]

[1]Dipartimento di Fisica "Ettore Pancini", Università degli Studi di Napoli Federico II, Monte S. Angelo, via Cinthia, Napoli, I-80126, Italy

2CNR-SPIN Institute of Superconductors, Innovative Materials and Devices, c/o Complesso Monte Sant'Angelo, Via Cinthia, I-80126, Napoli, Italy

[3]SeeQC-EU, via dei Due Macelli 66, Roma I-00187, Italy

[4]Department of Materials Science and Metallurgy, University of Cambridge, 27 Charles Babbage Road, Cambridge CB3 0FS, United Kingdom

[5]Department of Metallurgical Engineering and Materials Science, IIT Bombay, Mumbai 400076, India

[6]Dipartimento di Ingegneria, Università della Campania "Luigi Vanvitelli", via Roma 29, Aversa (CE) 81031, Italy

[7]Dipartimento di Ingegneria Elettrica e delle Tecnologie dell'Informazione, Università degli Studi di Napoli Federico II, via Claudio, Napoli, I-80125, Italy

PHYSICAL REVIEW APPLIED 13, 014017 (2020)

The continuous development of superconducting electronics is encouraging several studies on hybrid Josephson junctions (JJs) based on superconductor-ferromagnet-superconductor (SFS) heterostructures, as either spintronic devices or switchable elements in quantum and classical circuits. In this work, we provide an extensive characterization down to dilution temperatures of tunnel ferromagnetic JJs with an insulating ferromagnetic barrier (GdN), on devices with different barrier thickness. We demonstrate that a modeling of the I(V) curves within a microscopic approach, namely the Tunnel Junction Microscopic (TJM) model, allows to disentangle the dissipation effects due to the environment from the intrinsic dissipation processes, and to establish a protocol for the determination of the electrodynamic parameters, such as junction quality factor, subgap resistance and capacitance, as a function of the barrier thickness. The relevance of this work resides in providing the scaling behavior of the electrodynamic parameters, which represents a fundamental step for the feasibility of tunnel-ferromagnetic JJs as active elements in quantum and classical circuits, and are of general interest for hybrid tunnel junctions. Therefore, this study provides a pathway to the engineering of tunnel-ferromagnetic JJs for specific applications in superconducting hybrid qubits.

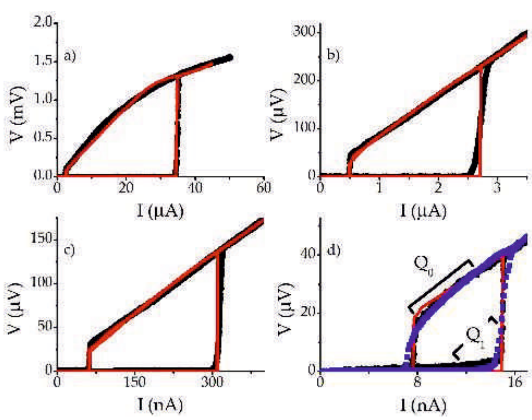


Fig.1: The measured I -V curves at 4.2 K (black points) and TJM model simulation (red curve) for spin-filter JJs with thicknesses of (a) 2.5, (b) 3.0, (c) 3.5, and (d) 4.0 nm. The blue squares in (d) represent the frequency-dependent RCSJ model fit curve, obtained for $Q0 = 2.8$ and $Q1 = 0.13$.

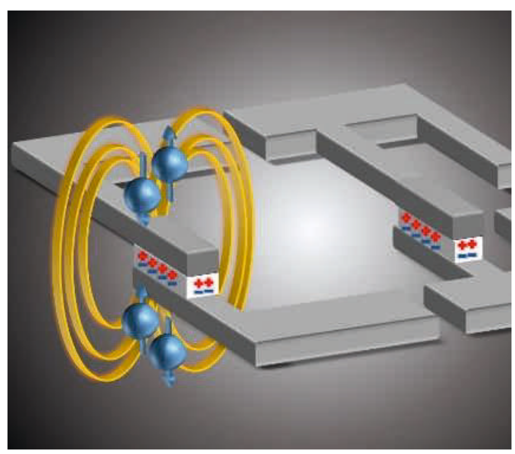


Fig.2: Picture of a tunnel ferromagnetic JJ integrated in a qubit design for novel superconducting hybrid quantum devices.

A Perspective on Conventional High-Temperature Superconductors at High Pressure: Methods and Materials

J. A. Flores-Livas[1], L. Boeri[1], A. Sanna[2], G. Profeta[3], R. Arita[4,5], M. Eremets[6]

[1]Department of Physics, Sapienza Universita' di Roma, Italy
[2]Max-Planck Institute of Microstructure Physics, Weinberg 2, 06120 Halle, Germany
[3]Department of Physical and Chemical Sciences and SPIN-CNR, University of L'Aquila, Via Vetoio 10, I-67100 L'Aquila, Italy
[4]Department of Applied Physics, Hongo Bunkyo-ku 113-8656, Japan
[5]RIKEN Center for Emergent Matter Science, 2-1 Hirosawa, Wako, 351-0198, Japan
[6]Max-Planck Institute for Chemistry, Hahn-Meitner-Weg 1 55128 Mainz, Germany

PHYSICS REPORTS 856, 1-78 (2020)

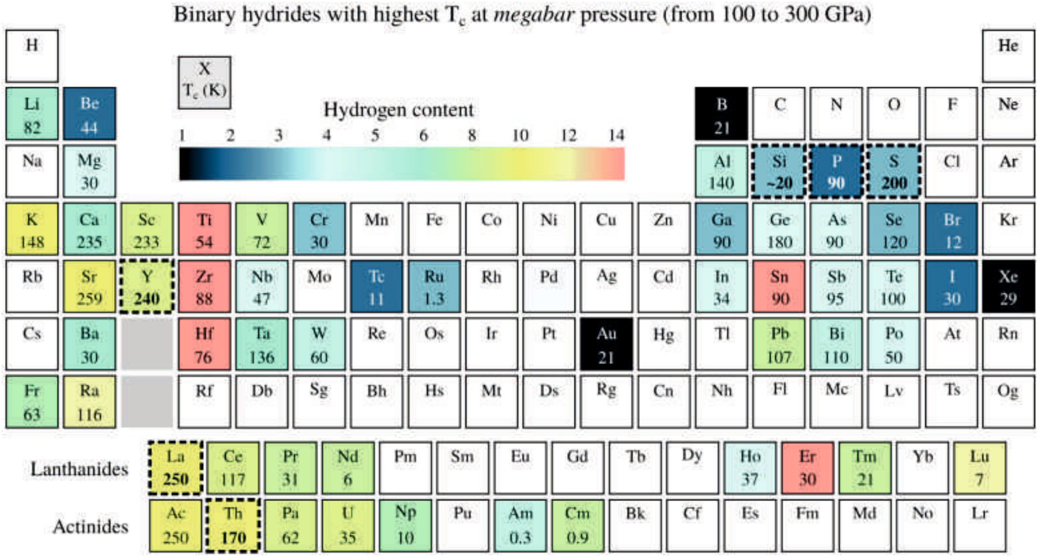
An international collaboration involving researchers from Italy, Germany and Japan has published one of the most complete reviews on the field of high-temperature superconductivity at high pressures.

The field of superconductivity has been galvanized by reports of critical temperatures of 203 K (2015) and 260 K (2019) in two hydrogen-based materials. These two reports have broken the previous records held by the cuprates, providing the first glimpse to the solution of the hundred-year-old problem of room-temperature superconductivity.

In the Review, published open access on Physics Reports, explain the mechanism underlying superconductivity in these exceptional compounds and provide a complete reference of the recent advances in experimental techniques, superconductivity theory and first-principles computational methods which have made these discoveries possible. Besides, in an attempt to evidence empirical rules governing superconductivity in hydrides under pressure, the authors also discuss general trends in the electronic structure and chemical bonding, possible strategies to optimize pressure and transition temperatures in conventional superconducting materials as well as future directions in theoretical, computational and experimental research.

In the words of the Referees, this work has been classified as "one of the most complete, and up-to-date Review on the superconductivity of Hydrides, that will definitely serve as a reference for future works."

Binary hydrides with highest T_c at *megabar* pressure (from 100 to 300 GPa)



Quantized conductance in a one-dimensional ballistic oxide nanodevice

A. Jouan[1], G. Singh [1,2], E. Lesne3, D. C. Vaz [3], M. Bibes [3], A. Barthélémy [3], C. Ulysse [4], D. Stornaiuolo [5,6], M. Salluzzo [6], S. Hurand [1,7], J. Lesueur [1], C. Feuillet-Palma [1] and N. Bergeal [1]

[1]Laboratoire de Physique et d'Etude des Matériaux, ESPCI Paris, PSL University, CNRS, Sorbonne Université, Paris, France.
[2]Quantum Device Physics Laboratory, Department of Microtechnology and Nanoscience Mc2, Chalmers University of Technology, Sweden.
[3]Unité Mixte de Physique CNRS-Thales, Université Paris-Sud/Université Paris-Saclay, Palaiseau, France.
[4]Centre for Nanoscience and Nanotechnology, CNRS, Université Paris-Sud/Université Paris-Saclay, Palaiseau, France.
[5]Department of Physics, University of Naples Federico II Complesso Monte S. Angelo, Napoli, Italy.
[6]CNR-SPIN Complesso Monte S. Angelo, Napoli, Italy.
[7]Institut Pprime, UPR 3346 CNRS, Université de Poitiers, ISAE-ENSMA, Chasseneuil, France.

NATURE ELECTRONICS 3, 201 (2020)

Within the Quantera QUANTOX project, coordinated by the CNR-SPIN, a quantum point contact (QPC) made of LAO/STO 2DEG have for the first time fabricated and **quantization of the conductance has been demonstrated. This work, coordinated by the ESCPI group in Paris**, in collaboration with the CNRS and CNR-SPIN, is a first important milestone toward the application of oxide 2DEGs in quantum applications. The studied QPC devices were created by electrostatic confinement of the $LaAlO_3/SrTiO_3$ 2DEG with a split-gate configuration. Figure 1 shows a schematic view of a QPC, which is formed by the deposition of a metallic split-gate on top of the $LaAlO_3$ to electrostatically deplete the 2DEG underneath. A 10 μm wide Hall bar was first designed in a 12 u.c. thick $LaAlO_3$ layer using the $LaAlO_3$ amorphous template method. After the growth, a metallic back gate was deposited on the back side of the 500 μm thick $SrTiO_3$ substrate enabling a global control of the electron density in the device. Finally, a metallic split-gate was patterned by lift-off directly on the top of the Hall bar (Fig. 6). Despite the reduced thickness of the $LaAlO_3$ layer ($\approx$5 nm) and the absence of additional insulating dielectric layer, no leakage current was observed in this device. The separation between the two fingers at the center of the split gate is W = 25 nm, which is comparable to the Fermi wavelength of the 2DEG. Near the bottleneck of the constriction, the split-gate imposes a smoothly varying confining potential that can be modeled by a harmonic potential in the transverse direction. Figure 1c shows the evolution of the conductance at zero source-drain voltage as a function of the gate voltage V_{SG} applied on the split-gate. At V_{SG} = -0.2 V the QPC is pinched off. Plateaus corresponding to the quantized values of the conductance in integer value of $G_0=2e^2/h$ appear when the split-gate voltage is increased, which indicates that ballistic transport involving spin-degenerated bands is taking place in the QPC. A maximum of three plateaus can be identified in this gate range, corresponding to $\lambda_F\approx15$ nm. A spectroscopy of the 3d-levels was performed by measuring non-linear transport at finite source-drain voltage (Fig. 1d).

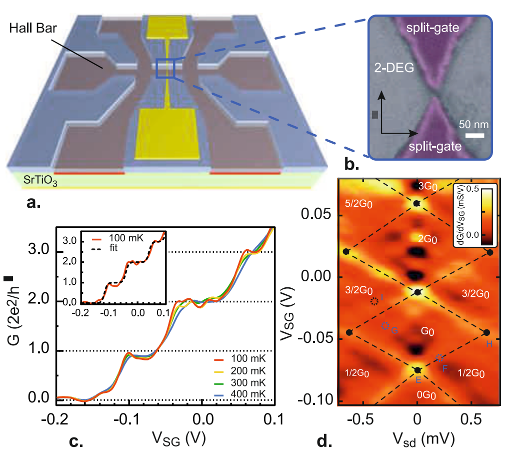


Fig. 1: Scheme of the QPC device in a $LaAlO_3/SrTiO_3$ interface. b) SEM image of the QP. c) Quantization of conductance in integer value of $2e^2/h$. d) Spectroscopy of the energy levels obtained by measuring the transconductance of the device (color code) as a function of source-drain voltage and split-gate voltage. Each diamond represents a well-defined quantized conductance.

Large Polarons as Key Quasiparticles in $SrTiO_3$ and $SrTiO_3$-Based Heterostructures

Andrey Geondzhian,[1] Alessia Sambri,[2] Gabriella M. De Luca,[3,2] Roberto Di Capua,[3,2] Emiliano Di Gennaro,[3,2] Davide Betto,[1] Matteo Rossi ,[4,5] Ying Ying Peng ,[4,6] Roberto Fumagalli,[4] Nicholas B. Brookes,[1] Lucio Braicovich,[1,4] Keith Gilmore,[1,7] Giacomo Ghiringhelli ,[4,8] and Marco Salluzzo [2,*]

[1]ESRF—The European Synchrotron, 71 Avenue des Martyrs, CS 40220, F-38043 Grenoble, France
[2]CNR-SPIN Complesso Monte-Santangelo via Cinthia, I-80126 Napoli, Italy
[3]Dipartimento di Fisica "Ettore Pancini" Universita` di Napoli "Federico II", Complesso Monte-Santangelo via Cinthia, I-80126 Napoli, Italy
[4]Dipartimento di Fisica, Politecnico di Milano, Piazza Leonardo da Vinci 32, I-20133 Milano, Italy
[5]Stanford Institute for Materials and Energy Sciences, SLAC National Accelerator Laboratory, 2575 Sand Hill Road, Menlo Park, California 94025, USA
[6]International Center for Quantum Materials,School of Physics, Peking University, Beijing 100871, China
[7]Condensed Matter Physics and Materials Science Division, Brookhaven National Laboratory, Upton, New York 11973-5000, USA
[8]CNR-SPIN, Piazza Leonardo da Vinci 32, I-20133 Milano, Italy

PHYSICAL REVIEW LETTERS 125, 126401 (2020)

Quasiparticles in metals and semiconductors are formed through the interactions of electrons (holes) with the elementary excitations of the solid, like phonons and magnons. Here, by using titanium L-edge resonant inelastic x-ray scattering (RIXS) with unprecedent energy resolution we demonstrate that the quasiparticles in bulk $SrTiO_3$ and related heterostructures are large polarons formed by the coupling of itinerant carriers to optical phonons. RIXS spectra on different samples, from barely undoped $SrTiO_3$ to strongly metallic heterostructures, show low (25-30 meV), mid (50-60 meV) and high energy (90-100 meV, LO3) optical phonons excitations and, at a higher energy (125-135 meV), an intra-t2g d-d excitation accompanied by the emission of an LO3 optical phonon, which represents a hallmark of large polarons in STO and LAO/STO bilayers. Furthermore, from the analysis of the RIXS cross section, we find that the electron-phonon coupling constant of the LO3 phonon mode decreases with the carrier density as consequence of the screening of the large-polaron self-induced polarization [1].

Beside confirming earlier signatures by ARPES at the surface of STO [2], in LAO/STO [3] and in FeSe/STO bilayers [4], our study demonstrates more generally the emergence of large polaron physics in both bi- and three-dimensional titanates. Finally, it emerges that polarons are observed also in nominally undoped STO, with a coupling constant well below the value expected for small polarons formation. Consequently, we can infer that even at the very low doping level, as that induced by residual defects or by long living photodoped carriers, $3d^1$ electrons are dressed by long-range polar lattice distortions, as theoretically predicted in other wide band gap materials like LiF [5]. Future investigations and theoretical modeling of the normal and superconducting state of STO and STO-based heterostructures will have to take in consideration the central role

References

[1] A. Geondzhian, et al., Phys. Rev. Lett. 125, 126401 (2020).
[2] Z. Wang et al., Nature Materials 15, 835 (2016).
[3] C. Cancellieri et al., Nature Communications 7, 10386 (2016).
[4] J.-F. Ge et al. , Nat. Mater. 14, 285 (2015).
[5] W.H. Sio, C. Verdi, S. Poncé, and F. Giustino, Phys. Rev. Lett. 122, 246403 (2019).

Self-Formed, Conducting $LaAlO_3/SrTiO_3$ Micro-Membranes

Alessia Sambri[1], M. Scuderi2, A. Guarino[1,3], E. Di Gennaro[1,4], R. Erlandsen[5], R. T. Dahm[5], A. V. Bjørlig[5], D. V. Christensen[6], R. Di Capua[1,4], S. Mirabella[2,7], T. S. Jespersen[5], G. Nicotra[2], C. Spinella[2], and F. Miletto Granozio[1,4]

[1]CNR-SPIN UOS of Naples, Complesso Universitario di Monte S. Angelo, Via Cintia, 80126 Naples, Italy
[2]IMM-CNR, Strada VIII n. 5 Zona Industriale, 95121 Catania, Italy
[3]CNR-DSFTM, NFFA Trieste, Area Science Park - Basovizza Strada Statale 14, 34149 Trieste, Italy
[4]Dipartimento di Fisica "E. Pancini", Complesso Universitario di Monte S. Angelo, Italy
[5]Niels Bohr Institutet, Universitetsparken 5, bygn. D, 2100 København, Denmark 6 Department of Energy Conversion and Storage, Technical University of Denmark, Roskilde, Denmark
[7]Dipartimento di Fisica e Astronomia, Universita` di Catania,Via S.Sofia 64, I-95123, Catania, Italy

ADVANCED FUNCTIONAL MATERIALS 2020, 1909964

The discovery of 2D conductivity at the $LaAlO_3/SrTiO_3$ interface has been linking, for over a decade, two of the major current research fields in materials science: correlated transition-metal-oxide systems and low- dimensional systems. Notably, despite the 2D nature of the interfacial electron gas, the samples are 3D objects with thickness in the mm range. This prevented researchers so far from adopting strategies that are only viable for fully 2D materials, or from effectively exploiting degrees of freedom related to strain, strain gradient and curvature. Here a method based on pure strain engineering for obtaining freestanding $LaAlO_3/SrTiO_3$ membranes with micrometer lateral dimensions is demonstrated. Detailed transmission electron microscopy investigations show that the membranes are fully epitaxial and that their curvature results in a huge strain gradient, each layer showing a mixed compressive/tensile strain state. Electronic devices are fabricated by realizing ad hoc circuits for individual micro-membranes transferred on silicon chips. The samples exhibit metallic conductivity and electrostatic field effect like 2D-electron systems in bulk heterostructures. The results open a new path for adding oxide functionalities into semiconductor electronics, potentially allowing for ultra-low voltage gating of a superconducting transistors, micromechanical control of the 2D electron gas mediated by ferroelectricity and flexoelectricity, and on-chip straintronics.

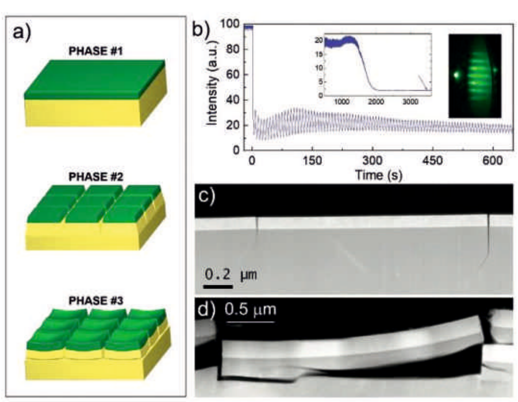


Fig. 1: a) Sketch depicting the three different stages for LAO/STO membrane formation, b) Evolution of RHEED (0,0) spot intensity for a 180 nm sample and final pattern, c) and d) Low-resolution cross section SEM image of phase #2 and #3, respectively.

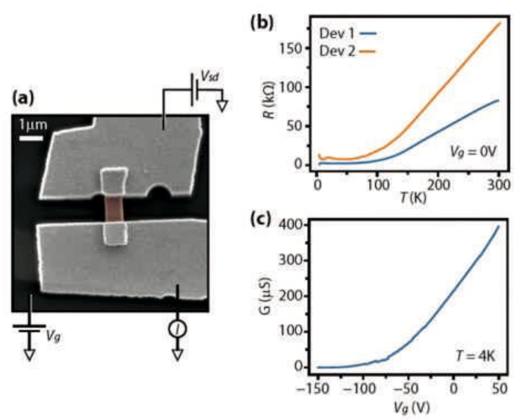


Fig. 2: a) False color SEM micrograph of a typical μHS device after transfer to a Si/SiO_2 substrate and contacted in a two-terminal configuration; b) Resistance as a function of temperature for two typical devices showing metallic behavior; c) The gate dependence of the conductance of Device 1 at 4 K.

Electric Transport in Gold-Covered Sodium-Alginate Free-Standing Foils

C. Barone[1,2], M. Bertoldo[3], R. Capelli[4], F. Dinelli[5], P. Maccagnani[6], N. Martucciello[2], C. Mauro[1], S. Pagano[1,2]

[1]Dipartimento di Fisica "E.R. Caianiello", Università degli Studi di Salerno, I-84084 Fisciano (SA), Italy
[2]CNR-SPIN, UOS Salerno c/o Università di Salerno - Via Giovanni Paolo II 132, 84084 Fisciano (SA), Italy
[3]Dipartimento di Scienze Chimiche, Farmaceutiche ed Agrarie, Università degli Studi di Ferrara, I-44121 Ferrara, Italy
[4]Dipartimento di Ingegneria E. Ferrari, Università di Modena e Reggio Emilia, I-41125 Modena, Italy
[5]CNR - Istituto Nazionale di Ottica, I-56124 Pisa, Italy
[6]CNR - Istituto per la Microelettronica e Microsistemi, I-40129 Bologna, Italy

NANOMATERIALS 11 (2021) 565

The development of *innovative and green electronics* calls for the usage of recyclable and environmentally sustainable materials. We have realized flexible and transparent conducting films, by sputtering ultrathin gold nanometric layers on sodium-alginate free-standing films. Their electric transport properties have been investigated in temperature range *from 300 K to 3 K*. For a gold layer thickness higher than 5 nm, a typical metallic resistivity behavior is observed. Conversely, an unusual resistance temperature dependence is found for gold thickness of 4.5 nm. In this last case, above 70 K, the rapid polymeric expansion by lowering the temperature is considered to explain the observed behavior. In the low-temperature regime, below 70 K, a fluctuation-induced tunneling process is identified as the dominant transport mechanism at work. The reported results are complemented with the information extracted from structural, mechanical, and optical characterizations, and represent a base for future developments of *eco-friendly technologies*.

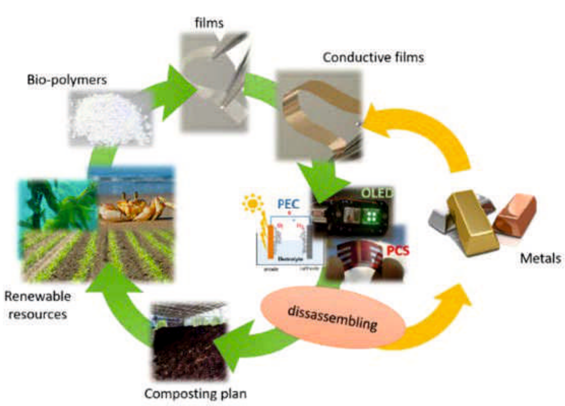


Fig.1: Driven by the recent sustainability issues, a very hot field of research is the development of emergent and innovative *bio-materials*, such as sodium-alginate, useful for the realization of advanced devices for *"green electronics"*.

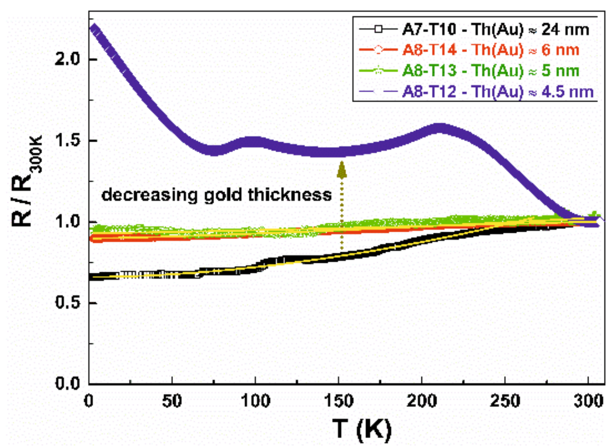


Fig.2: A detailed characterization in temperature of the conduction mechanisms on alginate compounds is shown and is discussed in terms of different theoretical interpretations.

Quantitative Ultrafast Electron-Temperature Dynamics in Photo-Excited Au Nanoparticles

M. Sygletou[1], S. Benedetti[2], M. Ferrera[1], G. M. Pierantozzi[3], R. Cucini[3], G. Della Valle[4], P. Carrara[5], A. De Vita[5], A. di Bona[2], P. Torelli[3], D. Catone[6], G. Panaccione[3], M. Canepa[1], F. Bisio[7]

[1]OptMatLab, Dipartimento di Fisica, Università di Genova, via Dodecaneso 33, I-16146 Genova, Italy
[2]CNR - Istituto Nanoscienze, via Campi 213/a, 41125 Modena, Italy
[3]Istituto Officina dei Materiali - CNR, Laboratorio TASC, Area Science Park, S.S. 14, Km 163.5, Trieste, I-34149 Italy
[4]Dipartimento di Fisica, IFN - CNR, Politecnico di Milano, Piazza Leonardo da Vinci 32, I-20133 Milano, Italy
[5]Dipartimento di Fisica, Università degli Studi di Milano, via Celoria 16, Milano, Italy
[6]Istituto di Struttura della Materia - CNR (ISM - CNR), EuroFEL Support Laboratory (EFSL), Via del Fosso del Cavaliere, 100, I-00133 Rome, Italy
[7]CNR-SPIN, Sede Genova c/o Università di Genova, Via Dodecaneso 33, 16146 Genova, Italy

SMALL 17 (2021) 2100050

The dynamic processes and the redistribution of the charges following the photoexcitation of metallic nanoparticles (NPs) lie at the very heart of some highly-appealing light-induced physical phenomena, with applications in nanophotonics, hyperthermia, and photocatalysis to name a few. In order to investigate the mechanisms of electromagnetic-energy conversion, we need to study the fundamental processes occurring after the interaction of light with matter. In this work, we report for the first time a direct measurement of the ultrafast electron-temperature dynamics in plasmonic gold NPs in the first femtoseconds after impulsive photoexcitation. We measured the ultrafast electron-temperature dynamics in NPs deposited onto a transparent conductive oxide; we excited the NPs by means of an ultrashort pulse with wavelength at 650 nm, and collected ultrafast time-resolved photoemission spectra as a function of the elapsed time by means of extreme-ultraviolet ultrashort pulses (photon energy 16.9 eV, Figure 1).

Tiny variations on the Fermi edge of gold NPs, ascribed to the ultrafast heating and relaxation of the electron gas, were observed. Fitting the Fermi edge, we directly extracted the temperature of the electron gas as a function of the delay time elapsed from the moment of excitation (Figure 2). After excitation, the electronic temperature quickly increased and reached the maximum value after several hundreds of femtoseconds (~800 fs) and then gradually relaxed towards the environment temperature, in agreement with theoretical simulations. These results represent a significant progress for future investigation in the field, opening exciting perspectives for direct and quantitatively accurate studies of the electrodynamics of metallic bulk and nanostructured systems.

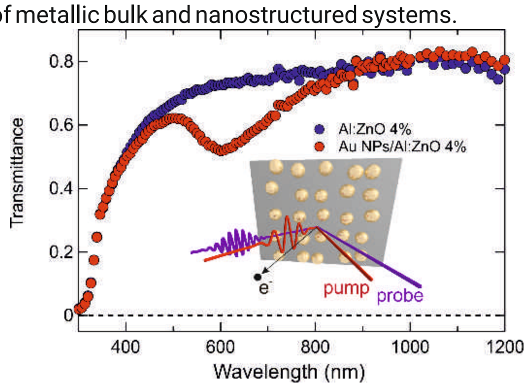


Fig. 1: Transmission spectra of 4 at% AZO film on MgO substrate with (red markers) and without (blue markers) Au NPs. Inset: Schematic diagram of the experimental setup.

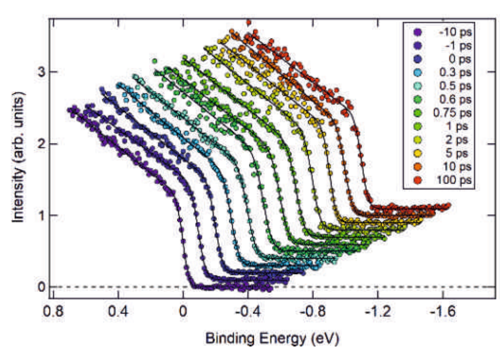


Fig. 2: Time-resolved pump-probe spectra of Au NPs at the Fermi edge (markers). Best fits according to Equation (1) (solid lines). The curves have been offset in energy and intensity for the sake of clarity.

Nanopatterning of oxide 2-dimensional electron systems using low-temperature ion milling

Maria D'Antuono[1,2] , Alexei Kalaboukhov[3] , Roberta Caruso[1,2,4] , Shai Wissberg[5], Sapir Weitz Sobelman[5], Beena Kalisky[5], Giovanni Ausanio[1,2], Marco Salluzzo[2], Daniela Stornaiuolo[1,2]

[1]Department of Physics, University of Naples Federico II Complesso Monte S. Angelo, Napoli, Italy
[2]CNR-SPIN, UOS Napoli c/o Complesso di Monte S. Angelo, via Cinthia 21, 80126 Napoli, Italy
[3]Department of Microtechnology and Nanoscience MC2, Chalmers University of Technology, Sweden
[4]Brookhaven National Laboratory, Condensed Matter Physics and Materials Science Department, USA
[5]Department of Physics and Institute of Nanotechnology and Advanced Materials, Bar-Ilan University Ramat-Gan, Israel

NANOTECHNOLOGY 33 (2021) 085301

In this work, we present a "top-down" technique to pattern oxide 2DEGs down to the nanoscale (160 nm) via an Ar ion milling process. Although developed for realizing LAO/ETO/STO devices, it can be applied to all types of oxide heterostructures.
The process is sketched in Fig. 1 . After realizing a resist mask, the sample is glued to a cold finger cooled with liquid nitrogen and patterned using low energy Ar ion milling. The lower panels of Figure 1 show Atomic Force Microscope images of some of the nanodevices we realized.
Electrical transport and scanning Superconducting Quantum Interference Device measurements (Fig. 2) demonstrate that the low-temperature ion milling process does not damage the 2DEG system properties, including gate tunability and ferromagnetic coupling, nor creates oxygen vacancies-related conducting paths in the STO substrate.
The presented technique shows some advantages compared to those used up to now for patterning of oxide 2DEG systems. Being a "top-down" approach, it does not involve manipulation of the substrate and it is suitable for the patterning of every kind of interfacial systems. The procedure can be applied also to pre-tested heterostructures, increasing the yield of the nanofabrication process and, unlike other nanopatterning techniques, it allows to expose the 2DEG along the in-plane directions. This last aspect opens the way to the realization of hybrid devices, where the 2DEG systems could be coupled other advanced materials.

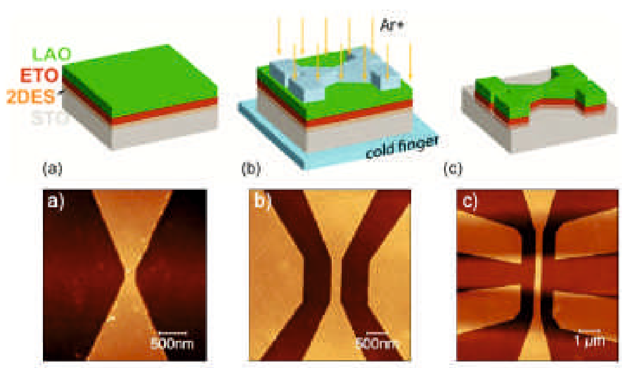


Fig. 1: Sketch of fabrication process of the LAO/ETO/STO nanodevices and AFM topography images of some of the LAO/ETO/STO devices realized: a) Dayem bridge, b) side gate device with one pair of lateral electrodes, c) side gate device with two pairs of lateral electrodes. In the AFM images, the lighter areas are the LAO/ETO bilayers, under which the 2DEG develops, while the darker areas are the exposed STO substrate.

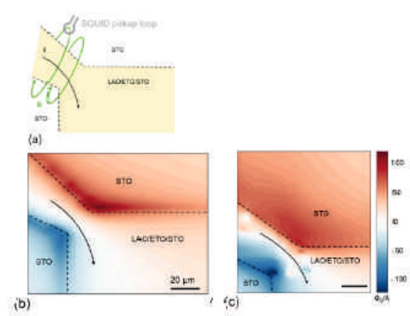


Fig. 2: (a) Schematic of scanning SQUID pickup loop capturing field lines near the surface of a current carrying device. (b) Simulation of the magnetic flux pattern in a homogeneous conductor with the same geometry as the measured LAO/ETO/STO device. (c) Scanning SQUID data over a patterned LAO/ETO/STO device taken at 4 K.

Irreversible multi-band effects and Lifshitz transitions at the $LaAlO_3/SrTiO_3$ interface under field effect

I. Pallecchi[1], N. Lorenzini[2], M. A. Safeen[3], M. M. Can[4], E. Di Gennaro[5,6], F. Miletto Granozio[6], D. Marré [2,1]

[1]CNR-SPIN, Sede Genova c/o Università di Genova, Via Dodecaneso 33, 16146 Genova, Italy
[2]Università di Genova, Dipartimento di Fisica, Genova, Italy
[3]Department of Physics, University of Poonch, Rawalakot, Pakistan
[4]Renewable Energy and Oxide Hybrid Systems Laboratory, Department of Physics, Istanbul University, Vezneciler, Istanbul, Turkey
[5]Università di Napoli "Federico II", Dipartimento di Fisica "E. Pancini", Napoli, Italy
[6]CNR-SPIN, UOS Napoli c/o Complesso di Monte S. Angelo, via Cinthia 21, 80126 Napoli, Italy

ADVANCED ELECTRONIC MATERIALS 7 (2021) 2001120

We investigate the irreversible effects of an applied electric field on the magnetotransport properties of $LaAlO_3/SrTiO_3$ conducting interfaces, with focus on their multiband character. We study samples of different types, namely with either crystalline or amorphous $LaAlO_3$ overlayer. Our two-band analysis highlights the similarity of the electronic properties of crystalline and amorphous interfaces, regardless much different carrier densities and mobilities. Furthermore, filling and depletion of the two bands follow very similar patterns, at least in qualitative terms, in the two types of samples. In agreement with previous works on crystalline interfaces, we observe that an irreversible charge depletion takes place after application of a first positive back gate voltage step. Such charge depletion affects much more, in relative terms, the higher and three-dimensional d_{yz}, d_{zx} bands than the lower and bidimensional d_{xy}, driving the system through the Lifshitz transition from two-band to single band behavior. The quantitative analysis of experimental data reveals the roles of disorder, apparent in the depletion regime, and temperature.

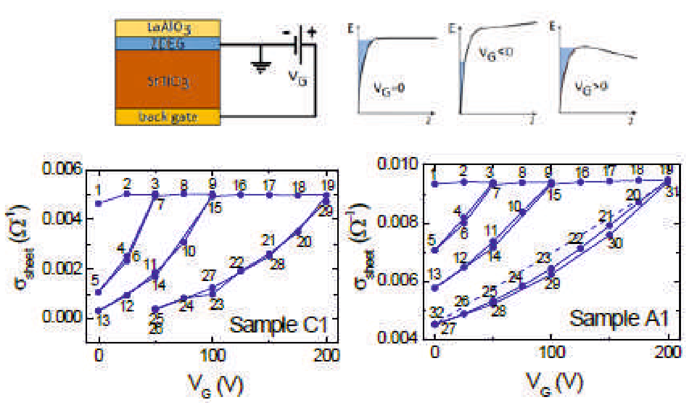


Fig. 1: Top: Sketches of the two dimensional electron gas (2DEG) at the interface and circuital configuration. Bottom: Zero field longitudinal conductance σ_{sheet} of crystalline (C1) and amorphous (A1) samples as a function of applied gate voltage VG, in successive VG ramps from zero to $V_{Gmax}(i)$, with increasing values $V_{Gmax}(i)$, measured at 20 K.

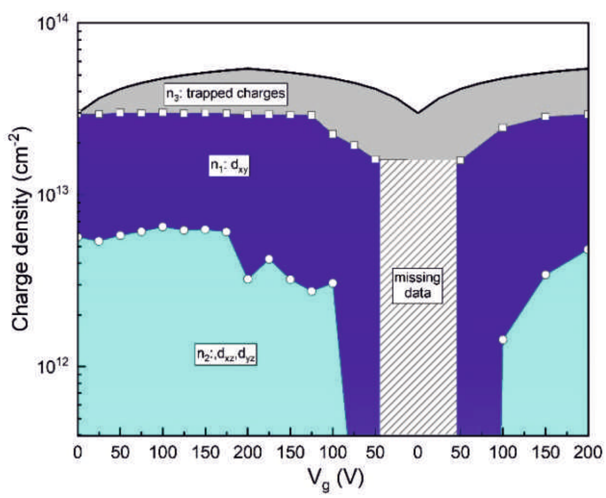


Fig. 2: Schematic diagram of charge densities in the two bands and in localized trap states during two increasing ramps up to 200V and one decreasing ramp. The n_1 and n_2 values represent our experimental data. The total charge, delimited by the black line, includes a calculated VG-dependent carrier density, allowing to deduce by difference the amount of trapped charge n_3 as a function of the gate voltage.

Size-Controlled Spalling of $LaAlO_3/SrTiO_3$ Micromembranes

R. T. Dahm [1,2], R. Erlandsen [1,2], F. Trier [1], A. Sambri [3], E. Di Gennaro [4], A. Guarino [3], L. Stampfer [1], D. V. Christensen [2], F. Miletto Granozio [3], T S. Jespersen [1]

[1]Center for Quantum Devices, Niels Bohr Institute, University of Copenhagen, 2100 Copenhagen, Denmark
[2]Department of Energy Conversion and Storage, Technical University of Denmark, 2800 Kgs. Lyngby, Denmark
[3]CNR-SPIN, UOS Napoli c/o Complesso di Monte S. Angelo, via Cinthia 21, 80126 Napoli, Italy
[4]Physics Department "E. Pancini", University of Naples "Federico II", Monte S. Angelo 80126 Naples, Italy

APPLIED MATERIALS AND INTREFACES 13(10) (2021) 12341

Some of the authors recently demonstrated a route for forming conducting heterostructure membranes of $LaAlO_3$ (LAO) and $SrTiO_3$ (STO), the canonical system for oxide electronics. There, the producing freestanding membranes had random sizes and locations. Here we extend this work by introducing a new concept for pregrowth substrate preparation allowing for control of where the LAO/STO membranes form on the substrate as well as their individual lateral dimensions. The method relies on patterning the stress discontinuities in the LAO/STO epitaxial hetero-structure by locally altering the growth substrate using argon milling prior to the growth. The process is schematically illustrated in Fig.1 and relies on a combination of lithography and Ar+-ion milling to define trenches in the STO substrate prior to LAO deposition. The dimensions of the squares $L_{x,y}$ = 0.5-20 um were varied between each field. Our results show that: 1) the size control is constricted by an upper and lower limit with respect to the yield and reproducibility of membranes; 2) the capability of direction fracture formation along directions di different from [100]/[010] otherwise strongly preferred without the pregrowth patterning; 3) the membranes can be manipulated in a controllable manner with a micromanipulator needle and transferred onto a silicon substrate (Fig.2). This method opens up the possibility to study and use the two-dimensional electron gas in LAO/STO membranes for advanced device concepts.

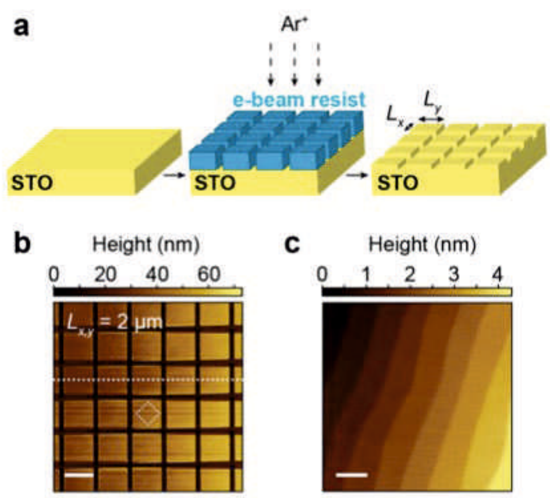


Fig. 1: (a) Schematic illustration of the surface patterning by Ar^+ion milling. (b) AFM topography map of the STO surface following Ar^+ion milling for a field with L = 2 um squares (scale bar is 2 um). The dashed square x,y and line correspond to the zoomed image in c. (c) High-resolution AFM image of the area in b showing STO-TiO_2-terraces (scale bar is 200 nm).

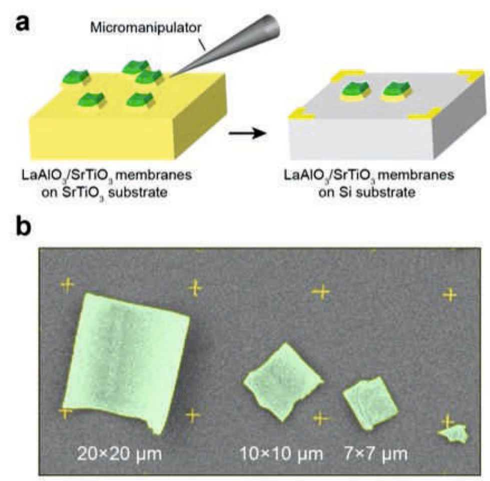


Fig. 2: (a) Schematic illustration of the controllable manipulation and transfer of LAO/STO membranes with a micromanipulator needle onto a silicon substrate. (b) SEM image of transferred membranes arranged into a row on the prepatterned silicon substrate.

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).

Spontaneous skyrmionic lattice from anisotropic symmetric exchange in a Ni-halide monolayer

D. Amoroso[1], P. Barone[1], S. Picozzi[1]

[1]CNR-SPIN Institute of Superconductors, Innovative Materials and Devices, c/o Università degli Studi 'G. D'Annunzio', 66100 Chieti, Italy

NATURE COMMUNICATIONS 11, 5784 (2020)

Magnetic skyrmions are localized topological spin structures carrying an integer topological charge Q. Their topological properties ensure the inherent stability that makes them technologically appealing for future memory devices. Typically, isolated skyrmions and skyrmion lattices can be realized by applied magnetic field in chiral magnets. Taking as a prototype system a monolayer of NiI2, a centrosymmetric and semiconducting van der Waals helimagnet in its bulk form, and combining density functional theory and Monte Carlo calculations, this work unveils a novel mechanism leading to a thermodynamically stable skyrmion lattice with well defined topology and chirality. When combined with magnetic frustration, arising from competing exchange interactions in a geometrically frustrated triangular lattice, the anisotropic part of the symmetric exchange tensor may act as an emerging chiral interaction, thus leading to a stable lattice of Q=2, nanosized antibiskyrmions shown in Fig. 1 (left).

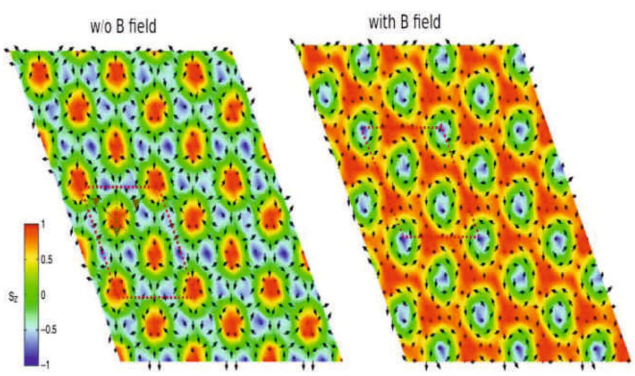


Fig. 1: Snapshots of spin configurations obtained from Monte Carlo calculations at T=1K showing the spontaneous antibiskyrmion lattice (left) and the magnetic field-induced skyrmion lattice (right) predicted in NiI_2 monolayer. Black arrows represent in-plane components of spins, while the out-of-plane Sz component is indicated by the color map.

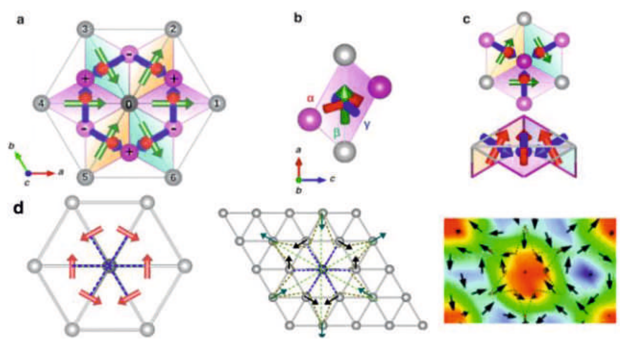


Fig. 2: Top view of NiI_2 (a), highlighting the principal axes of the exchange tensor within each Ni2I2 plaquette (b), that arrange in a non-coplanar fashion within the triangular lattice (c). The local spin configuration around each antibiskyrmion core is dictated by the principal axes of the anisotropic symmetric exchange (red arrows) shown in (d).

Indeed, the non-coplanarity of the principal axes of the exchange tensors introduces an additional frustration in the relative orientation of neighboring spins, thus determining the local topological spin configuration (Fig. 2). Furthermore, it is predicted that a magnetic field applied perpendicularly to the layer drives a topological transition to a Q=1 skyrmion lattice, shown in Fig. 1 (right). The proposed mechanism does not rely on the typically invoked antisymmetric and chiral Dzyaloshinskii-Moriya interaction, and as such it enlarges the kind of short-range magnetic interactions able to drive the stabilization of topological spin lattices.

Berry phase engineering at oxide interfaces

D. J. Groenendijk[1], C. Autieri2,3, T. C. van Thiel[1], W. Brzezicki[2,3], J. R. Hortensius[1], D. Afanasiev[1], N. Gauquelin[4], P. Barone[2], K. H. W. van den Bos[4], S. van Aert4, J. Verbeeck[4], A. Filippetti[5,6], S. Picozzi[2], M. Cuoco[2,7], and A. D. Caviglia[1]

[1]Kavli Institute of Nanoscience, Delft University of Technology, P.O. Box 5046, 2600 GA Delft, Netherlands
[2]Consiglio Nazionale delle Ricerche, CNR-SPIN, Italy
[3]International Research Centre MagTop, Institute of Physics, Polish Academy of Sciences,
Aleja Lotników 32/46, PL-02668 Warsaw, Poland
[4]Electron Microscopy for Materials Science (EMAT), University of Antwerp, 2020 Antwerp, Belgium
[5]Dipartimento di Fisica, Università di Cagliari, Cagliari, Monserrato 09042-I, Italy
[6]CNR-IOM, Istituto Officina dei Materiali, Cittadella Universitaria, Cagliari, Monserrato 09042-I, Italy
[7]Dipartimento di Fisica "E. R. Caianiello" Università degli Studi di Salerno, 84084 Fisciano, Italy

PHYS. REV. RESEARCH 2, 023404 (2020)

Three-dimensional strontium ruthenate ($SrRuO_3$) is an itinerant ferromagnet that features Weyl points acting as sources of emergent magnetic fields, anomalous Hall conductivity, and unconventional spin dynamics. Integrating $SrRuO_3$ in oxide heterostructures is potentially a novel route to engineer emergent electrodynamics (Fig. 1), but its electronic band topology in the two-dimensional limit remains unknown. Here we show that ultrathin $SrRuO_3$ exhibits spin-polarized topologically nontrivial bands at the Fermi energy. Their band anticrossings show an enhanced Berry curvature and act as competing sources of emergent magnetic fields (Fig. 2). We control their balance by designing heterostructures with symmetric and asymmetric interfaces. Symmetric structures exhibit an interface-tunable single-channel anomalous Hall effect, while ultrathin $SrRuO_3$ embedded in asymmetric structures shows humplike features consistent with multiple Hall contributions (Fig. 2). The band topology of two-dimensional SrRuO3 proposed here naturally accounts for these observations and harmonizes a large body of experimental results.

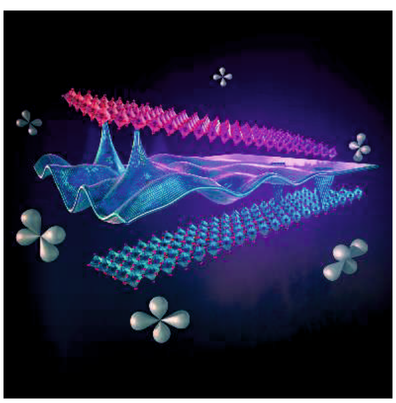


Fig. 1: Sketch of the geometric profile of the wave-function at oxides interfaces.

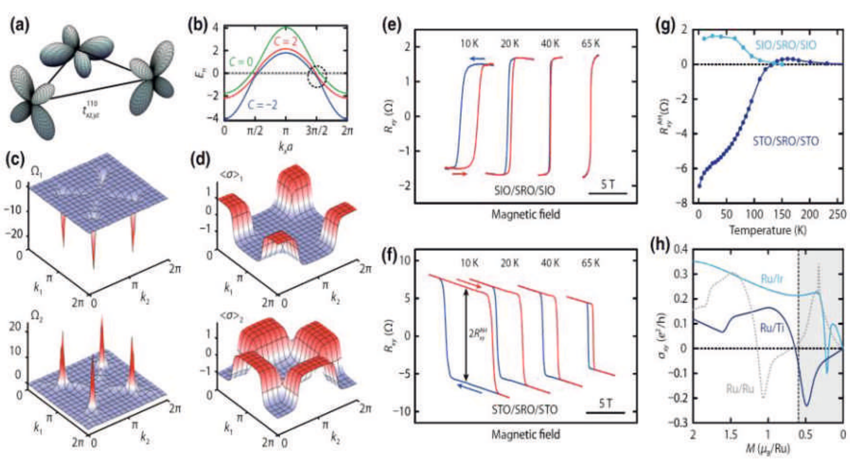


Fig. 2: (a) Next-nearest-neighbor hopping amplitude. Dispersion of Ru t_{2g} bands. (c) Berry curvature associated with topologically nontrivial Ru t_{2g} bands. (d) Spin polarizations for the corresponding bands. (e) and (f) Hall resistance of symmetric heterostructures as a function of temperature. (g) Temperature evolution of the amplitude of the AHE. (h) Evolution of the intrinsic contribution to the Hall conductance for various bilayers configurations as a function of the average Ru magnetization.

Impact of local structure on halogen ion migration in layered methylammonium copper halide memory devices

A. Ray[1,2], B. Martìn-Garcìa[3,4], A. Martinelli[5], D. Spirito[6], F. Locardi[2,7], D. Altamura[8], C. Giannini[8], M. Prato[9], L. Manna[1], A. L. Abdelhady[1]

[1]Nanochemistry Department, Istituto Italiano di Tecnologia, Via Morego 30, 16163 Genova, Italy
[2]Dipartimento di Chimica e Chimica Industriale, Università degli Studi di Genova, Via Dodecaneso, 31, 16146, Genova, Italy
[3]Graphene Labs, Istituto Italiano di Tecnologia, Via Morego 30, 16163 Genova, Italy
[4]CIC nanoGUNE, Tolosa Hiribidea 76, 20018 Donostia-San Sebastian, Basque Country, Spain
[5]CNR-SPIN Institute of Superconductors, Innovative Materials and Devices, UOS-Genova, C.so Perrone 24, I-16152 Genova, Italy
[6]IHP—Leibniz-Institut f¨ur Innovative Mikroelektronik, Im Technologiepark 25, D-15236 Frankfurt (Oder), Germany
[7]Physics and Chemistry of Nanostructures (PCN), Ghent University, Krijgslaan 281 –Building S3 (Campus Sterre), 9000 Gent, Belgium
[8]Istituto di Cristallogra a, Consiglio Nazionale delle Ricerche, v. Amendola 122/O, 70126 Bari, Italy
[9]Materials Characterization Facility, Istituto Italiano di Tecnologia, Via Morego 30, 16163 Genova, Italy

JOURNAL OF MATERIALS CHEMISTRY A

Ion migration is associated with hysteresis observed in halide perovskite-based solar cells and light-emitting diodes, however, it is crucial for their effective performance in memory devices. In the halide perovskites field, a direct link between the average/local structure and the preferred ion migration hopping pathway has yet to be established. Adopting a combined study of average/local structural characterization and detailed electrical measurements, we shine light on the interrelationships between structure and efficiency of ion migration in layered methylammonium copper halide materials (MA_2CuX_4). In our experimental investigation, we observe that the presence of mixed Cl/Br anions not only influences the optical band gap and thermal stability but also induces intricate local structural changes that affect the ion migration and, consequently, the ON/OFF ratio in the memory devices. Through comparing the structural data obtained by detailed XRPD-PDF analysis and our devices performances, we identify several favorable conditions for halogen ion/vacancy mobility These experimental results made on single crystalline samples highlights the need to study detailed structural factors that could affect ionic migration in perovskite and perovskite-related compounds, which is important for the performance of memristor and optoelectronic devices.

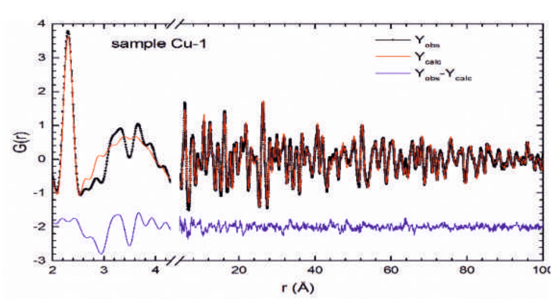


Fig. 1: Fitting of the experimental X-ray PDF function of MA_2CuCl_4.

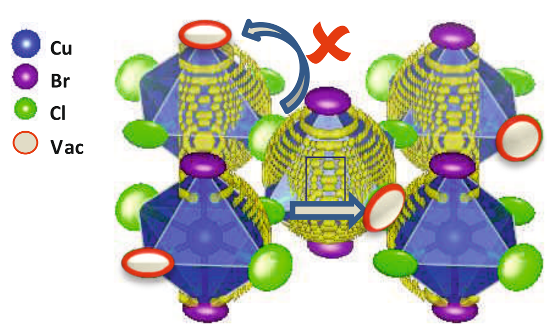


Fig. 2: Preferred migration pathways for halogen ions in Br-substituted MA_2CuCl_4 (as obtained from bond valence sum maps calculated by using XRPD and PDF data).

Persistent Spin-Texture and Ferroelectric Polarization in 2D Hybrid Perovskite Benzylammonium Lead-halide

Fanhao Jia[1], Shunbo Hu[1*], Shaowen Xu[1], Heng Gao[2], Guodong Zhao[1], Paolo Barone[3], Alessandro Stroppa[3*], Wei Ren[1*]

[1]Physics Department, State Key Laboratory of Advanced Special Steel, and International Centre for Quantum and Molecular Structures, Shanghai University, Shanghai 200444, China
[2]Beijing National Laboratory for Condensed Matter Physics, Institute of Physics, Chinese Academy of Sciences, Beijing, 100190, China
[3]CNR-SPIN c/o Università degli Studi dell'Aquila, Via Vetoio , I-67100 Coppito (L'Aquila), Italy.

THE JOURNAL OF PHYSICAL CHEMISTRY LETTERS 11, 5177 (2020)

A collaboration between Shanghai University and CNR-SPIN (L'Aquila) reveals persistent spin-texture, for the first time in a layered hybrid perovskite system with strong spin-orbital coupling.

2D ferroelectric Hybrid Organic-Inorganic Perovskites (HOIPs) are gaining considerable attention with merits of effective light absorption in the broadband range, high photogenerated carrier yield, and high charge carrier injection efficiency.

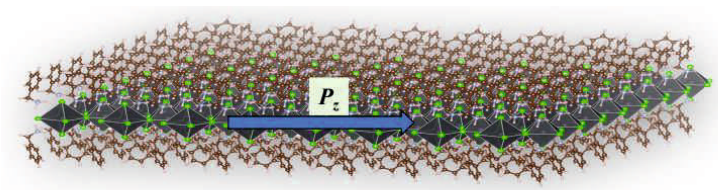
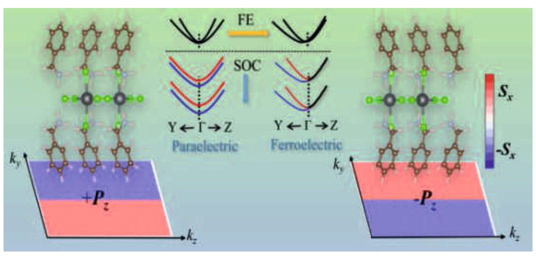


Fig. 1: The crystal structures of BA_2PbCl_4. There is an in-plane ferroelectric polarization in the system, in which organic molecules contribute 65% and inorganic frameworks contribute 35%.

In this work, a density functional study was performed on the electronic and ferroelectric properties of the bulk and monolayer benzylammonium lead-halide $(C_6H_5CH_2NH_3)2PbCl_4$ which was firstly synthesized and characterized by Liao et al in Nat. Commun. 2015, 6, 7338. The calculations suggest that both the bulk and monolayer systems display a band gap of ~3.3 eV and a spontaneous polarization of ~5.4 μC/cm2. The similar physical properties of bulk and monolayer systems support a strong decoupling among the layers in this hybrid organic-inorganic perovskite. Both the ferroelectricity, through associated structure distortion, and the spin-orbit coupling (SOC), through splitting induced in the electronic bands, significantly change the band gaps. Most importantly, for the first time in 2D hybrid organic-inorganic class of material, a peculiar spin texture topology was found, such as a unidirectional spin–orbit field, which may lead to a protection against spin-decoherence, thus supporting extraordinary long spin-lifetime of carriers, which is promising for spintronic applications.

This work is the result of the collaboration between Shanghai University and CNR-SPIN in L'Aquila. The first author Fanhao Jia is a PhD student of Shanghai University, Dr. Paolo Barone is a SPIN researcher providing a solid theoretical insight the spin texture. Prof. Wei Ren and Dr. Shunbo Hu of Shanghai University, and Dr. Alessandro Stroppa (SPIN) are the co-corresponding authors. The work has been published in *The Journal of Physical Chemistry Letters* (JPCL, Impact factor 2018: 7.329), a journal publishing "new and original experimental and theoretical basic research reporting a significant scientific advance and/or physical insight such that rapid publication is essential". The journal has dedicated the Supplementary Cover to this work (https://pubs.acs.org/toc/jpclcd/11/13).

Fig. 2: The spin texture is indicated by the red and blue colors, which corresponds to the spin up or spin down along the out-of-plane x direction. The spin direction can be switched by ferroelectric polarization reversal. The unidirectional character of the spin texture tends to reduce the spin scattering, thereby leading to a protection against spin-decoherence. The inset is the band splitting of conduction band minimum due to SOC.



Tunable spin textures in polar antiferromagnetic hybrid organic-inorganic perovskites by electric and magnetic fields

Feng Lou1,2,†, Teng Gu[1,2,†], Junyi Ji[1,2], Junsheng Feng[3], Hongjun Xiang[1,2,4,*], and Alessandro Stroppa[5,*]

[1]Key Laboratory of Computational Physical Sciences (Ministry of Education), State Key Laboratory of Surface Physics, and Department of Physics, Fudan University, Shanghai 200433, China.

[2]Collaborative Innovation Center of Advanced Microstructures, Nanjing 210093, China.

[3]School of Physics and Materials Engineering, Hefei Normal University, Hefei 230601, China

[4]Shanghai Qizhi Institution, Shanghai 200433, China

[5]CNR-SPIN, c/o Department of Physical and Chemical Sciences, University of L' Aquila, 67100 Coppito (AQ), L'Aquila, Italy

NPJ COMPUTATIONAL MATERIALS 6, 114 (2020)

A collaboration between Fudan University (Shanghai – China) and CNR-SPIN (L'Aquila) reveals a spin-texture which is tunable by antiferromagnetic order parameter.

The hybrid organic-inorganic perovskites (HOIPs) have attracted much attention for their potential applications as novel opto-electronic devices where the Rashba band-splitting, together with specific spin orientations in k-space (i.e. spin texture), has been found to be relevant for their performances. Here, we study the electric polarization, magnetism, and spin texture properties of the antiferromagnetic (AFM) HOIP ferroelectric TMCM-MnCl3 (TMCM=$(CH_3)_3NCH_2Cl$+, trimethylchloromethyl ammonium). This compound is ferroelectric with a large piezoelectric response, high ferroelectric transition temperature, and excellent photoluminescence properties [You *et al.*, Science 357, 306 (2017)]. The inversion symmetry breaking coupled to the spin-orbit coupling gives rise to a Rashba-like band-splitting and a related robust persistent spin texture (PST) and/or typical spiral spin texture, which can be manipulated by tuning the ferroelectric or, surprisingly, also by the AFM magnetic order parameter. The tunability of spin texture upon switching of AFM order parameter is largely unexplored and our findings not only provide a platform to understand the physics of AFM spin texture but also support the AFM HOIP ferroelectrics as a promising class of opto-electronic materials. [npj *Comput Mater* **6**, 114 (2020). https://doi.org/10.1038/s41524-020-00374-8]

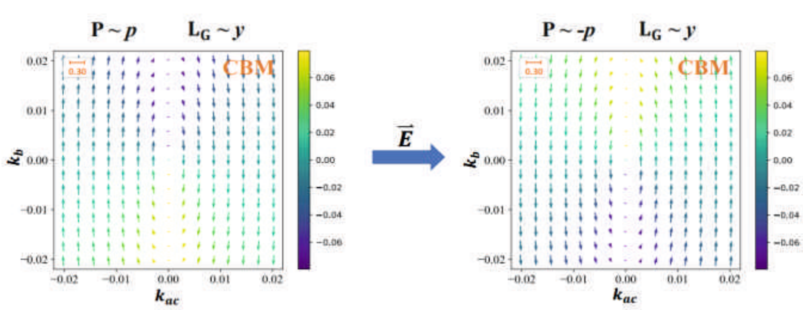


Fig. 1: (Right). The interplay between electric polarization and spin textures in G-type AFM state. Here we show the spin textures at Conduction Band Maximum (CBM). **P~ *p* (P~ - *p*)** refers to polarization along [101] ([101]), respectively. **L_G~*y*** present G-type AFM state with spin moment along *y* axis. K_b and K_{ac} denote the *k*-path with the Å^{-1}. The arrows refer to the in-plane orientation of spin mean-values and the scale is shown in the top left corner, while colors indicate the out-of-plane component. Under external electric field, the spin texture can be tuned.

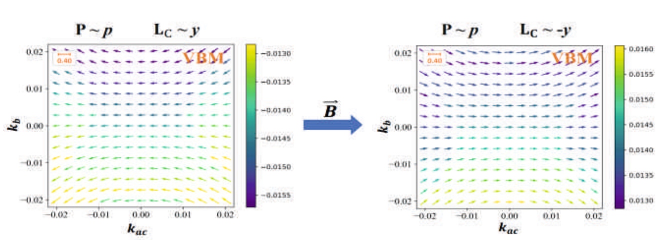


Fig. 2: (Right). Interplay between magnetic ordering and spin textures at CBM in C-type AFM state. **P~ *p*** denotes polarization along [101]. **L_c~*y*** present C-type AFM state with spin moment along *y* (-*y*) axis, respectively K_b and K_{ac} denote the *k*-path with the unit of Å^{-1}. The arrows refer to the in-plane orientation of spin mean-values and the scale is shown in the top left corner, while colors indicate the out-of-plane component. Under external magnetic field, the spin texture can be tuned.

Half-metallic ferromagnetism in layered CdOHCl induced by hole doping

H. Banerjee[1,3], P. Barone[2], S. Picozzi[2]

[1]The Abdus Salam International Centre for Theoretical Physics (ICTP), 34151 Trieste, Italy
[2]CNR-SPIN, UOS Aquila c/o Università G. d'Annunzio, Via dei Vestini 31, 66100 Chieti, Italy
[3]Institute of Theoretical and Computational Physics, Graz University of Technology, NAWI Graz 8010, Austria

2D Materials 8, 025027 (2021)

Next-generation spintronic devices will benefit from low-dimensionality, ferromagnetism, and half–metallicity, possibly controlled by electric fields. These technologically–appealing features are predicted, via first-principles calculations, to be combined in doped CdOHCl, a van der Waals material from which 2D layers may be exfoliated. A homogeneous hole–doping is found to give rise to p-band itinerant magnetism in both the bulk and few-layer phases arising from a Stoner instability: as the Fermi level is tuned via hole–doping through singularities in the 2D-like density of states, ferromagnetism develops with large saturation magnetization of 1 μB per hole, leading to a half-metallic behaviour for layer carrier densities of the order of 1014 cm^{-2} . Furthermore, we put forward electrostatic doping as an additional handle to induce magnetism in monolayers and bilayers of CdOHCl. Upon application of critical electric fields perpendicular to atomically–thin-films (as low as 0.2 and 0.5 V Å^{-1} in the bilayer and monolayer case, respectively), we envisage the emergence of a magnetic half-metallic state.

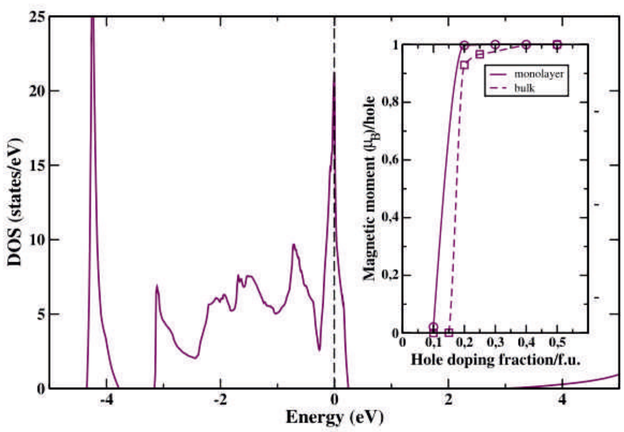


Fig. 1: Total density of states in the paramagnetic phase at the critical hole doping, tuning the Fermi energy at a sharp peak in the DOS and driving a Stoner-like magnetic instability. CdOHCl displays a half-metallic ferromagnetic phase in both bulk and monolayer structures, with a magnetic moment quickly saturating to 1 μB per hole as a function of the hole concentration, as shown in the inset.

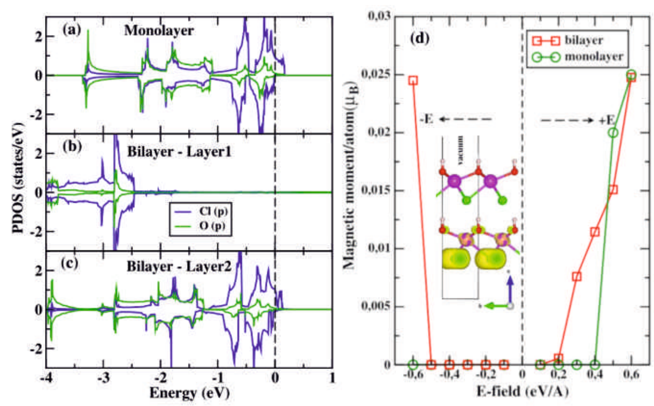


Fig. 2: Projected DOS for monolayer (a) and bilayer (panels (b),(c) for top and bottom layers) on application of an electric field E=0.6 eV Å−1, highlighting field-induced band shift and fully spin-polarized half-metallicity. Panel (d) shows the magnetic moments as a function of applied electric fields: the asymmetric response as well as the stronger tendency of bilayer to develop magnetism are ascribed to the inherent polarity of CdOHCl atomic stack (displayed in the inset, alongside the magnetic density of bilayer).

Coupling Charge and Topological Reconstructions at Polar Oxide Interfaces

T. C. van Thiel, [1] **W. Brzezicki ,**[2,3] **C. Autieri ,**[2] **J. R. Hortensius ,**[1] **D. Afanasiev,**[1] **N. Gauquelin,**[4] **D. Jannis,**[4] **N. Janssen,**[1] **D. J. Groenendijk ,**[1] **J. Fatermans,**[4,5] **S. Van Aert ,**[4] **J. Verbeeck ,**[4] **M. Cuoco,**[6,7] **and A. D. Caviglia**[1]

[1]Kavli Institute of Nanoscience, Delft University of Technology, Lorentzweg 1, 2628CJ Delft, Netherlands
[2]International Research Centre Magtop, Institute of Physics, Polish Academy of Sciences, Aleja Lotników 32/46, PL-02668 Warsaw, Poland
[3]Institute of Theoretical Physics, Jagiellonian University, ulica S. Łojasiewicza 11, PL-30348 Kraków, Poland
[4]Electron Microscopy for Materials Science (EMAT), University of Antwerp, Groenenborgerlaan 171, 2020 Antwerp, Belgium
[5]Imec-Vision Lab, University of Antwerp, Universiteitsplein 1, 2610 Wilrijk, Belgium
[6]CNR-SPIN, UOS Salerno c/o Università di Salerno - Via Giovanni Paolo II 132, 84084 Fisciano (SA), Italy
[7]Dipartimento di Fisica "E. R. Caianiello", Università di Salerno, IT-84084 Fisciano (SA), Italy

PHYSICAL REVIEW LETTERS 127 (2021) 127202

In oxide heterostructures, different materials are integrated into a single artificial crystal, resulting in a breaking of inversion symmetry across the heterointerfaces. This approach paved the way for the discovery of numerous unconventional properties absent in the bulk constituents. However, control of the geometric structure of the electronic wave functions in correlated oxides remains an open challenge. Here, we create heterostructures consisting of ultrathin $SrRuO_3$, an itinerant ferromagnet hosting momentum-space sources of Berry curvature, and $LaAlO_3$, a polar wide band gap insulator (Figure 1). We demonstrate control of the momentum space topological properties of ultrathin SRO by creating a charge-frustrated interface. Through magneto-optical characterization, theoretical calculations and transport measurements we show that the real-space charge reconstruction drives a reorganization of the topological charges in the band structure, thereby modifying the momentum-space Berry curvature in $SrRuO_3$ (Figure 2). Our results illustrate how the topological and magnetic features of oxides can be manipulated by engineering charge discontinuities at oxide interfaces.

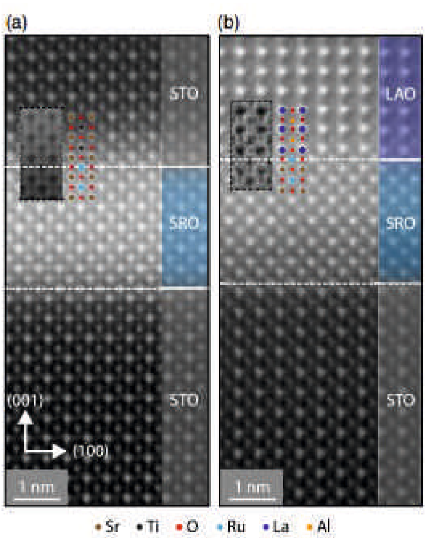


Fig. 1: Atomic characterization. High-angle annular dark-field images of (a) STO/SRO/STO and (b) STO/SRO/LAO heterostructres.

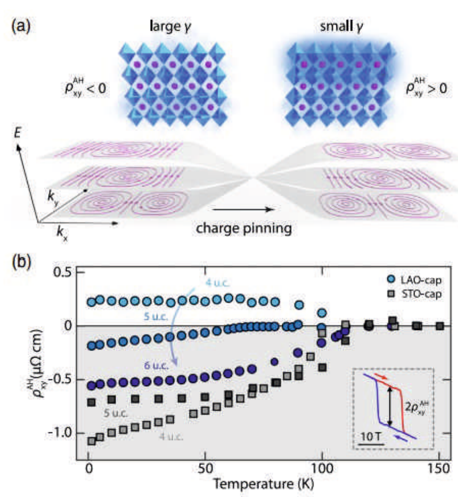


Fig. 2: Anomalous Hall effect. (a) Illustration representing the evolution of the momentum-space topological charges. Upon increasing the charge pinning, the system moves through a Weyl point in the synthetic space spanned by k_x, k_y and the charge pinning parameter γ. (b) The measured anomalous Hall resistivity resistivity for SRO films of varying thickness.

Angle, Spin, and Depth Resolved Photoelectron Spectroscopy on Quantum Materials

P.D.King,[1], S. Picozzi[2], R. Egdel[3], G. Panaccione[4]

[1]SUPA, School of Physics and Astronomy,University of St Andrews, St Andrews KY16 9SS, United Kingdom;
[2]CNR-SPIN, UOS Aquila c/o Università G. d'Annunzio, Via dei Vestini 31, 66100 Chieti, Italy
[3]Department of Chemistry, Inorganic Chemistry Laboratory, University of Oxford, Oxford OX13QR, United Kingdom
[4]Istituto Officina dei Materiali (IOM)-CNR, Laboratorio TASC, I-34149 Trieste, Italy

CHEMICAL REVIEWS 121 (2021) 2816

The role of X-ray based electron spectroscopies in determining chemical, electronic, and magnetic properties of solids has been well-known for several decades. A powerful approach is angle-resolved photoelectron spectroscopy, whereby the kinetic energy and angle of photoelectrons emitted from a sample surface are measured. This provides a direct measurement of the electronic band structure of crystalline solids. Moreover, it yields powerful insights into the electronic interactions at play within a material and into the control of spin, charge, and orbital degrees of freedom, central pillars of future solid state science. With strong recent focus on research of lower-dimensional materials and modified electronic behavior at surfaces and interfaces, angle-resolved photoelectron spectroscopy has become a core technique in the study of quantum materials. In this review, we provide an introduction to the technique. Through examples from several topical materials systems, including topological insulators, transition metal dichalcogenides, and transition metal oxides, we highlight the types of information which can be obtained. We show how the combination of angle, spin, time, and depth-resolved experiments are able to reveal "hidden" spectral features, connected to
semiconducting, metallic and magnetic properties of solids, as well as underlining the importance of dimensional effects in quantum materials.

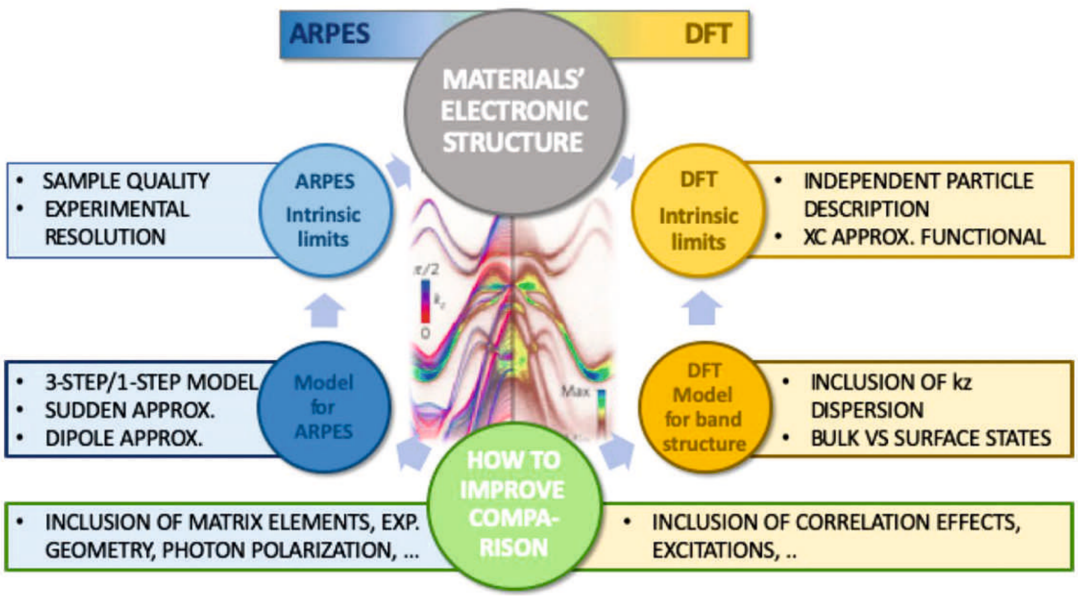


Fig. 1 Comparison between Angle Resolved PhotoEmission Spectroscopy (ARPES) and Density Functional Theory (DFT): Strengths and limitations.

Room-temperature ferroelectric switching of spin-to-charge conversion in germanium telluride

S. Varotto[1,11], L. Nessi[1,2], S. Cecchi [3], J. Sławińska [4,5], P. Noël[6], S. Petrò[1], F. Fagiani [1], A. Novati[1], M. Cantoni[1,2], D. Petti [1], E. Albisetti [1], M. Costa[7], R. Calarco[3,8], M. Buongiorno Nardelli[5], M. Bibes [9], S. Picozzi[10], J.-P. Attané[6], L. Vila [6], R. Bertacco[1,2], C. Rinaldi [1,2]

[1]Dipartimento di Fisica, Politecnico di Milano, Milan, Italy.
[2]Istituto di Fotonica e Nanotecnologie CNR-IFN, Milan, Italy.
[3]Paul-Drude-Institut für Festkörperelektronik, Leibniz-Institut im Forschungsverbund Berlin e.V., Berlin, Germany.
[4]Zernike Institute for Advanced Materials, University of Groningen, Groningen, Netherlands.
[5]Department of Physics, University of North Texas, Denton, TX, USA.
[6]Univ. Grenoble Alpes, CNRS, CEA, Spintec, Grenoble, France.
[7]Department of Physics, Fluminense Federal University, Niterói, Brazil.
[8]Consiglio Nazionale delle Ricerche-Istituto per la Microelettronica e Microsistemi (CNR-IMM), Rome, Italy.
[9]Unité Mixte de Physique, CNRS, Thales, Université Paris-Saclay, Palaiseau, France.
[10]CNR-SPIN, UOS Aquila c/o Università G. d'Annunzio, Via dei Vestini 31, 66100 Chieti, Italy
[11]Present address: Unité Mixte de Physique, CNRS, Thales, Université Paris-Saclay, Palaiseau, France

NATURE ELECTRONICS 4 (2021) 740

The development of spintronic devices has been limited by the poor compatibility between semiconductors and ferromagnetic sources of spin. The broken inversion symmetry of some semiconductors may allow for spin–charge interconversion, but its control by electric fields is volatile. This has led to interest in ferroelectric Rashba semiconductors, which combine semiconductivity, large spin–orbit coupling and non-volatility. Here we report room-temperature, non-volatile ferroelectric control of spin-to-charge conversion in epitaxial germanium telluride films. We show that ferroelectric switching by electrical gating is possible in germanium telluride, despite its high carrier density. We also show that spin-to-charge conversion has a similar magnitude to what is observed with platinum, but the charge current sign is controlled by the orientation of ferroelectric polarization. Comparison between theoretical and experimental data suggests that the inverse spin Hall effect plays a major role in switchable conversion.

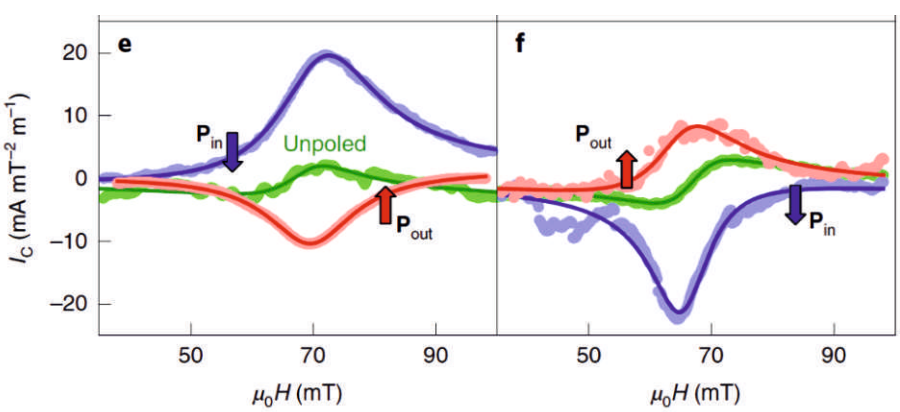


Fig. 1 Ferroelectric control of Spin-to-charge-conversion in GeTe. Normalized current production (a,b) versus magnetic field for a GeTe slab oriented along the ZA (a) and ZU (b) symmetry lines, for different ferroelectric polarizations. μ0 is the magnetic permeability in vacuum. The blue curves correspond to polarization P_{in} and red to P_{out}. The peak is positive (negative) for P_{in} and negative (positive) for P_{out}. The green curve refers to the pristine (unpoled) states.

Magnetic-Field Tunable Intertwined Checkerboard Charge Order and Nematicity in the Surface Layer of Sr_2RuO_4

Carolina A. Marques[1], Luke C. Rhodes[1], Rosalba Fittipaldi[2], Veronica Granata[3], Chi Ming Yim[1], Renato Buzio[4], Andrea Gerbi[4], Antonio Vecchione[2], Andreas W. Rost[5], and Peter Wahl[1]

[1]School of Physics and Astronomy University of St Andrews North Haugh, St Andrews, Fife KY16 9SS, UK
[2]CNR-SPIN, UOS Salerno c/o Università di Salerno - Via Giovanni Paolo II 132, 84084 Fisciano (SA), Italy
[3]Dipartimento di Fisica "E. R. Caianiello" Universitá di Salerno, Fisciano, Salerno I-84084, Italy
[4]CNR-SPIN, Sede Genova, Area della Ricerca di Genova, C.so F. M. Perrone 24, 16152 Genova, Italy
[5]Max-Planck-Institute for Solid State Research Heisenbergstr. 1, 70569 Stuttgart, Germany

ADVANCED MATERIALS 33 (2021) 2100593

In strongly correlated electron materials, the electronic, spin, and charge degrees of freedom are closely intertwined. This often leads to the stabilization of emergent orders that are highly sensitive to external physical stimuli promising opportunities for technological applications. In perovskite ruthenates, this sensitivity manifests in dramatic changes of the physical properties with subtle structural details of the RuO_6 octahedra, stabilizing enigmatic correlated ground states, from a hotly debated superconducting state via electronic nematicity and metamagnetic quantum criticality to ferromagnetism. Here, it is demonstrated that the rotation of the RuO_6 octahedra in the surface layer of Sr_2RuO_4 generates new emergent orders not observed in the bulk material. Through atomic-scale spectroscopic characterization of the low-energy electronic states, four van Hove singularities are identified in the vicinity of the Fermi energy. The singularities can be directly linked to intertwined nematic and checkerboard charge order. Tuning of one of these van Hove singularities by magnetic field is demonstrated, suggesting that the surface layer undergoes a Lifshitz transition at a magnetic field of ≈32T.

This work has been supported from the Bilateral Project "Atomic-scale imaging of the superconducting condensate in the putative triplet superconductor Sr_2RuO_4: a platform for topological quantum computations?" in a joint RSE - CNR Bilateral Scheme.

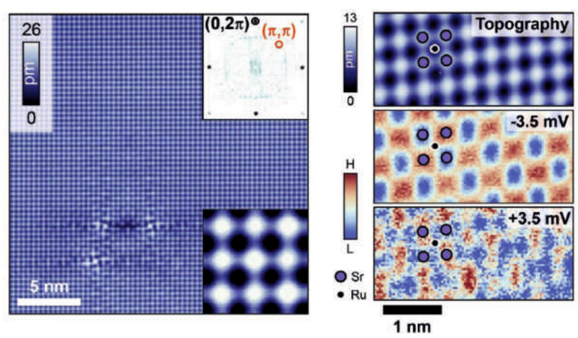


Fig. 1: Left: Topography showing the Sr square lattice. Lower inset: enlarged topography. Upper inset: Fourier transformation with Bragg peaks at $(0, 2\pi)$ and $(2\pi, 0)$. Peaks at (π, π) and $(-\pi, \pi)$ coincide with the periodicity of the surface reconstruction. Right, top: Topography with a model indicating the positions of the Sr atoms. Bottom: Real-space g(r,V) maps at V=−3.5mV and +3.5mV recorded simultaneously with the topography. A strong checkerboard charge order is observed.

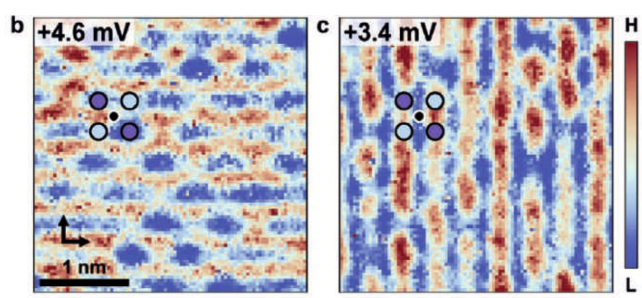


Fig. 2: Nematicity and the equivalence of checkerboard charge order with C4 symmetry breaking. The charge order on the Sr lattice combined with the octahedral rotations leads to a broken C4 symmetry, due to which oxygen atoms along the [10] and [01] directions are in an inequivalent environment. The measurements reported above show nematicity in the atomic scale charge modulations (T = 1.8 K).

Unveiling unconventional magnetism at the surface of Sr_2RuO_4

R. Fittipaldi[1,2], R. Hartmann[3], M. T. Mercaldo[2], S. Komori[4], A. Bjørlig[5], W. Kyung [6], Y. Yasui [7], T. Miyoshi[7], L. A. B. Olde Olthof[4], C. M. Palomares Garcia[4], V. Granata2, I. Keren[8], W. Higemoto[9], A. Suter[8], T. Prokscha[8], A. Romano[1,2], C. Noce[1,2], C. Kim[6], Y. Maeno[7], E. Scheer[3], B. Kalisky[5], J. W. A. Robinson[4], M. Cuoco [1,2], Z. Salman[8], A. Vecchione[1,2], A. Di Bernardo[3]

[1]CNR-SPIN, UOS Salerno c/o Università di Salerno - Via Giovanni Paolo II 132, 84084 Fisciano (SA), Italy
[2]Dipartimento di Fisica "E. R. Caianiello" Universitá di Salerno, Fisciano, Salerno I-84084, Italy
[3]Department of Physics, University of Konstanz, 78457 Konstanz, Germany
[4]Department of Materials Science and Metallurgy, University of Cambridge, Cambridge CB3 0FS, UK.
[5]Department of Physics, Bar Ilan University, Ramat Gan 5920002, Israel
[6]Department of Physics and Astronomy,Seoul National University, Seoul 08826, Korea
[7]Department of Physics, Kyoto University, Kyoto 606-8502, Japan
[8]Laboratory for Muon Spin Spectroscopy,Paul Scherrer Institute, CH-5232 Villigen, PSI, Switzerland
[9]Advanced Science Research Center, Japan Atomic Energy Agency, Tokai, Ibaraki 319-1195, Japan

NATURE COMMUNICATIONS 12 (2021) 5792

Materials with strongly correlated electrons often exhibit interesting physical properties. An example of these materials is the layered oxide perovskite Sr2RuO4, which has been intensively investigated due to its unusual properties. Whilst the debate on the symmetry of the superconducting state in Sr2RuO4 is still ongoing, a deeper understanding of the Sr_2RuO_4 normal state appears crucial as this is the background in which electron pairing occurs. By using low-energy muon spin spectroscopy we discover the existence of surface magnetism in Sr_2RuO_4 in its normal state. We detect static weak dipolar fields yet manifesting at an onset temperature higher than 50 K. We ascribe this unconventional magnetism to orbital loop currents forming at the reconstructed Sr_2RuO_4 surface. Our observations set a reference for the discovery of the same magnetic phase in other materials and unveil an electronic ordering mechanism that can influence electron pairing with broken time reversal symmetry.

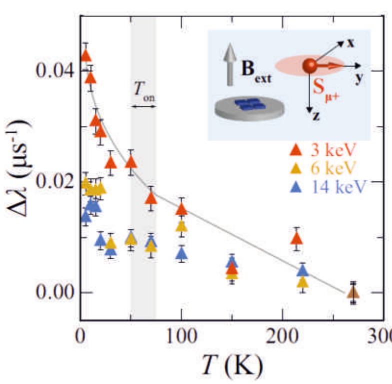


Fig. 1: Temperature dependence of magnetism in Sr_2RuO_4 at different implantation depths. Shift in the muon depolarization rate, Δλ, from the λ value measured at T = 270 K as a function of temperature T measured in a transverse field setup (inset) with applied field amplitude B_{ext}=100G at different implantation energy E values: E=3 keV, E=6 keV and E =16 keV.

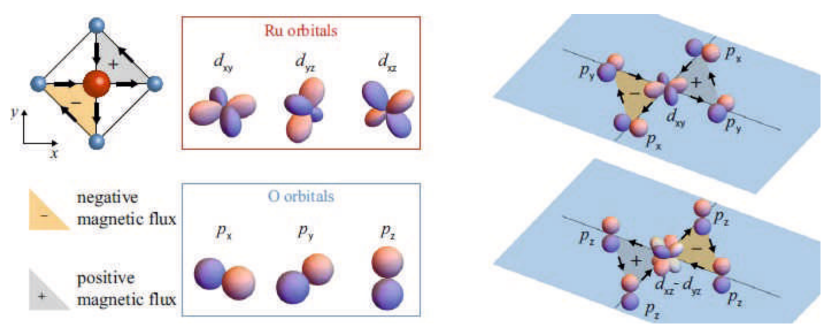


Fig. 2: Magnetism due to orbital loop currents in Sr_2RuO_4. Illustration of the RuO_4 plaquette and of the corresponding d-orbitals for the Ru atoms and p-orbitals for the O atoms (with asymmetric loop current distributions generating magnetic flux pointing inward (yellow triangle) or outward (grey triangle) the RuO_4 plane. Possible orbital loop currents for a given RuO_4 plaquette associated with the Ru−O hybridization of the dxy orbitals and of the (d_{xz}, d_{yz}) orbitals.

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.

All-carbon THz components based on laser-treated diamond

S. Amoruso[1,2], A. Andreone[1,2], A. Bellucci[3], C. Koral[4], M. Girolami3, M. Mastellone[3], S. Mou[1], S. Orlando[3], G.P. Papari[1], D. Paparo[5], R. Polini6, A. Rubano[1,5], A. Santagata[3], V. Serpente[3], V. Valentini[3], and D.M. Trucchi[3]

[1]Dipartimento di Fisica, Università di Napoli Federico II, Complesso Universitario di Monte S. Angelo, Via Cintia, I-80126 Napoli, Italy
[2]CNR-SPIN, SuPerconducting and other INnovative materials and devices Institute, UOS Napoli, Complesso Universitario di Monte S. Angelo, Via Cintia, I-80126 Napoli, Italy
[3]CNR-ISM, Institute for Structure of Matter ISM-CNR, DiaTHEMA Lab, Via Salaria km 29.300, Monterotondo Scalo (RM), Italy
[4]Istituto Nazionale di Fisica Nucleare, Sezione di Napoli, via Cintia, I-80126, Napoli, Italy
[5]CNR-ISASI, Institute of Applied Science & Intelligent Systems (ISASI) 'E. Caianiello', Via Campi Flegrei 34, 80078 Pozzuoli (NA), Italy
[6]Università di Roma "Tor Vergata", Dipartimento di Scienze e Tecnologie Chimiche, Via della Ricerca Scientifica 1, 00133 Roma, Italy

CARBON 163, 197-201 (2020)

Diamond and graphite are two allotropes of carbon with very different physical properties that arise from their distinct crystal structures. Laser induced graphitization of diamond can therefore provide an interesting route for the fabrication of novel functional materials thanks to the extremely different electrical and optical properties of diamond and graphitic-like materials allowing one to engineer a sample of diamond crystal at the surface or in the volume. In this context, a proof of principle experiment was carried out on the transmittance in the THz spectral range of diamond plates irradiated by ultrashort laser pulses. The laser irradiation generates laser induced periodic surface structures (LIPSS) with a period of about 170 nm allowing to fabricate a layer presenting graphitized ripples with a preferential orientation. The transmittance of the samples to THz with polarization parallel and perpendicular to the ripples formed on the laser structured sample was analyzed both in a narrow (0.2-1.5 THz) and a broad (0.25-6 THz) spectral range. The experimental findings evidence a clear anisotropic absorption to polarized THz radiation in the range 0.25-3 THz that can be exploited for the fabrication of robust,

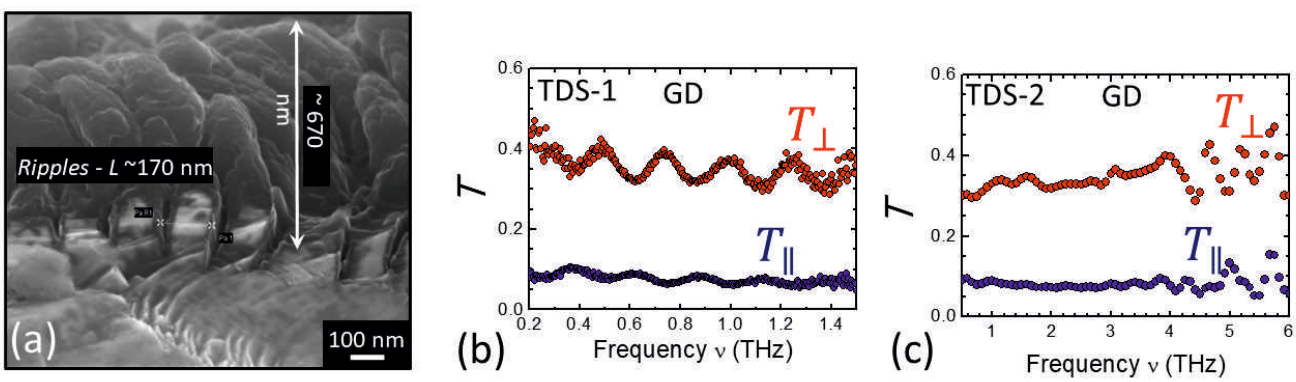


Fig. 1: (a) SEM images showing a cross-section of graphitized diamond and LIPSS; Panels (b) and (c): transmittance of graphitized diamond samples to a THz wave for THz electric field polarization orthogonal (T⊥, red symbols) parallel (T||, blue symbols) to the LIPSS orientation.

Superconducting nanowire single photon detectors based on disordered NbRe films

C. Cirillo,[1,2] J. Chang,[3] M. Caputo,[2] J. W. N. Los,4 S. Dorenbos,[4] I. Esmaeil Zadeh,[3] and C. Attanasio[1,2]

[1]CNR-SPIN, c/o Università degli Studi di Salerno, Via Giovanni Paolo II 132, 84084 Fisciano, SA, Italy
[2]Dipartimento di Fisica "E.R. Caianiello", Università degli Studi di Salerno, Via Giovanni Paolo II 132, 84084 Fisciano, SA, Italy
[3]Optics Research Group, ImPhys Department, Faculty of Applied Sciences, Delft University of Technology, Delft 2628 CJ, The Netherlands
[4]Single Quantum B.V., Delft 2628 CJ, The Netherlands

APPLIED PHYSICS LETTERS 117, 172602 (2020)

Superconducting Nanowire Single Photon Detectors (SNSPDs) based on 8-nm-thick $Nb_{0.15}Re_{0.85}$ nanowires are developed. The devices have a meander structure of wires 50–100 nm wide, with a detection area of about 10–16 μm in diameter. The characteristics of the detectors are extracted from flood illumination at about 3 K, and the promising performance of NbRe-based SNSPDs at an easily accessible cryogenic temperature are demonstrated. Due to both the reduced value of the superconducting coherence length and the disordered film structure, the superconducting properties are robust with respect to the nanopatterning process. The devices show saturated detection efficiency up to λ = 1.3 μm with a time resolution of 33.1 ps and recovery times of about 8-19 ns. In addition, at infrared wavelengths, simulations return an extinction parameter exceeding 6, and an absorption of more than 99% for a filling factor 0.4, which may also indicate good performance of shorter devices. This work paves the way for the optimization of future devices based on NbRe, in particular, by tuning the film microscopical properties as well as geometry, along with the experimental setup, and NbRe-based devices may represent an alternative to nitride-based SNSPDs and amorphous materials because of their improved performances in

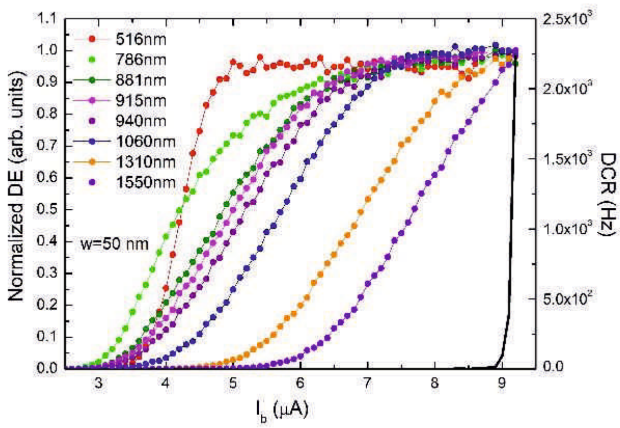


Fig. 1: Normalized detection efficiency (left) and dark count rates (right) for device 50 nm wide as a function of the bias current measured at different wavelengths at T=2.8 K.

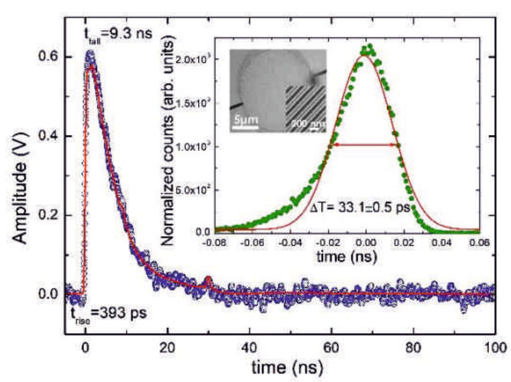


Fig. 2: Detection pulse for device 80 nm wide at T=2.8 K. The single pulse data (points) are superimposed on the averaged measurement (line). The characteristic times are indicated. Inset: Timing jitter, ΔT, for the same detector at T=3.3 K fitted by a Gaussian dependence. ΔT is evaluated evaluated as the full width half maximum. SEM image of typical fabricated devices i salso shown

Underground Sagnac gyroscope with sub-prad/s rotation rate sensitivity: Toward general relativity tests on Earth

Angela D. V. Di Virgilio,[1] Andrea Basti,[2] Nicolò Beverini,[2] Filippo Bosi,[1] Giorgio Carelli,[2] Donatella Ciampini,[2] Francesco Fuso,[2] Umberto Giacomelli,[1] Enrico Maccioni,[1,2] Paolo Marsili,[2] Antonello Ortolan,[3] Alberto Porzio,[4] Andrea Simonelli,[1] and Giuseppe Terreni[1]

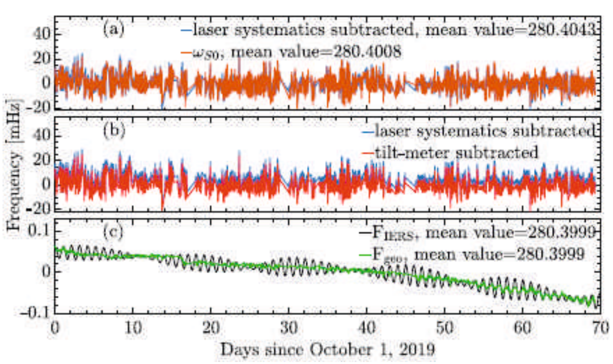
[1]INFN Sezione di Pisa, Largo Bruno Pontecorvo 3, I-56127 Pisa, Italy
[2]Dipartimento di Fisica Enrico Fermi, Università di Pisa, Largo Bruno Pontecorvo 3, I-56127 Pisa, Italy
[3]INFN-National Laboratories of Legnaro, viale dell'Università 2, I-35020 Legnaro (PD), Italy
[4]CNR-SPIN and INFN, Napoli, Complesso Universitario di Monte Sant'Angelo, via Cintia, I-80126 Napoli, Italy

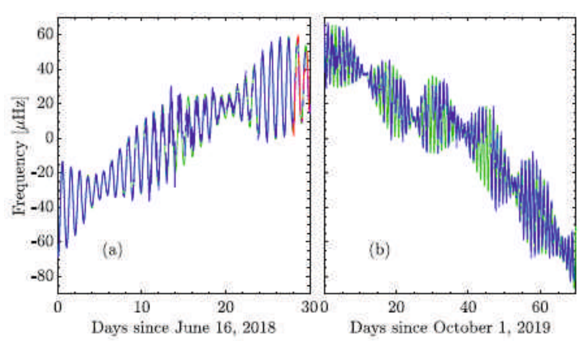
Physical Review Research 2, 032069(R) (2020)

Measuring in a single location on Earth its angular rotation rate with respect to the celestial frame, with a sensitivity enabling access to the tiny Lense-Thirring effect, is an extremely challenging task. GINGERINO is a large-frame ring laser gyroscope (RLG), operating as free running and unattended inside the underground laboratory of the Gran Sasso, Italy. The main geodetic signals, i.e., annual and Chandler wobbles, daily polar motion, and length of the day, are recovered from GINGERINO data using standard linear regression methods, demonstrating a sensitivity approaching tens of frad/s, therefore close to the requirements for Earth-based Lense-Thirring and Lorentz violation tests. RLGs, based on the Sagnac effect, are the top sensitivity instruments for measuring rotation rates relative to an inertial frame with excellent accuracy.

Accessing GR signals paves the way to a novel approach for testing general relativity on the Earth looking at the gravitational field that we directly experience on our planet. In this paper, we demonstrated that the sensitivity of a heterolithic RLG, GINGERINO, can be pushed to the envelope of the GR sensitivity region by applying statistical methods to data analysis. In particular, a linear regression procedure evaluates the parameters' weighting contribution of different signals accounting for laser dynamics, local rotation as measured by a colocated tilt meter, and environmental probes (local temperature and tides), in order to find the best estimate of known geodetic signals as given by IERS (International Earth Rotation Reference Systems Service). In this case geodetic signals play the role of calibration signals.

GINGERINO represent a prototype of a more ambitious RLG array that, being multi-dimensional, will be able to reconstruct not only the absolute value of the Erath rotation rate but also its vectorial nature thus allowing the identification of GR signals not measured elsewhere. In the figures you can find: (left) the progress of the linear regression procedure (single-fit method): (a) ωs0 and F_{eff} obtained by subtracting effects related to laser systematics; (b) F_{eff} after further subtraction of the effects related to tilt-meter signals; (c) the evaluated F_{geo} compared with FIERS. In order to better show the sensitivity of the measurement, the plotted data are subtracted for the mean values, as reported in the legends in Hz; (right) The evaluated Fgeo compared with F_{IERS} (blue and green lines, respectively) for (a) the 2018 and (b) the 2019 data sets. Uncertainties are below 1 μHz (equivalent to an error in the evaluated angular rotation rate of 1.7 × 10−13 rad/s) in a bandwidth corresponding to a 600 s measurement time. An evaluation is carried out with the separated time window method. Data marked in red in (a) demonstrate the predictive abilities of the approach. In both panels the mean values have been subtracted, and error bars are not visible in this scale.





Laser ablation and structuring of CdZnTe with femtosecond laser pulses

J.J.J. Nivas[1,2], E. Allahyaria[2], A. Vecchione3, Q. Hao[4], S. Amoruso[1,2], X. Wang[2,5]

[1]Dipartimento di Fisica "Ettore Pancini", Università di Napoli "Federico II", Via Cintia, I-80126 Napoli, Italy
[2]CNR-SPIN, UOS Napoli, Via Cintia, I-80126 Napoli, Italy
[3]CNR-SPIN, UOS Salerno, Via Giovanni Paolo II, 132, I-84084 Fisciano (SA), Italy
[4]North China Research Institute of Electro-Optics, Beijing 100015, China
[5]School of Remote Sensing and Information Engineering, Wuhan University, Wuhan 430072, China

JOURNAL OF MATERIALS SCIENCE & TECHNOLOGY 48, 180 (2020)

We report an experimental investigation on laser ablation and associated surface structuring of CdZnTe by femtosecond Ti:Sa laser pulses (laser wavelength λ≈800 nm, ≈35 fs, 10 Hz), in air. By exploiting different static irradiation conditions, the fluence threshold and the incubation effect in CdZnTe are estimated. Interestingly, surface treatment with a low laser fluence (laser pulse energy E≈5-10 μJ) and number of shots (5≤ N ≤50) show the formation of well-defined cracks in the central part of the shallow crater, which is likely associated to a different thermal expansion coefficients of Te inclusions and matrix during the sample heating and cooling processes ensuing femtosecond laser irradiation. Irradiation with a larger number of pulses (N≈500, 1000) with higher pulse energies (E≈30-50 μJ) results in the formation of well-defined laser-induced periodic surface structures (LIPSS) in the outskirts of the main crater, where the local fluence is well below the material ablation threshold. Both low spatial frequency and high spatial frequency LIPSS perpendicular to the laser polarization are found together and separately depending on the irradiation condition. These are ascribed to a process of progressive aggregation of randomly distributed nanoparticles produced during laser ablation of the deep crater in the region of the target irradiated by a fluence below the ablation threshold with many laser pulses.

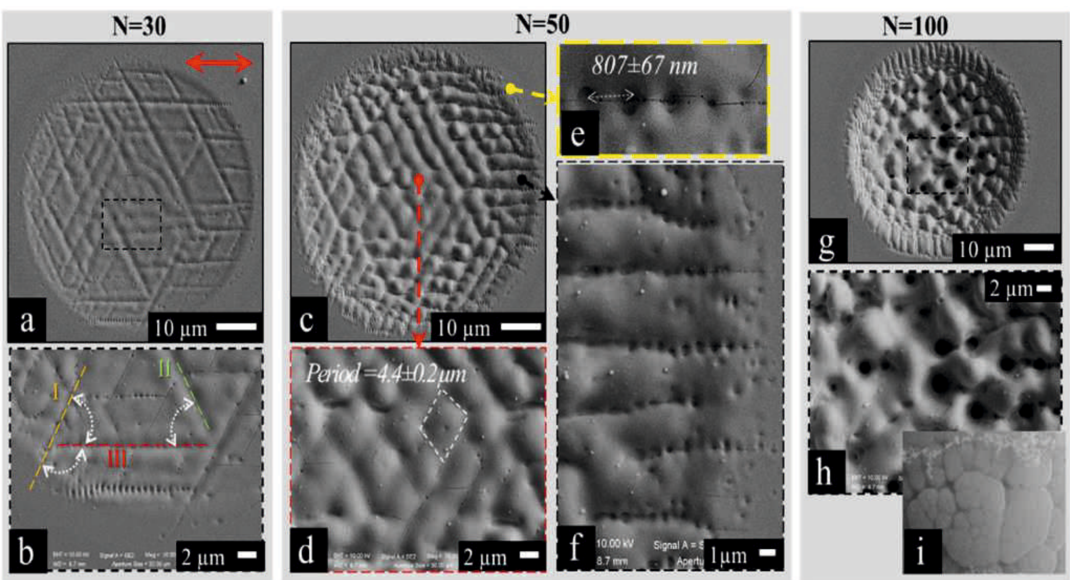


Fig. 1 SEM images of CdZnTe after irradiation with a sequence of various number of pulses N, at E = 5 μJ and corresponding zoomed views: (a, b) N = 30; (c-f) N = 50; (g-i) N = 100. The red arrow in panel (a) indicates the laser polarization direction. In the zoomed view of panel (b) cracks directed along three different directions are indicated and termed as type I, II, and III. Panel (d) shows the central region of the spot displayed in panel (c) evidencing periodic bumps separated by cracks, while periodic arrays of subwavelength holes formed close to the spot edges are shown in panels (e, f). The zoomed view of panel (h) addresses the columnar features formed at the center of the spot for N = 100.

NbReN: A disordered superconductor in thin film form for potential application as superconducting nanowire single photon detector

C. Cirillo[1], V. Granata[2], A. Spuri[3], A. Di Bernardo[3], C. Attanasio[2]

[1]CNR-SPIN, UOS Salerno c/o Università di Salerno - Via Giovanni Paolo II 132, 84084 Fisciano (SA), Italy
[2]Dipartimento di Fisica "E.R. Caianiello", Università degli Studi di Salerno, I-84084 Fisciano (Sa), Italy
[3]Universität Konstanz, Fachbereich Physik, Universitätsstraße 10, 78457 Konstanz, Germany

PHYSICAL REVIEW MATERIALS 5 (2021) 085004

The increasing demand for superconducting nanowire single photon detectors (SNSPDs) with improved performances compared to existing ones fosters the research activity in the field of material science. The current challenge is twofold and consists, on one hand, of improving the properties of superconducting materials already established for the fabrication of SNSPDs (mostly transition metal nitrides, such as NbN and NbTiN) , and, on the other hand, of finding alternative materials that can improve specific figures of merit of the existing SNSPD devices. A new superconductor, N_{bReN}, in thin film form is synthesized by reactive dc sputtering to study its potential for the realization of SNSPDs with improved performances. The deposition conditions are systematically varied to optimize the superconducting and electrical properties of the resulting samples. Films with polycrystalline structure and moderate texture are obtained. The transport properties reveal that NbReN films have well- established superconducting ordering and behave as a dirty superconductors, with values of the critical temperature lower than its parent compound NbRe. The combination of disorder-dominated transport and low energy gap may in principle enhance the sensitivity to longer wavelength photons. Detection experiments are needed to confirm these expected performances.

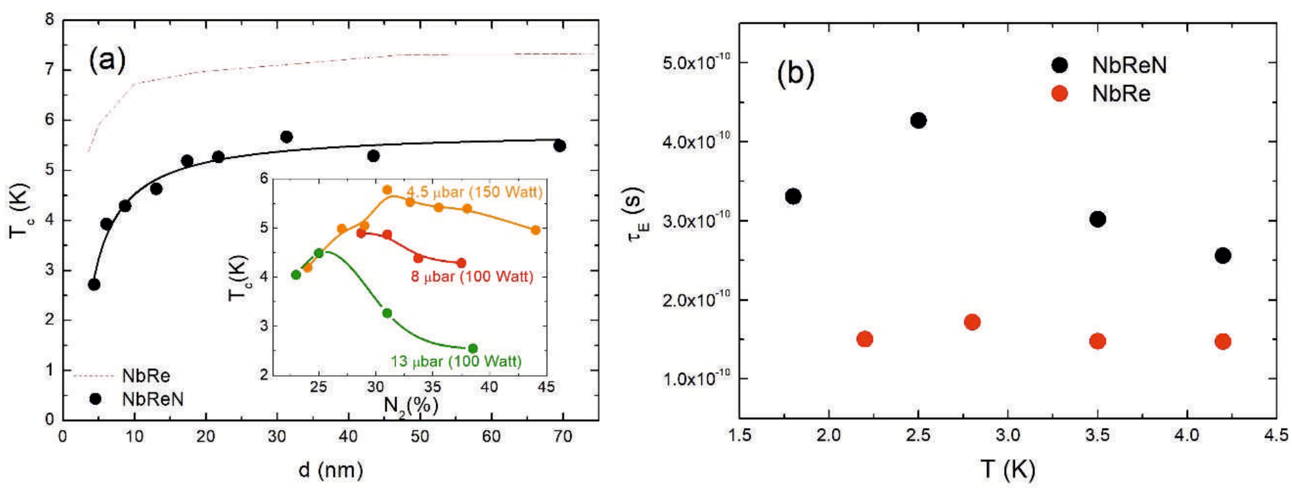


Fig. 1: (a) Thickness dependence of the superconducting critical temperature for NbReN films (filled circles) deposited at 150W and total pressure of 4.5 mbar, and NbRe films (dotted line). Inset: Critical temperature, Tc, as a function of the nitrogen concentration, $N2^{\%}$, for films with fixed thickness (d_{NbReN}=36 nm) and deposited at different sputtering conditions (see labels for total pressure and power). (b) Temperature dependence of the quasiparticles relaxation times for NbReN and NbRe bridges evaluated at µ0H = 0.5 and 0.6 T, respectively.

Coexistence of negative and positive photoconductivity in few-layer $PtSe_2$ field-effect transistors

A. Grillo[1], E. Faella[1,2], A. Pelella1,2, F. Giubileo[2], L. Ansari3, F. Gity[3], P. K. Hurley[3], N. McEvoy[4], A. Di Bartolomeo[1,2]

[1]Physics Department "E. R. Caianiello", University of Salerno, via Giovanni Paolo II n. 132, Fisciano, Salerno 84084, Italy
[2]CNR-SPIN, UOS Salerno c/o Università di Salerno - Via Giovanni Paolo II 132, 84084 Fisciano (SA), Italy
[3]Tyndall National Institute, University College Cork, MicroNano Systems Centre, Lee Maltings, Dyke Parade, Cork T12 R5CP, Ireland
[4]AMBER and School of Chemistry, Trinity College Dublin, Dublin 2 D02, Ireland

ADVANCED FUNCTIONAL MATERIALS 31 (2021) 2105722

Platinum diselenide ($PtSe_2$) field-effect transistors with ultrathin channel regions exhibit p-type electrical conductivity that is sensitive to temperature and environmental pressure. Exposure to a supercontinuum white light source reveals that positive and negative photoconductivity coexists in the same device. The dominance of one type of photoconductivity over the other is controlled by environmental pressure. Indeed, positive photoconductivity observed in high vacuum converts to negative photoconductivity when the pressure is raised. Density functional theory calculations confirm that physisorbed oxygen molecules on the $PtSe_2$ surface act as acceptors. The desorption of oxygen molecules from the surface, caused by light irradiation, leads to decreased carrier concentration in the channel conductivity. The understanding of the charge transfer occurring between the physisorbed oxygen molecules and the $PtSe_2$ film provides an effective route for modulating the density of carriers and the optical properties of the material.

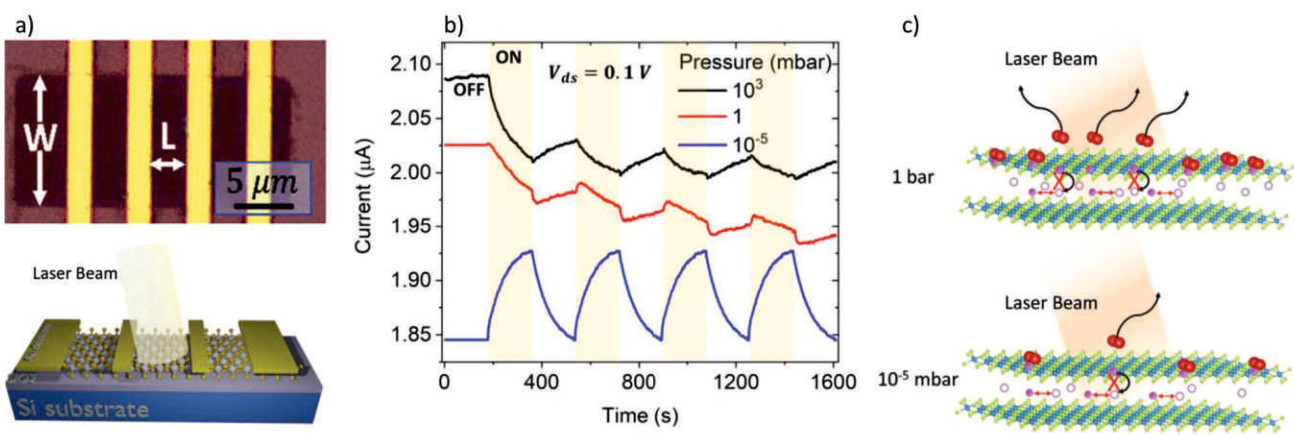


Fig. 1: a) Schematic of the device under light irradiation by a super-continuous white laser with wavelength ranging from 450 to 2400 nm. The laser spot of about 10 mm^2 was located between the two contacts to completely cover the channel. b) Current versus time characteristics at 103 mbar (black dots), 1 mbar (red dots), 10^{-5} mbar (blue dots) under switching light. The laser was switched on (yellow zone) and off (white zone) every 3 min. c) When the device is exposed to light (at 1 bar), oxygen is removed from the surface. Free electrons are trapped or recombine with holes reducing the density of available carriers and resulting in a negative photoconductivity. When the device is exposed to light at 10^{-5} mbar, the photogenerated electron–hole pairs and charge-carrier detrapping increase the conduction in the material, leading to a positive photoconductivity.

Graphene-Silicon Device for Visible and Infrared Photodetection

Aniello Pelella[1,2], Alessandro Grillo1,2, Enver Faella1,2, Giuseppe Luongo[3], Mohammad Bagher Askari[4], Antonio Di Bartolomeo[1,2]

[1]Department of Physics and Interdepartmental Centre NanoMates, University of Salerno, via Giovanni Paolo II, Fisciano, Salerno, 84084, Italy

[2]CNR-SPIN, UOS Salerno c/o Università di Salerno - Via Giovanni Paolo II 132, 84084 Fisciano (SA), Italy

[3]IHP-Microelectronics, Im Technologie Park 25, Frankfurt Oder, 15236, Germany

[4]Department of Physics, Faculty of Science, University of Guilan, P.O. Box: 41335-1914, Rasht, Iran

ACS APPLIED MATERIALS AND INTERFACES 13 (2021) 47895

The fabrication of a graphene–silicon (Gr-Si) junction involves the formation of a parallel metal–insulator–semiconductor (MIS) structure, which is often disregarded but plays an important role in the optoelectronic properties of the device. In this work, the transfer of graphene onto a patterned n-type Si substrate, covered by Si_3N_4, produces a Gr-Si device, in which the parallel MIS consists of a Gr-Si_3N_4-Si structure surrounding the Gr-Si junction (see Figure1a). The Gr-Si device exhibits rectifying behavior with a rectification ratio up to 104, as displayed in Figure 1b. Figure 1b also shows that the device responds to light, with an unexpected current set up (kink) at V=-1.2 V. Moreover, the device can be operated as a photodetector in both photocurrent and photovoltage mode in the visible and infrared (IR) spectral regions. Figure 2a shows that the device's responsivity is up to 350 mA/W and the external quantum efficiency (EQE) reaches 75% in the 500–1200 nm wavelength range. Decreases in responsivity to 0.4 mA/W and EQE to 0.03% are observed above 1200 nm, which is in the IR region beyond the silicon optical band gap, in which photoexcitation is driven by graphene. A model based on two parallel and opposite diodes, one for the Gr-Si junction and the other for the Gr-Si_3N_4-Si MIS structure, is proposed to explain the electrical behavior of the Gr-Si device. In reverse bias, the negative voltage attracts holes at the Si-Si_3N_4 interface. As the holes accumulate, the Si undergoes an inversion and becomes p-type. When the voltage is high enough to enable tunneling through the insulator a p-type Schottky diode is formed in the MIS region. This means that, in reverse bias, the device behaves as two parallel and opposite diodes. This parallel configuration explains the aforementioned kink. Indeed, for -1.2 V<V<0 V, holes accumulated at the interface Si-Si_3N_4 can only diffuse towards the Gr-Si junction and contribute to its reverse current originating the leakage of ~10-7A. For V<-1.2 V, instead, the electric field enables also FN tunneling through the Si_3N_4 layer (Figure2b), resulting in an increase of current, which generates the kink.

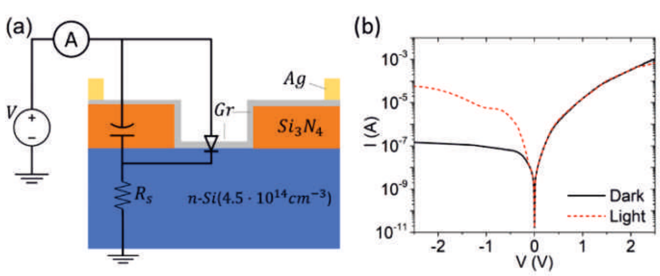


Fig. 1 - (a) Device schematic showing a Gr-Si junction modelled by a diode in parallel with a MIS structure, here represented as a capacitor. (b) IV characteristics in dark and with incident white laser.

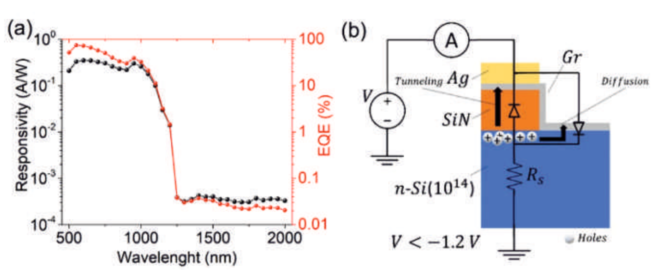
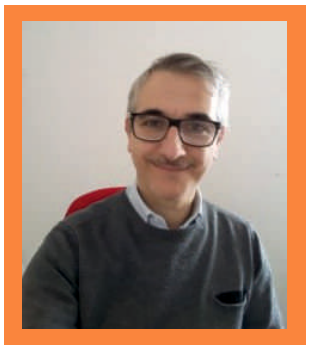


Fig. 2 – (a) Responsivity and EQE of the device in the visible and IR spectral region. (b) Schematic model of the Gr-Si device and charge carrier transport in reverse bias.

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.

Suppression of the morphology mismatch at graphene/n-type organic semiconductor interfaces: a scanning Kelvin probe force microscopy investigation

Federico Chianese[1,2], Fabio Chiarella[2], Mario Barra2, Andrea Candini[3], Marco Affronte[4], Antonio Cassinese[1,2]

[1]Department of Physics, Università Degli Studi di Napoli Federico II, Piazzale Tecchio 80, Napoli-Italy
[2]CNR-SPIN Institute of Superconductors, Innovative Materials and Devices, UOS-Naples, Piazzale Tecchio 80, Napoli-Italy
[3]Istituto per la Sintesi Organica e la Fotoreattivita` (ISOF)–CNR, Via P. Gobetti 101, Bologna-Italy
[4]Dipartimento di Scienze Fisiche Informatiche e Matematiche, Universita` di Modena e Reggio Emilia, Via G. Campi 2113/A, Modena-Italy

JOURNAL OF MATERIALS CHEMISTRY C 8, 8145-8154 (2020)

The close affinity between organic semiconductors and graphene has stimulated a new research interest on Graphene-Organic Hybrid Electronics (GOHE) with a potentially high technological impact on the next generation of flexible and light-weight electronics. In this framework, we fabricated and analyzed the response of n-type bottom-contact bottom-gate Organic Field Effect Transistors (OFETs) based on thermally-evaporated PDI8-CN2 thin films and CVD-Graphene as source/drain electrodes. Our efforts were mainly aimed to a quantitative analysis of contact resistance (RC) through the direct evaluation of parasitic voltage drops at PDI8-CN2/Graphene contact regions via Scanning Kelvin Probe Force Microscopy (SKPFM). The contact effect contribution of both source and drain interfaces was separately analyzed as a function of the applied voltages (gate–source VGS and drain–source VDS) and in the temperature range of 300 K < T < 360 K. The SKPFM analysis demonstrates unambiguously that the physical mechanisms driving the charge injection and extraction phenomena are distinctively based on the electrode material. While for OFETs with gold electrodes, the RC effect is mainly ascribable to the degraded quality of the charge transport in the semiconducting film regions close to the electrodes, for graphene-based devices, it is related to the presence of a Schottky-like barrier at the injecting electrode. Ultimate proof of the totally different behaviors occurring at the graphene/organic and gold/ organic interfaces was achieved by the fabrication of a hybrid gold–graphene device. These results could address future strategies aimed at optimizing the response of organic field-effect transistors equipped with transparent monolayer graphene electrodes.

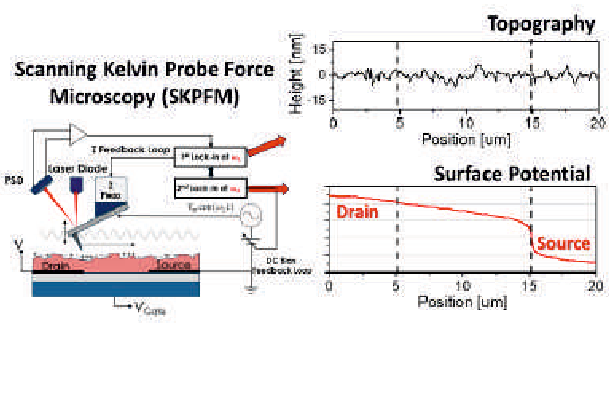


Fig. 1: Graphical abstract depicting the SKPFM technique applied to our bottom contacts/bottom gate OFETs with CVD graphene as Source-Drain electrodes. SKPFM allows to simultaneously acquire the topography and surface potential of the surface under investigation

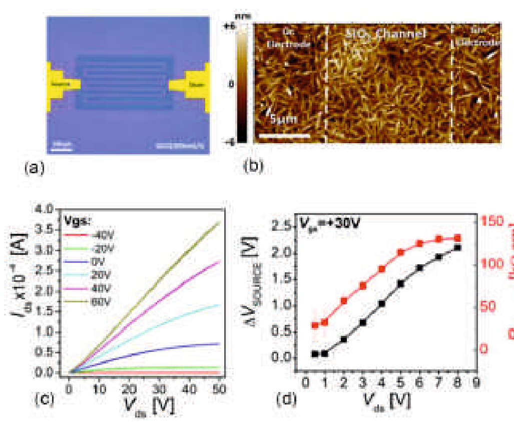


Fig. 2: (a) Optical micrographs of interdigitated micrometric layouts. (b) AFM image of a PDI8-CN2 thin film. The white dashed lines mark the edges of the graphene electrodes. (c) Output curve acquired in vacuum (d) Voltage drops at the source electrodes (black symbols) and width-normalized contact resistance values (red symbols).

Benchmarking β-Ga_2O_3 Schottky Diodes by Nanoscale Ballistic Electron Emission Microscopy

R. Buzio[1], A.Gerbi[1], Q. He[2], Y. Qin[2], W. Mu[3], Z. Jia[3], X. Tao[3], G. Xu[4], S. Long[4],

[1]CNR-SPIN Institute of Superconductors, Innovative Materials and Devices, UOS-Genova, C.so F.M. Perrone 24, 16152 Genova, Italy
[2]Key Laboratory of Microelectronics Devices and Integration Technology, Institute of Microelectronics of Chinese Academy of Sciences, 100029 Beijing, China
[3]State Key Laboratory of Crystal Materials and the Key Laboratory of Functional Crystal Materials and Device, Shandong University 250100 Jinan, China
[4]The School of Microelectronics, University of Science and Technology of China, 230026 Hefei, China

ADV. ELECTRON. MATER. 6, 1901151 (2020)

Monoclinic beta-phase gallium oxide (β-Ga_2O_3) is an ultrawide-bandgap semiconductor, intensively studied as a viable candidate for next-generation power electronics, optoelectronics, and extreme environment electronics. Schottky contacts to β-Ga_2O_3 are of paramount importance to this end; however, they are not yet fundamentally understood. Intrinsic sources of interfacial disorder, including oxygen-related defects and extrinsic fabrication factors, are thought to greatly determine the properties of such contacts, for example by originating Fermi level pinning and causing patches with different Schottky barrier heights (SBHs). Ballistic electron emission microscopy (BEEM) is used to probe band bending and interfacial inhomogeneity at the nanoscale for prototypical Au/ and Pt/(100)β-Ga_2O_3 single crystal Schottky barrier diodes. It is shown that SBH fluctuations amount to 40-60 meV under vacuum, occurring over length scales of tens of nanometers. Furthermore, a remarkable SBH modulation of ≈0.2 eV takes place upon exposure of devices from vacuum to ambient air. Such findings—better obtained by BEEM than by macroscale approaches—point to the existence of an ubiquitous inhomogeneous interfacial layer, controlling band bending and ambient sensitivity via oxygen ionosorption and interface redox chemistry. This study ascribes a key role to interfacial oxygen vacancies, and has practical implications for transport modelling and interface engineering.

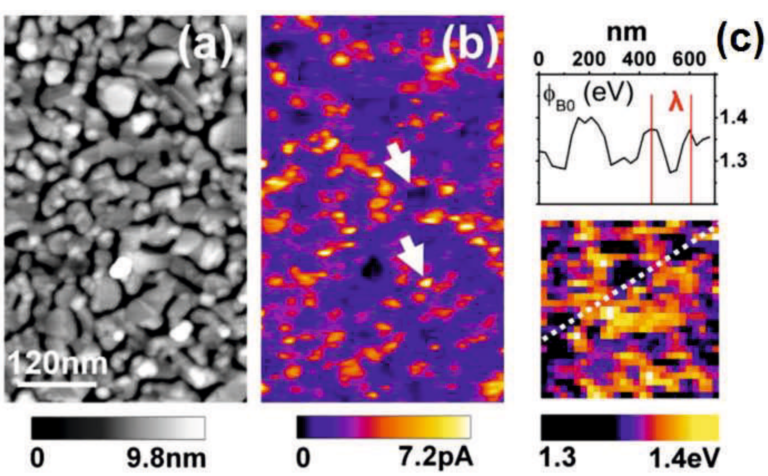


Fig. 1: a) STM topography and b) BEEM map acquired simultaneously over a representative Au region of the Au/(100)β-Ga_2O_3 Schottky junction (IT =36nA, VT= −1.95 V, T = 296 K). The arrows highlight two localized spots with high BEEM contrast. (c) Spatially resolved map of the local Schottky barrier height φB0. Along the dash line, φB0 fluctuates over a length scale λ as large as ≈200 nm.

Electric Control of Spin-Orbit Coupling in Graphene-Based Nanostructures with Broken Rotational Symmetry

Alessandro Ciattoni[1], Claudio Conti[2,3], Anatoly V. Zayats[4], Andrea Marini[5]

[1]CNR-SPIN, c/o Dip.to di Scienze Fisiche e Chimiche - Via Vetoio, 67010 Coppito (AQ), Italy
[2]Institute for Complex Systems (ISC-CNR), Via dei Taurini 19, 00185, Rome, Italy
[3]Department of Physics, University Sapienza, Piazzale Aldo Moro 5, 00185, Rome, Italy
[4]Department of Physics and King's College London, Strand, London WC2R 2LS, UK
[5]Department of Physical and Chemical Sciences, University of L'Aquila, Via Vetoio, 67100 L'Aquila, Italy.

LASER PHOTONICS REV. 14, 2000214 (2020)

Spin and orbital angular momenta of light are important degrees of freedom in nanophotonics which control light propagation, optical forces, and information encoding. Here, it is shown that graphene-supported plasmonic nanostructures with broken rotational symmetry provide a surprising spin to orbital angular momentum conversion, which can be continuously controlled by changing the electrochemical potential of graphene. Upon resonant illumination by a circularly polarized plane wave, a polygonal array of indium-tin-oxide nanoparticles on a graphene sheet generates the scattered field carrying electrically-tunable orbital angular momentum.

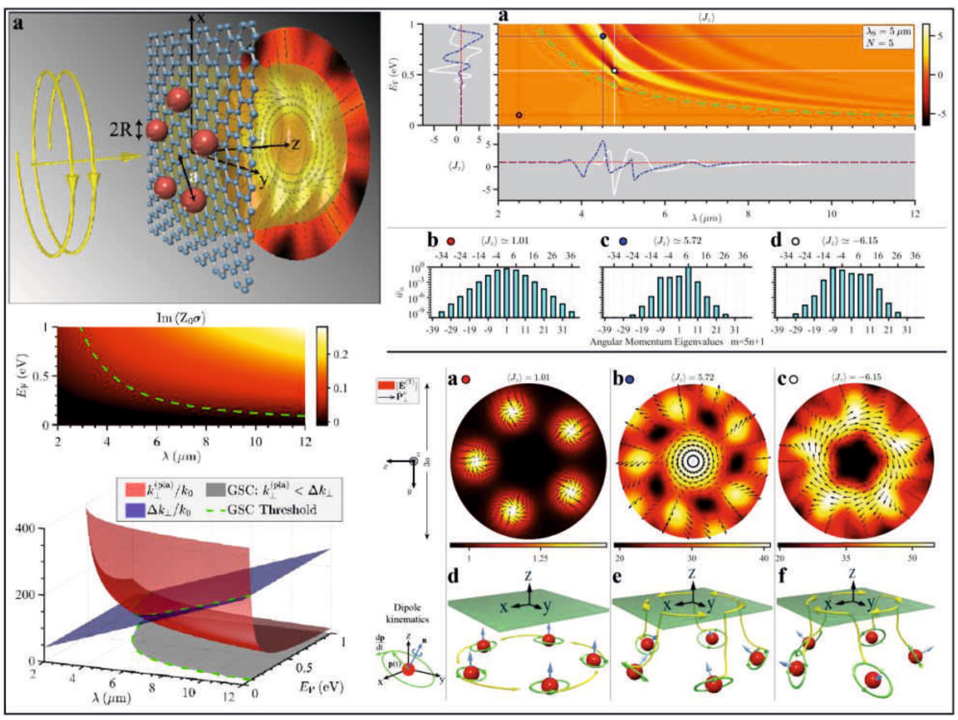


Fig. 1 This unique photonic spin-orbit interaction occurs due to the coupling between graphene plasmon polaritons and localized surface plasmons of the nano- particles and leads to the controlled directional excitation of graphene plasmons. The tuneable spin-orbit conversion paves the way for high-rate information encoding in optical communications, electric steering functionalities in optical tweezers, and nanorouting of higher-dimensional entangled photon states.

Macroscopic Versus Microscopic Schottky Barrier Determination at (Au/Pt)/Ge(100): Interfacial Local Modulation

Andrea Gerbi[1], Renato Buzio[1], Cesar González[2], Nicola Manca[1], Daniele Marrè[1,7], Sergio Marras[3], Mirko Prato3, Lloyd Bell[4], Sergio Di Matteo[5], Fernando Flores[2], and Pedro L. de Andres[6]

[1]CNR-SPIN Institute for Superconductors, Innovative Materials and Devices, UOS-Genova
Corso Perrone 24, I-16152 Genova, Italy
[2]Física Teórica de la Materia Condensada-IFIMAC,
Universidad Autonoma de Madrid, E-28049 Madrid, Spain
[3]Materials Characterization Facility, Instituto Italiano di Tecnologia,
Via Morego 30, I-16163 Genova, Italy
[4]Jet Propulsion Laboratory, California Institute of Technology,
4800 Oak Grove Dr. Pasadena, CA 91104, USA
[5]Univ. Rennes, CNRS, IPR (Institut de Physique de Rennes) - UMR 6251,
F-35000 Rennes, France
[6]Instituto de Ciencia de Materiales de Madrid-CSIC, Cantoblanco,
E-28049 Madrid, Spain
[7]Dipartimento di Fisica, Universita degli Studi di Genova, via Dodecaneso 33, Italy

ACS APPL. MATER. INTERFACES 12, 28894 (2020)

Macroscopic current–voltage measurements and nanoscopic ballistic electron emission spectroscopy (BEES) have been used to probe the Schottky barrier height (SBH) at metal/Ge(100) junctions for two metal electrodes (Au and Pt) and different metallization methods, specifically, thermal-vapor and laser-vapor deposition. Analysis of macroscopic current–voltage characteristics indicates that a SBH of 0.61–0.63 eV controls rectification at room temperature. On the other hand, BEES measured at 80 K reveals the coexistence of two distinct barriers at the nanoscale, taking values in the ranges 0.61–0.64 and 0.70–0.74 eV for the cases studied. For each metal–semiconductor junction, the macroscopic measurement agrees well with the lower barrier found with BEES. Ab initio modeling of BEES spectra ascribes the two barriers to two different atomic registries between the metals and the Ge(100) surface, a significant relevant insight for next-generation highly miniaturized Ge-based devices.

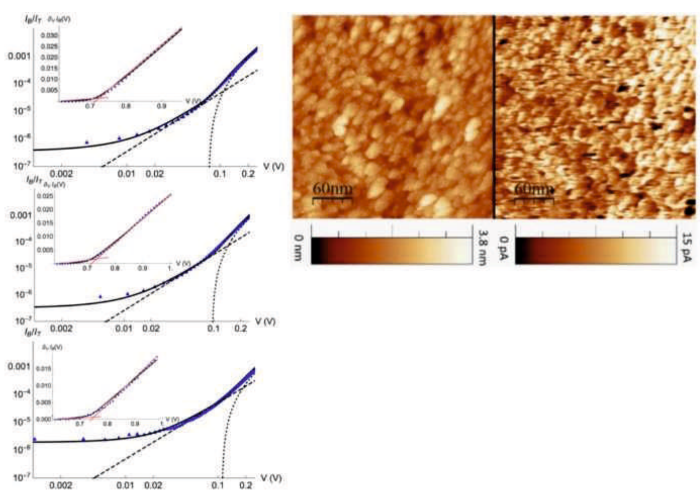


Fig. 1: (left panel) Experimental BEES data (blue triangles, T=80K) for the three different samples: top panel (Au-PLD, IT=2:5nA), middle panel (Au-PVD, IT=2 nA), lower panel (Pt-PLD, IT=3nA). The origin of each Log-Log plot corresponds to the lowest barrier for each case. Black thick line: best fit from theoretical model derived from an ab-initio calculation at T=80K. Black dashed and dotted lines give the individual contributions of each barrier at T=0K. Insets: a comparison of derivatives for experimental data and best fits (black line).
(right panel) Representative images for topography and the related BEEM current map acquired over a representative region (300x300 nm^2) of the Au electrode at 80 K.

Electronic properties of one-dimensional pentacene crystals

C. Nappi1, F. Romeo2, E. Sarnelli1,
1CNR-SPIN Institute of Superconductors, Innovative Materials and Devices, UOS-Naples, Naples 80126, Italy
2Physics Department "E. R. Caianiello" , University of Salerno, Fisciano 84084, Salerno, Italy
3INFN, Naples Division, Naples 80126, Italy

NANO EXPRESS 1, 030002 (2020)

We have studied the charge transport properties of a 1D pentacene crystal with a general view to provide clues in understanding the peculiar physics of the organic semiconductors. In the tight binding approximation, and neglecting hydrogens, we have calculated the energy band structure of the pentacene solid system allowing for a variable coupling Γ between molecules. In this way we can range from the coupling of a tight packing structure, close to that of a graphene nanoribbon (Γ~3eV), to the loose packing one of a weak interacting pentacene aggregate (Γ → 0eV). Our model illustrates how an energy bandgap opens up and evolve in amplitude, reaching a maximum of ~1.4 eV in correspondence of Γ=1.74 eV. This maximum value is characterized by a crossover in the energy bands between HOMO LUMO and secondary HOMO LUMO levels. The subsequent evolution with Γ consists in a lowering of the bandgap amplitude, up to zero (existence of a second metallic point) and a regrowth, up to the energy difference between HOMO and LUMO of an isolated pentacene molecule (1.3eV). Next, we used the model to calculate the conductance of an assigned micrometric length portion of crystal and simulate a gate operation in a voltage range of a few ten of volts (Figure 1) . No specific disordered has been introduced in the regular crystal structure, while we have considered a generic scattering mechanism represented by a phenomenological relaxation time τ. We obtain typical conductance values of 0.01–0.2μS with a relaxation time of 1fs. After having derived the relationship between conductance and mobility of the 1 D model, we have obtained mobility values as a function of the gate voltage (Figure 2) for two significant cases of semiconductive crystals with moderately low overlap integrals: Γ=0.15 eV and Γ=0.12 eV (corresponding to a bandgap of Eg=1.05 eV and Eg=0.6 eV, respectively) obtaining mobility values in very good agreement with the observed values of literature.

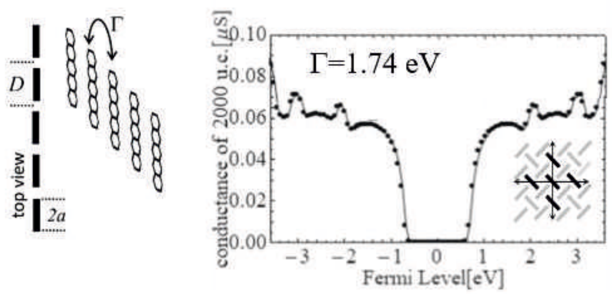


Fig. 1: (Left) Schematic representation of a one-dimensional pentacene crystal studied in this work. Γ is the (distance dependent) inter-molecular hopping energy. (Right) Calculated conductance of a 2000 unit cell long (L~1μm) pentacene crystal vs chemical potential, for Γ°1.74eV. The bandgap energy of the crystal is maximum for this value (Eg=1.4eV). A relaxation time τ of 10^{-15} s was used.

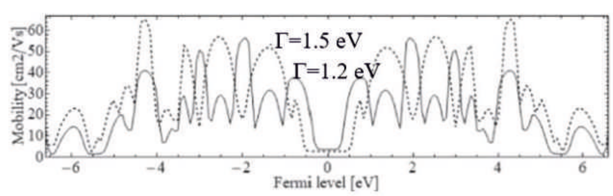


Fig. 2: 1D pentacene crystal mobility as a function of the Fermi level calculated in the present model with Γ=1.5eV and Γ=1.2eV. The obtained mobility values span the range between 10 cm^2/Vs and 50 cm^2/Vs which is compatible with the accepted experimental values from the literature. In close vicinity of the Fermi level of the pristine system (EF=0) the channel conductance can be effectively controlled by using a back gate, the latter observation being relevant to set the device working point for applications.

Balanced ambipolar charge transport in phenacene/perylene heterojunction-based organic field-effect transistors

T. Taguchi[1], F. Chiarella[2], M. Barra[2], F. Chianese[2,3], Y. Kubozono[1], A. Cassinese[2,3]

[1]Research Institute for Interdisciplinary Science, Okayama University, Okayama 700-8530, Japan
[2]CNR-SPIN, UOS Napoli c/o Complesso di Monte S. Angelo, via Cinthia 21, 80126 Napoli, Italy
[3]Department of Physics "Ettore Pancini", University "Federico II", I-80125, Naples, Italy

ACS APPLIED MATERIALS AND INTERFACES, 13 (7) (2021) 8631

Electronic devices relying on the combination of different conjugated organic materials are considerably appealing for their potential use in many applications such as photovoltaics, light emission and digital/analog circuitry. In this study, the electrical response of field-effect transistors achieved through the evaporation of picene and PDIF-CN2 molecules, two well-known organic semiconductors with remarkable charge transport properties, was investigated (Fig.1). With the main goal to get a balanced ambipolar response, various device configurations bearing double layer, triple-layer, and co-deposited active channels were analyzed. The most suitable choices for the layer deposition processes, the related characteristic parameters, and the electrode position were identified to this purpose. In this way, ambipolar organic field-effect transistors exhibiting balanced mobility values exceeding 0.1 cm2 V−1 s−1 for both electrons and holes were obtained (Fig.2). These experimental results highlight also how the combination between picene and PDIF-CN2 layers allows tuning the threshold voltages of the p-type response. Scanning Kelvin probe microscopy (SKPM) images acquired on picene/PDIF-CN2 heterojunctions suggest the presence of an interface dipole between the two organic layers. This feature is related to the partial accumulation of space charge at the interface being enhanced when the electrons are depleted in the underlayer.

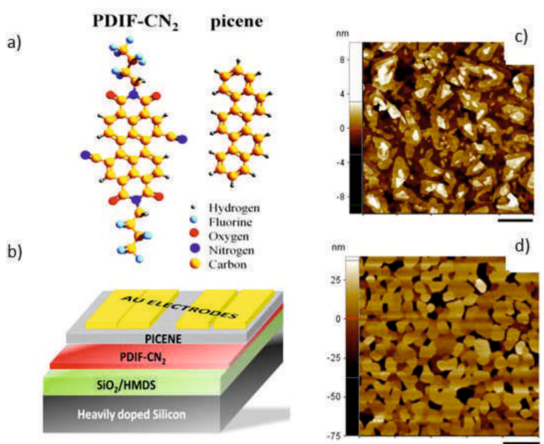


Fig.1:(a) PDIF-CN2 and picene molecular structures. (b) The bottom-gate top-contact device configuration mainly analyzed in this work. 5x5 μm^2 AFM images of (c) a 30 nm thick PDIF-CN$_2$ single layer and (d) of a PDIF-CN$_2$(15 nm)/picene (60 nm) bilayer. The black sign is a reference of 1 μm.

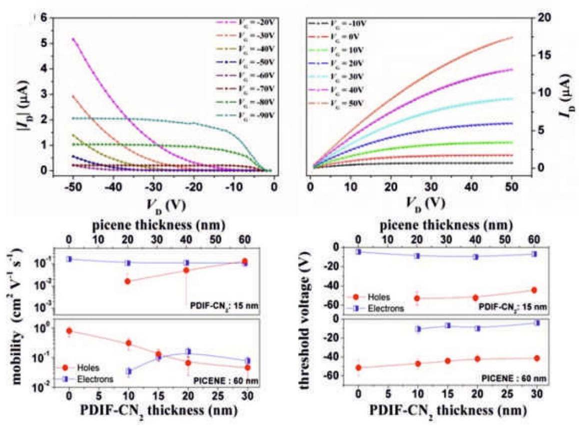


Fig.2: (top) A typical ambipolar response of a PDIF-CN$_2$/picene bilayer field-effect transistor. (bottom) Hole and electron (right) mobility and (left) threshold voltages values achieved with PDIF-CN$_2$/picene bilayer devices as a function of the thickness of the two organic layers.

Space-charge accumulation and band bending at conductive P3HT/PDIF-CN_2 interfaces investigated by Scanning-Kelvin Probe Microcopy

F. Chianese[1,2], S. Fusco[1,3], M. Barra[2], F. Chiarella[2], A. Carella[3] A. Cassinese[1,2]

[1]Department of Physics "Ettore Pancini", University "Federico II", I-80125, Naples, Italy
[2]CNR-SPIN, UOS Napoli c/o Complesso di Monte S. Angelo, via Cinthia 21, 80126 Napoli, Italy
[3]Department of Chemical Sciences, University "Federico II", I-80126, Naples, Italy

JOURNAL OF MATERIALS CHEMISTRY C 9 (47) (2021) 17143

The possibility to achieve localized regions with enhanced charge density is a powerful strategy to strongly improve the performances of a large number of organic electronic devices such as light emitting diodes, photodetectors and field-effect transistors. Because of the complex structures of many organic compounds and the diversity of electronic interactions ruled by specific morphological features, however, the interfacial energy landscape of any combination of materials needs to be carefully investigated. In this work, the surface potential landscape of poly(3-hexylthiophene) (P3HT)/PDIF-CN_2 donor/acceptor organic heterointerfaces was analyzed. The electrical characterization, relying on the field-effect transistor configuration, outlined that the presence of a PDIF-CN_2 overlayer induces a semiconductor-to-conductor transition in spin-coated P3HT polymer films (Fig.1a). The mutual doping effect was investigated by Scanning Kelvin Probe Force Microscopy (SKPFM) as a function of the PDIF-CN2 coverage and nominal thickness (Fig.1b,c), with the results clearly pointing at the occurrence of charge transfer phenomena between the two materials. The related band bending (Fig.1d) at the interface leads to the formation of a hole rich area within the P3HT layer and an electron rich area within the PDIF-CN^2layer. The related thickness and charge density have been estimated as 15 nm and E~10^{18} cm^{-3}, respectively. Significantly, by tuning the PDIF-CN_2 overlayer coverage, the P3HT work function can be tuned within 1 eV, opening an interesting perspective for the achievement of organic optoelectronic devices with improved functionalities.

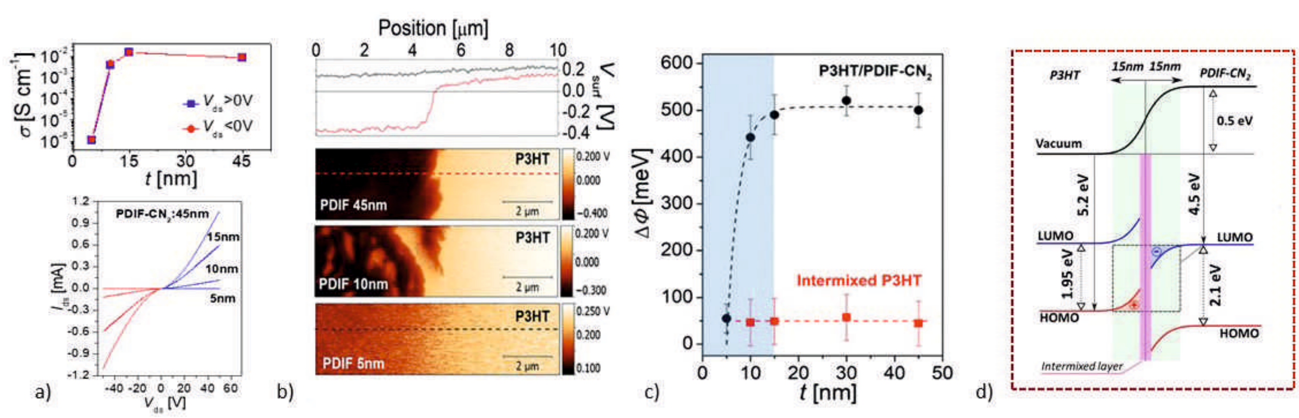


Fig.1: (a) Output (IV) curves measured in vacuum (at V_{GS}=0V) for the P3HT/PDIF-CN_2 heterostructures as a function of the PDIF-CN_2 overlayer thickness (t). The upper panel reports the corresponding estimated conductivity values. (b) Surface potential maps acquired in the boundary region between P3HT and shadow-masked PDIF-CN_2 for t = 5, 10 and 45 nm. The upper panel shows the corresponding surface potential profile for t = 5 nm and 45 nm (black and red lines, respectively) (c) Summary of the work function differences of panel (b) expressed as function of t. (d) Band diagram of the P3HT/PDIF-CN_2 heterointerface highlighting the band bending phenomenon along the organic boundary.

Optical parametric amplification by monolayer transition metal dichalcogenides

C. Trovatello[1,2], A. Marini[3], X. Xu[1], C. Lee[1], F. Liu[4], N. Curreli[1,5], C. Manzoni[6], S. Dal Conte[2], K. Yao[1], A. Ciattoni[7], J. Hone[1], X. Zhu[4], P. J. Schuck[1] and G. Cerullo[2,6]

[1]Department of Mechanical Engineering, Columbia University, New York, NY, USA
[2]Dipartimento di Fisica, Politecnico di Milano, Milano, Italy
[3]Department of Physical and Chemical Sciences, University of L'Aquila, L'Aquila, Italy
[4]Department of Chemistry, Columbia University, New York, NY, USA
[5]Graphene Labs, Istituto Italiano di Tecnologia, Genova, Italy
[6]IFN - CNR, Milano, Italy
[7]CNR-SPIN, UOS Aquila c/o Dip.to di Scienze Fisiche e Chimiche - Via Vetoio - 67100 - Coppito (AQ), Italy

NATURE PHOTONICS 15, 6 (2021)

Optical parametric amplification is a second-order nonlinear process whereby an optical signal is amplified by a pump via the generation of an idler field. This mechanism is inherently related to spontaneous parametric down-conversion, which currently constitutes the building block for entangled photon pair generation, a process that is exploited in modern quantum technologies. In this paper experimental demonstration is provided of a single-pass optical parametric amplification at the ultimate atomic thickness limits. Using semiconducting transition metal dichalcogenides, amplification over propagation through a single atomic layer has be attained. Such a second-order nonlinear interaction at the two-dimensional limit bypasses phase-matching requirements and achieves ultrabroad amplification bandwidths. In agreement with first-principle calculations, the amplification process has been shown to be independent of the in-plane polarization of signal and pump fields. By the use of AA-stacked multilayers, a clear pathway towards the scaling of conversion efficiency has been proven. The results pave the way for the development of atom-sized tunable sources of radiation with potential applications in nanophotonics and quantum information technology.

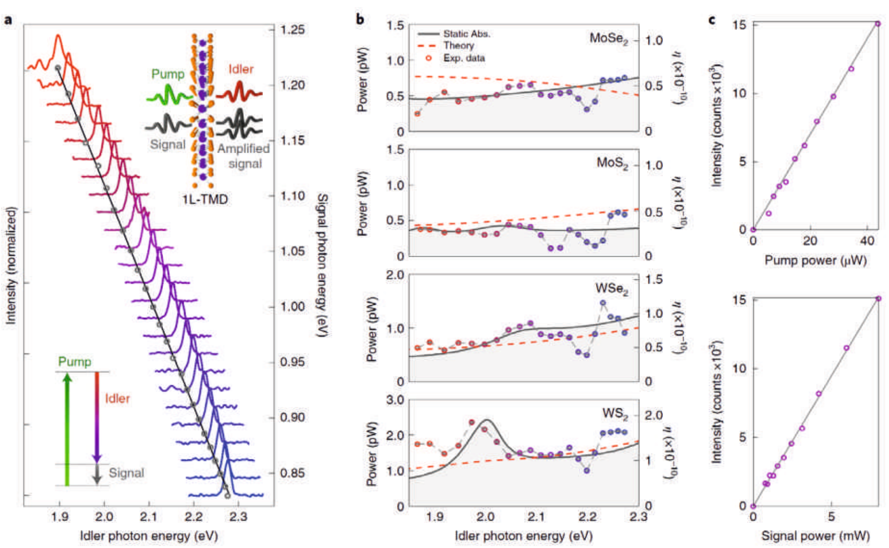


Fig. 1: Broadband OPA in 1L-TMDs.
a Normalized tunable idler spectra measured on 1L-$MoSe_2$; the spectra are vertically offset. The nominal idler photon energy (black solid line) and measured peak values (grey dots) are shown.
b. Absolute idler power and efficiency (η) as a function of the idler photon energy measured on the four semiconducting 1L-TMDs (coloured dots), as well as the corresponding calculated theoretical efficiencies divided by a factor of 2.5 (dashed lines).
c. The idler linear intensity dependence on pump and signal powers measured on 1L-$MoSe_2$.

Anisotropic Temperature-Driven Strain Dynamics in Vo_2 Solid-State Microactuators

N. Manca[1,2], T. Kanki[3], F. Endo[3], E. Ragucci[2], L. Pellegrino[1], D. Marré[2]

[1]CNR-SPIN, Sede Genova, Area della Ricerca di Genova, C.so F. M. Perrone 24, 16152 Genova, Italy
[2]Dipartimento di Fisica, Università degli Studi di Genova, 16146 Genova, Italy
[3]Institute of Scientific and Industrial Research, Osaka University, Osaka 567-0047, Japan

ACS Applied Electronic Materials 3 (2021) 211

VO_2 is a particularly appealing material for the development of solid-state micro- and nano-actuators due to its phase transition characterized by a large lattice change associated with a high energy density. Its martensitic transformation is strongly anisotropic: upon heating the *c*-axis contracts by almost 1%, while the a and b axes expand by about 0.5 and 0.4%, respectively. Such anisotropic behavior could be fully exploited or almost compensated by controlling the microstructure of VO_2. In this work we characterize the in-plane strain state of VO_2 thin films grown on top of MgO(100) and MgO(110) substrates. The microstructures of VO2 on MgO(100) are "tasselleted", i.e. made of orthogonal VO_2 domains that results in an almost-isotropic behavior. VO_2 grown on top of MgO(110), instead, is characterized by aligned domains showing wider strain dynamics and marked anisotropy. We perform a quantitative analysis of the strain state of VO_2 across its phase transition and along different lattice directions by measuring the profile of suspended micro-bridges aligned along different directions. Strain is obtained by calculating the profile lengths of the buckled bridges and comparing them with their nominal values (flat state). Our results show that the strain dynamics and anisotropy of VO2 devices is comparable with bulk values and can be controlled by the VO_2 crystalline microstructure. Moreover, we demonstrate that there exists an interplay between electrical resistivity and strain which is mediated by the bridge geometry, where clamping conditions allow the accumulation of tensile strain but relax compressive one by buckling.

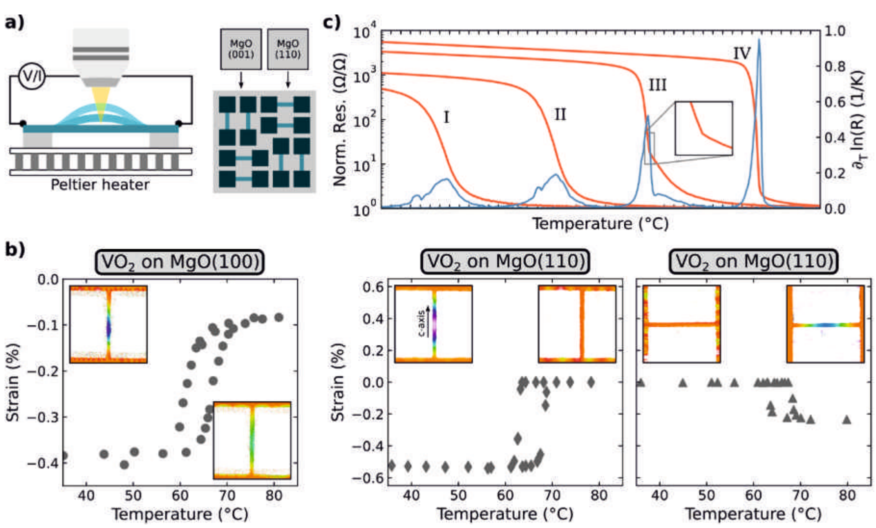


Fig. 1: a) Experimental configuration relied on the concurrent measurement of the electrical resistivity and the profile of double-clamped micro-bridges fabricated from VO_2. b) In-plane strain of VO_2 as a function of temperature as obtained from optical profilometry data (extremal cases and bridge directions are shown in the inset). Different MgO substrate cut-planes determines different Vo_2 crystalline microstructures, affecting strain dynamics and absolute values across the phase transition. c) R(T) and its relative derivative for two orthogonal bridges on MgO(100) and MgO(110). I and II are comparable while III and IV shows anisotropy due to different strain state of the bridges at different temperatures, the kind marks the transition from buckle to flat condition.

Investigation of random telegraph signal in two junction layouts of proton irradiated CMOS SPADs

F. Di Capua[1,5,6], M. Campajola[1,5,6], D. Fiore[2,6], L. Gasparini[4], E. Sarnelli[3] & A. Aloisio[1,5]

[1]Department of Physics "E. Pancini", University of Naples Federico II, Naples, Italy
[2]Center National d'Etude Spatiales, Toulouse, France
[3]CNR-SPIN, UOS Napoli, Via Campi Flegrei 34, 80078 Pozzuoli (NA), Italy
[4]Fondazione Bruno Kessler (FBK), Integrated Radiation and Image Sensors Division, Trento, Italy
[5]Istituto Nazionale di Fisica Nucleare, Naples, Italy

SCIENTIFIC REPORTS 11 (2021) 1

This paper focuses on the understanding of the Random Telegraph Signal (RTS) in Single-Photon Avalanche Diodes (SPAD). We studied the RTS of two different SPAD layouts, designed and implemented in a 150-nm CMOS process, after proton irradiation. The two structures are characterized by different junction types: the first structure is constituted by a P+/Nwell junction, while the second is formed by a Pwell/Niso junction, see Fig. 1. RTS occurrence has been measured in about one thousand SPAD pixels and the differences addressed in two layouts are motivated and discussed. Hypotheses on the RTS origin are drawn by analyzing the RTS time constants and the RTS occurrence evolution as a function of the annealing temperature.
In order to investigate the RTS behaviour, we measured the RTS characteristics in a sub-set of two-level RTS pixels for each of two SPAD layouts. In a two-level RTS, the time distribution of the DCR levels spent in the high (low) state follows an exponential distribution, see Fig. 2. The distribution time constants represent the inverse of the DCR switching probability. In Fig. 3, the RTS probabilities as a function of sensitive area for two different proton doses are reported.

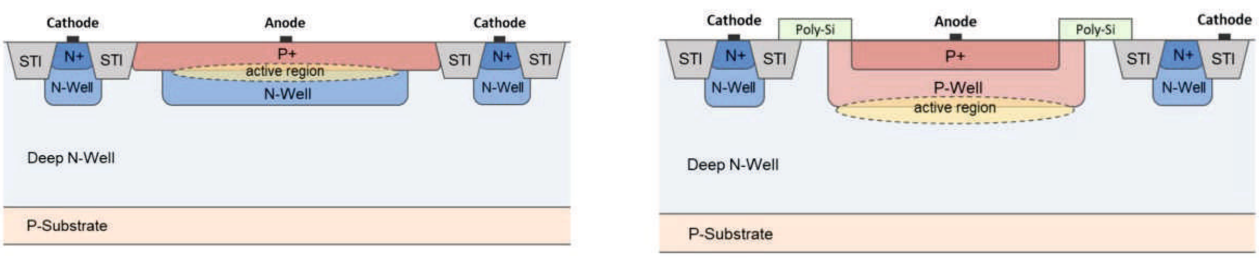


Fig. 1: Layout of SPAD structures: P+/Nwell (left) and Pwell/Niso (right)

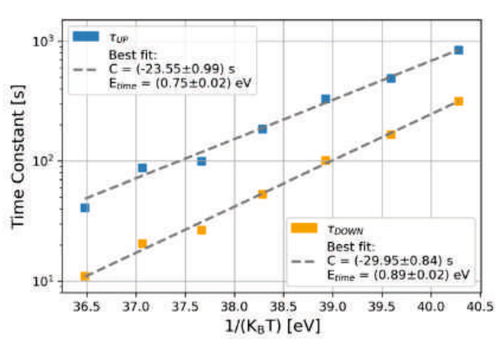


Fig. 2: RTS time constants (for up and down levels) as a function of1/KBT and the extracted values for the activation energy E_{time}.

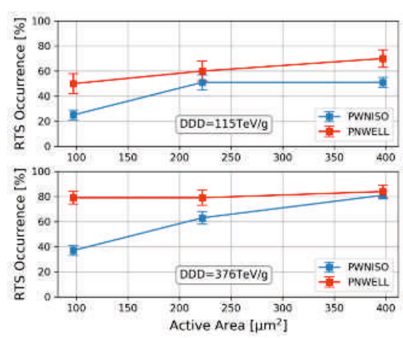


Fig. 3: RTS occurrence as a function of sensitive area for the 115 TeV/g sample (top) and for the 376 TeV/g sample (bottom).

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.

Dissipative dynamics of an open quantum battery

M. Carrega[1], **A. Crescente**[1,2], **D. Ferraro**[1,2], **M. Sassetti**[1,2]

[1]CNR-SPIN Superconductors, Innovative Materials and other Devices Institute, Via Dodecaneso 33, 16146 Genoa, Italy
[2]Physics Department, University of Genoa, Via Dodecaneso 33, 16146 Genoa, Italy

NEW JOURNAL OF PHYSICS 22, 083085 (2020)

Recently, in the study of thermodynamic processes at the nanoscale, it has been realized that quantum systems can be exploited to efficiently store energy by relying on quantum coherences and correlations, hence coining the word quantum battery (QB). Most of the literature on QBs focused on the dynamics of closed systems where the energy is coherently transferred from a charger to the battery without losses. In view of realistic modeling, it is however an important task to understand how an external environment affects the charging performances of a quantum battery. Here we model the QB as a two-level system, with energy separation Δ, coupled to an external charger, and we take into account dissipation effect by introducing a microscopic model for a thermal reservoir. The latter is coupled to both longitudinal and transverse spin components of the quantum battery in order to include decoherence and pure dephasing mechanisms. Charging and discharging dynamics of the quantum battery, subjected to a static driving of amplitude A, are obtained analytically in the case of weak dissipation strength, by exploiting an exact mapping to the so-called spin-boson model. In this framework, the impact of decoherence and pure dephasing mechanisms on charging performance of a QB are discussed in detail (see Fig. 1). We have found that the former is a better choice of coupling, since there the QB can absorb energy both from the charger and the reservoir. In contrast, in the latter case the charger supplies energy both to the QB and to the reservoir, resulting in a more dissipative dynamics (see Fig. 2). This study represents an important step toward a realistic and microscopic description of QBs that can be realized on solid-state quantum technology, where unavoidable presence of external environments has to be properly considered and engineered.

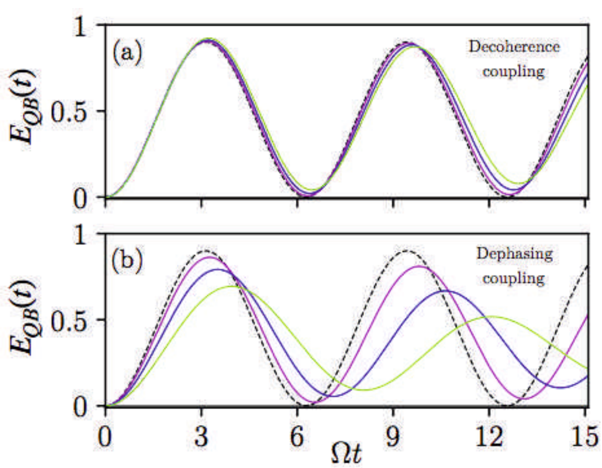


Fig. 1: Time evolution of the average energy stored in the quantum battery EQB(t) (in units of Δ) as function of Ωt [with $\Omega=(A^2+\Delta^2)1/2$ the Rabi frequency] for increasing dissipation strengths (magenta, blue and green curves) compared to the non-dissipative case (dashed black curves). Panel (a) shows the results obtained in the decoherence case, while panel (b) represents the dephasing one.

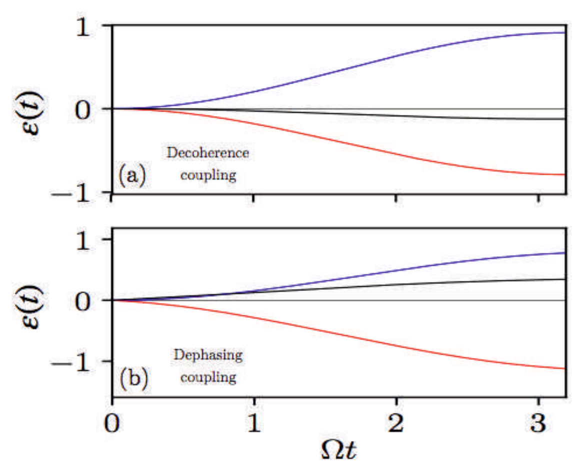


Fig. 2: Average energy flows ε(t)=E(t)-E(0) (in units of Δ) for the quantum battery (blue curve), the charger (red curve) and the reservoir (black curve). Panel (a) shows the results obtained in the decoherence case, while panel (b) represents the dephasing one.

Electron irradiation of metal contacts in monolayer MoS_2 Field-Effect Transistors

Aniello Pelella[1,2], Osamah Kharsah[5], Alessandro Grillo[1,2], Francesca Urban[1,2,3], Maurizio Passacantando[4], Filippo Giubileo[2], Laura Iemmo[1,2], Stephan Sleziona[5], Erik Pollmann[5], Lukas Madauß[5], Marika Schleberger[5], and Antonio Di Bartolomeo[1,2]

[1] Department of Physics and Interdepartmental Centre NanoMates, University of Salerno, via Giovanni Paolo II, Fisciano, 84084, Italy
[2]CNR-SPIN Institute of Superconductors, Innovative Materials and Devices, UOS-Salerno, Italy
[3] INFN – Gruppo collegato di Salerno, via Giovanni Paolo II, Fisciano, 84084, Italy
[4] Department of Physical and Chemical Sciences, University of L'Aquila, and CNR-SPIN L'Aquila, via Vetoio, Coppito, L'Aquila, 67100, Italy
[5] Fakultät für Physik and CENIDE, Universität Duisburg-Essen, Lotharstrasse 1, D-47057, Duisburg, Germany

ACS APPLIED MATERIALS & INTERFACES 12, 40532–40540 (2020)

Metal contacts play a fundamental role in nanoscale devices. In this work, Schottky metal contacts in monolayer molybdenum disulfide (MoS_2) field-effect transistors (FETs) are investigated under electron beam irradiation. It is shown that the exposure of Ti/Au source/drain electrodes to an electron beam reduces the contact resistance and improves the transistor performance. The electron beam conditioning of contacts is permanent, while the irradiation of the channel can produce transient effects. It is demonstrated that irradiation lowers the Schottky barrier at the contacts, due to thermally induced atom diffusion and interfacial reactions. The simulation of electron paths in the device reveals that most of the beam energy is absorbed in the metal contacts. The study demonstrates that electron beam irradiation can be effectively used for contact improvement through local annealing.

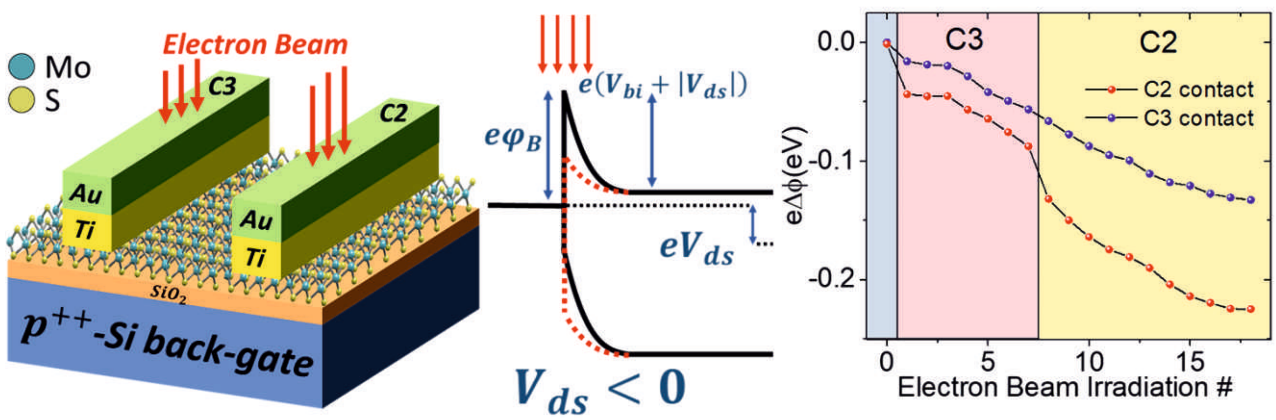


Fig. 1: (a) MoS2 FET layout. (b) Low-bias energy band diagrams (black) and modification under electron irradiation (red) of contact, resulting in barrier lowering ($\overline{\varphi}_b$) (c) Zero-bias Schottky barrier variation at the contact C2 and C3 as a function of the irradiation number.

Field Emission in Ultrathin $PdSe_2$ Back-Gated Transistors

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

[1]Physics Department "E. R. Caianiello", University of Salerno, Italy
[2]CNR-SPIN Institute of Superconductors, Innovative Materials and Devices, Salerno, Italy
[3]Department of Physical and Chemical Science, University of L'Aquila and CNR-SPIN L'Aquila, Italy
[4]National Laboratory of Solid State Microstructures, Nanjing University, China

ADVANCED ELECTRONIC MATERIALS 6 (2020) 2000094

The material research of the last decade has been largely dominated by 2D transition metal dichalcogenides (TMDs), which have been explored for numerous applications in electronics, optoelectronics, sensors, catalysis, etc. Palladium diselenide ($PdSe_2$) has been the first isolated layered material with pentagonal structure that is stable in air. The monolayer has a puckered morphology where each Pd atom is coordinated with four Se atoms and exhibits an indirect bandgap of ≈1.3 eV that vanishes with the increasing number of layers up to the metallic behavior of the bulk material. This study deals with the electrical transport in back-gate field-effect transistors with ultrathin $PdSe_2$ channels. The devices are normally-on and exhibit dominant n-type conduction at low pressure. The electron conduction of PdSe2 nanosheets, combined with the sharp edge and the work function decreasing with the number of layers, opens up new applications in vacuum electronics. This work is the first experimental demonstration of field emission current from few-layer $PdSe_2$ by using a tip shaped anode precisely positioned at small distance from the emitting surface. Field-emission from $PdSe_2$ nanosheets is obtained with a turn-on field below 100 V μm^{-1} and attains currents up to the μA. This finding extends the plethora of applications of this recently isolated pentagonal layered material.

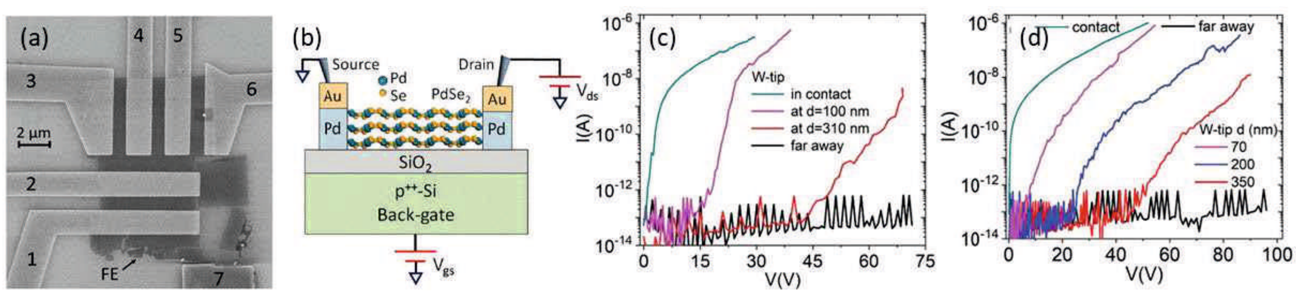


Fig. 1: (a) SEM image of a $PdSe_2$ flake contacted with Pd/Au leads. The FE arrow points to the flake used for field emission measurements. (b) Schematic cross-section and biasing of the $PdSe_2$ field-effect device in common-source configuration. (c) and (d) I–V curves with the anode W-tip at growing distances from the $PdSe_2$ nanosheet showing the evolution from electric contact to FE regime. The substrate back-gate was grounded during all the above measurements.

Anyons in quantum Hall interferometry

Matteo Carrega[1], Luca Chirolli[2], Stefan Heun[2], Lucia Sorba[2]

[1]CNR-SPIN, Sede Genova, Area della Ricerca di Genova, C.so F. M. Perrone 24, 16152 Genova, Italy
[2]Nest, Istituto Nanoscienze CNR and Scuola Normale Superiore, P.zza San Silvestro 12 56127 Pisa (Italy)

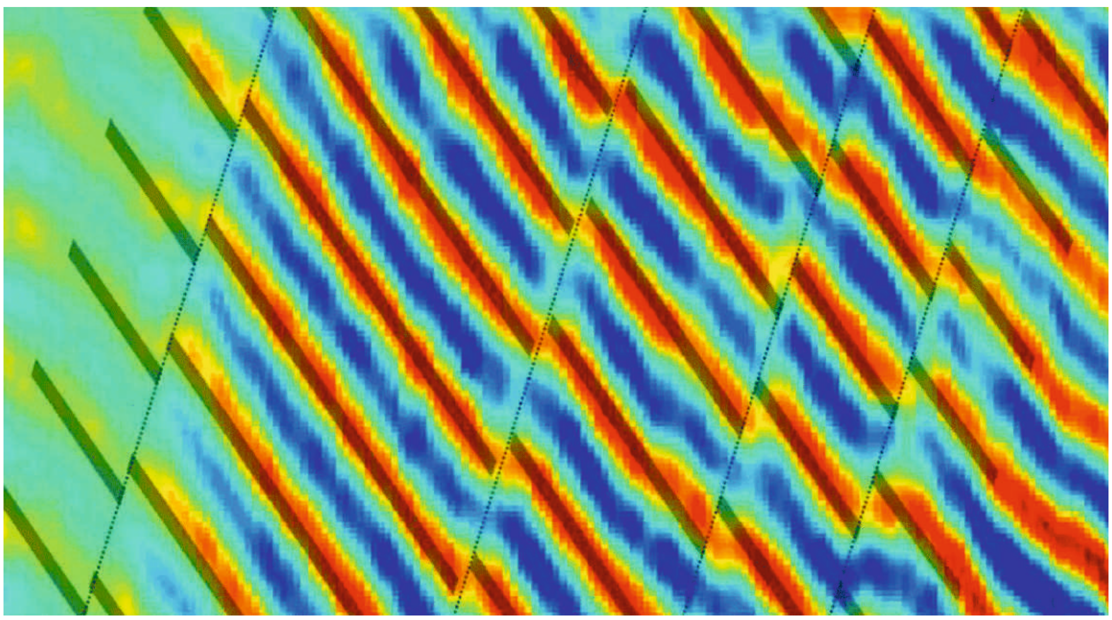
NATURE REVIEW PHYSICS 3 (2021) 698

The quantum Hall effect is a unique playground to exploit quantum coherence of electrons for various applications, from metrology to quantum computation. A Review article by Cnr SPIN and CNR NANO researchers gives a survey of the main results achieved in Quantum Hall interferometry.

The review article "Anyons in quantum Hall interferometry" has been published on the journal Nature Reviews Physics in 2021.

In the paper, researchers focus their attention on anyons, emergent quasiparticles that are neither bosons nor fermions and possess fractional statistics. The fractional statistics, in particular, has attracted a lot of interest in view of potential applications in topological quantum computation.

The review offers a survey on the two mainly investigated interferometric setups, showing their basic working principles, fabrication issues and the main results achieved so-far, including the first observation of fractional statistics for Laughlin fractional quantum Hall states.



Optimal energy conversion through anti-adiabatic driving breaking time-reversal symmetry

Loris Maria Cangemi[1], Matteo Carrega[2], Antonio De Candia[1,2,3], Vittorio Cataudella[1,3,4] Giulio De FIlippis[1,3,4,] Maura Sassetti[2,5], Giuliano Benenti[6]

[1]Dipartimento di Fisica ``E. Pancini'', Università di Napoli ``Federico II'', Complesso di Monte S. Angelo, via Cinthia, 80126 Napoli, Italy

[2]CNR-SPIN, Sede Genova c/o Università di Genova, Via Dodecaneso 33, 16146 Genova, Italy

[3]CNR-SPIN, UOS Napoli c/o Complesso di Monte S. Angelo, via Cinthia 21, 80126 Napoli, Italy

[4]INFN, Sezione di Napoli, Complesso Universitario di Monte S. Angelo, I-80126 Napoli, Italy

[5]Dipartimento di Fisica, Università di Genova, Via Dodecaneso 33, 16146 Genova, Italy

[6]Center for Nonlinear and Complex Systems, Dipartimento di Scienza e Alta Tecnologia, Università degli Studi dell'Insubria, via Valleggio 11, 22100 Como, Italy

[7]Istituto Nazionale di Fisica Nucleare, Sezione di Milano, via Celoria 16, 20133 Milano, Italy

PHYSICAL REVIEW RESEARCH 3 (2021) 013237

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.

Strain-induced topological phase transition at (111) $SrTiO_3$ -based heterostructure

M. Trama[1,2], V. Cataudella[3,4], C. A. Perroni[3,4]

[1]Physics Department "E.R. Caianiello", Universitá degli studi di Salerno, Via Giovanni Paolo II, 132, I-84084 Fisciano (Sa), Italy
[2]INFN - Sezione di Napoli, Complesso Univ. Monte S. Angelo, I-80126 Napoli, Italy
[3]Physics Department "Ettore Pancini", Universitá degli studi di Napoli "Federico II", Complesso Univ. Monte S. Angelo, I-80126 Napoli, Italy
[4]CNR - SPIN Napoli Unit, Complesso Univ. Monte S. Angelo, Via Cintia, I-80126 Napoli, Italy

PHYSICAL REVIEW RESEARCH 3 (2021) 043038

The quasi-two-dimensional electronic gas at the (111) $SrTiO_3$-based heterostructure interfaces is described by a multiband tight-binding model providing electronic bands in agreement at low energies with photoemission experiments. We analyze both the roles of the spin-orbit coupling and of the trigonal crystal-field effects. We point out the presence of a regime with sizable strain where the band structure exhibits a Dirac cone whose features are consistent with ab initio approaches. The combined effect of spin-orbit coupling and trigonal strain gives rise to nontrivial spin and orbital angular momenta patterns in the Brillouin zone and to quantum spin Hall effect by opening a gap at the Dirac cone. The system can switch from a conducting to a topological insulating state via modification of trigonal strain within a parameter range which is estimated to be experimentally achievable.

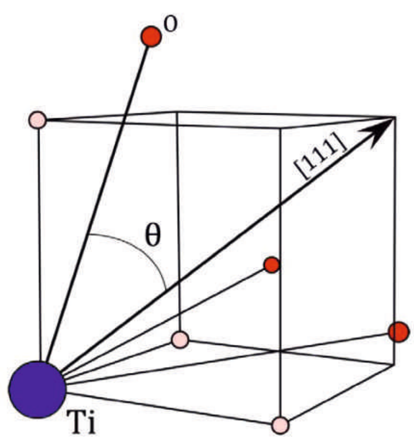


Fig. 1: Cubic structure under a trigonal distortion. The blue sphere is the Ti atom, while the red ones are the O atoms. The pink spheres are the positions of the O atoms in the undistorted structure. The black arrow is the (111) direction. ϑ represents the distortion angle. When $\vartheta_{arcocos}$ (1/√3) the structure is unstrained; smaller (larger) values of ϑ lead to dilatation (contraction) along (111) direction.

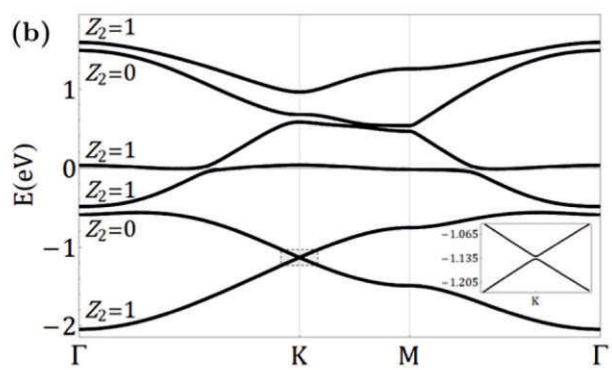


Fig. 2: Electronic band structure of strained (111) $LaAlO_3/SrTIO_3$, exhibiting a Dirac cone at the K point of the Brillouin zone. The inset shows the detail of the Dirac cone. The Z_2 invariant for each band is highlighted: a topological phase is present when the chemical potential is within the band gap at K.

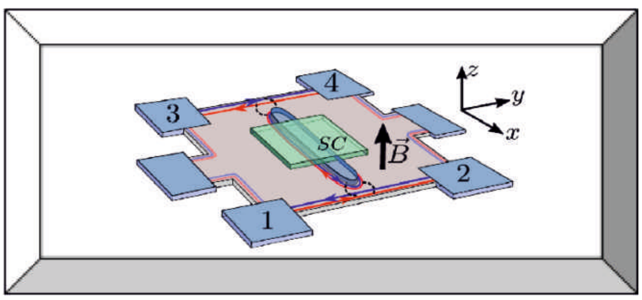
Formation and detection of Majorana modes in quantum spin Hall trenches

C. Fleckenstein[1], N. Traverso Ziani[2,3], A. Calzona[1], M. Sassetti[2,3], B. Trauzettel[1]

[1]Institute of Theoretical Physics and Astrophysics, University of Wurzburg, 97074 Wuerzburg, Germany
[2]Dipartimento di Fisica, Università di Genova, 16146 Genova, Italy
[2]CNR-SPIN, Sede Genova c/o Università di Genova, Via Dodecaneso 33, 16146 Genova, Italy

PHYSICAL REVIEW B 103 (2021) 125303

We propose a novel realization for a topologically superconducting phase hosting Majorana zeromodes on the basis of quantum spin Hall systems. Remarkably, our proposal is completely free of ferromagnets. Instead, we confine helical edge states around a narrow defect line of finite length in a two-dimensional topological insulator. We demonstrate the formation of a new topological regime, hosting protected Majorana modes in the presence of s-wave superconductivity and Zeeman coupling. Interestingly, when the system is weakly tunnel-coupled to helical edge state reservoirs, a particular transport signature is associated with the presence of a non-Abelian Majorana zero-mode.



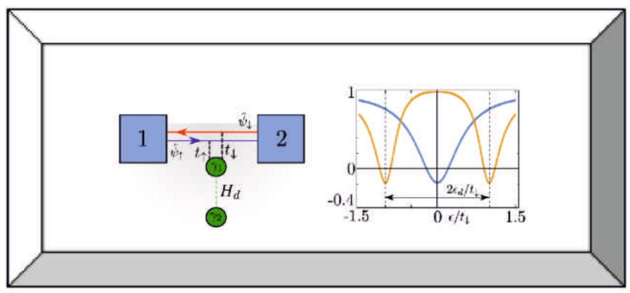
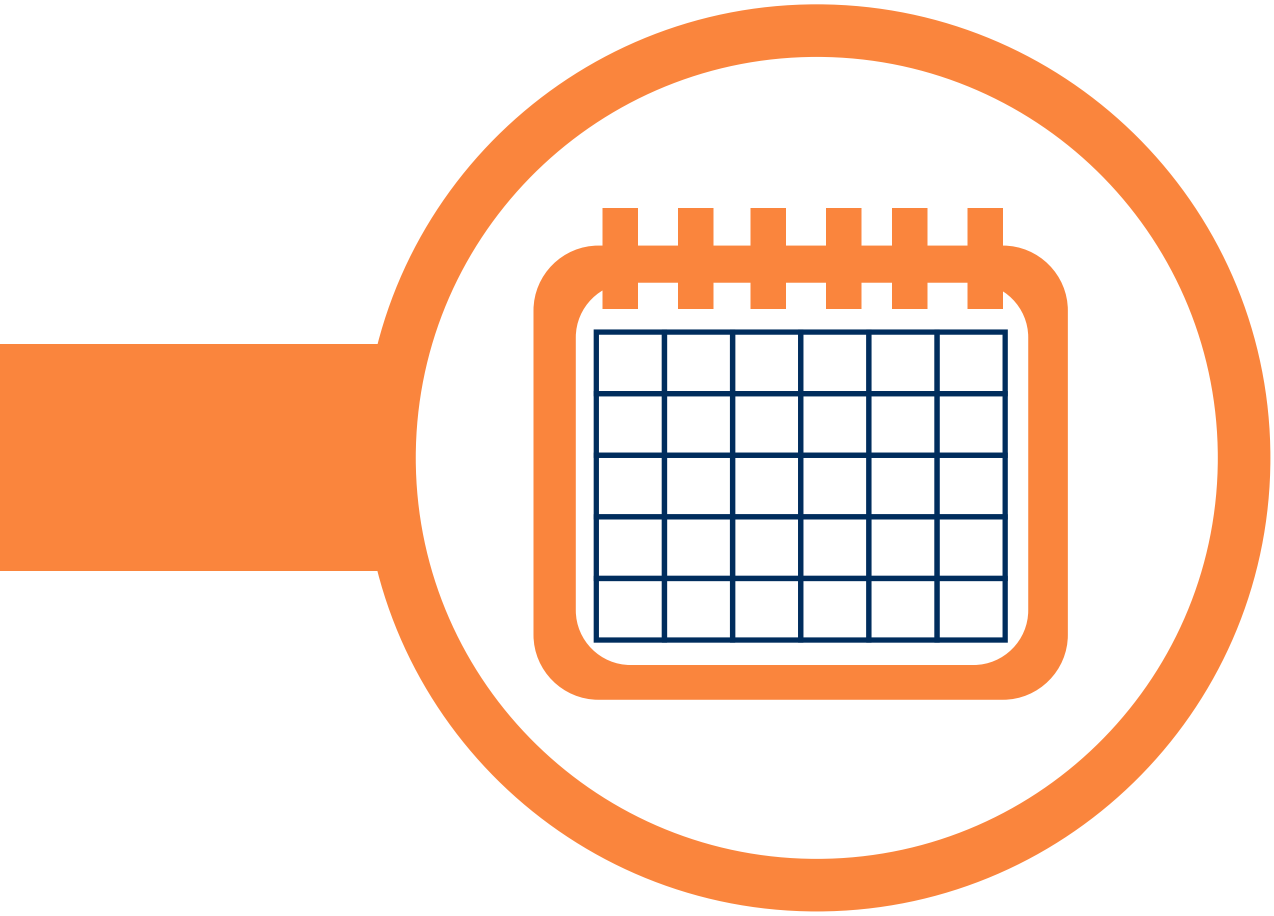


Fig. 1: The setup we analyze. It consists of a long constriction between the helical edges of a two-dimensional topological insulator. The constriction implements a novel type of mass at the helical edge. The system is proximitized with an s-wave superconductor and a magnetic field is applied. The ingredients just mentioned are enough to the implementation of Majorana fermions

Fig. 2: The topological phase extends for a wide range of parameters. Moreover, it is detected almost unambiguously through transport experiments. Such a special property is enabled by the fact that the system is naturally embedded in a two-dimensional structure with helical contacts. Moreover, the structure we envisioned seems easy to scale in terms of number of Majorana fermions.



Life and events

Life and Events

2020

January 2020

SPIN-GE Workshop 2020

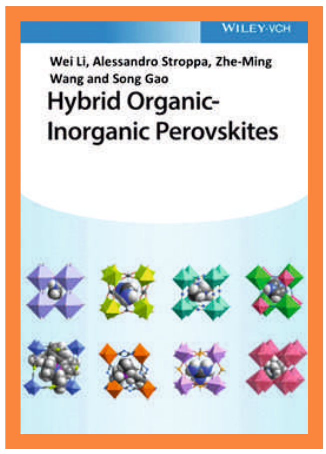
On January, 21st, the SPIN-GE Workshop 2020 was held at the Genoa headquarter, a pleasant occasion in which to present and share the research work of the researchers working on the different topics at SPIN-Genoa laboratories. In particular, the spirit of the day was to share not only the results but also, above all, the issues related to research, thus exploring the possibilities of collaboration and "help" that may exist within the Institute laboratories. In short, an opportunity to renew the team spirit.

February 2020

Reality beyond the mirror: having fun with symmetries

In collaboration with the Department of Human Sciences (DSU) of the University of L'Aquila, Alessandro Stroppa (CNR-SPIN) organized a full-day workshop addressed to primary school teachers and DSU students. Aim of the workshop was to explore the different ways in which a child can experience the concept of symmetry and to introduce them to the deep consequences it may have in science. Besides oral contributions from invited speakers with complementary expertise (from physics to music), including Alessandro Stroppa himself, the workshop proposed also dedicated hands-on sessions to introduce pedagogical tools and activities for the primary school.

A book on hybrid organic-inorganic perovskites



In collaboration with leading experts in the field, Alessandro Stroppa (CNR-SPIN) proposed a book reviewing the synthesis, structures, properties and applications of hybrid organic-inorganic perovskites, a class of materials that have attracted great interest in the past decade due to their chemical variability, structural diversity and abundant physical properties. The book presents a comprehensive and complete landscape of hybrid organic-inorganic perovskites, including halides, formates, azides, dicyanamides, cyanides, hypophosphites, dicyanometallates, perovskite-like hybrid materials and metal-free perovskites. Intriguing physical and multifunctional properties are discussed, including photovoltaic and optoelectronic properties, dielectricity, magnetism, mechanical properties, ferroelectricity, ferroelasticity and multiferroicity. Finally, the current challenges and future opportunities in this exciting field are envisaged.

IBS2App workshop

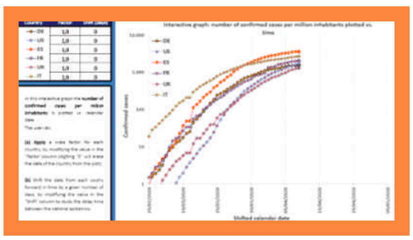
The International Workshop on Iron-based Superconductors, organized by Valeria Braccini (CNR-SPIN Genoa), Laura Gozzelino (Politecnico di Torino) and Enrico Silva (University of RomaTre), was held from 12 to 14 February 2022 in Santa Margherita (GE). The event was supported by IEEE CSC Council of Superconductivity and by the Department of Physics of the University of Genoa, as well as by the Project of Relevant National Interest (PRIN) *"High performance-low cost Iron BaSed Coated condUctorS for high field magnets - HIBISCUS"*. The Workshop saw a wide participation with 72 scientists from 11 countries and 4 continents, 4 keynote speakers, 9 invited speakers and 29 contributed orals which made the discussion very lively and productive. Topics ranged from the properties of the Iron-based superconducting materials to their possible applications, with a special focus on those related to high field magnets in accelerators.

2020

March 2020

"Vecchia Alassio" award

Nicola Manca (CNR-SPIN) has been awarded the 2019 "Vecchia Alassio" award, a prize assigned every year to those people from Liguria town of Alassio who excelled in their respective professional fields. This follows another important award recently conferred to Nicola, the Galileo Galilei prize for young (under 35) researchers. Both awards have been based on the evaluation of the professional and scientific activity of Nicola, in the field of nanodevices with innovative applications in biomedicine, sensing and microrobotics.



April 2020

CNR-SPIN and COVID-19

The COVID-19 pandemic and the exceptional situation everybody had to live in during the 2020-2021 period stimulated the creation of a dedicated website "CNR-SPIN and COVID-19". Aim of the website was to contribute to the analysis of the pandemic evolution providing approaches usually adopted in the study of physical problems for controlled, non-trivial examination of experimental dataset. The website included an international and a national section collecting public data mostly from Western countries and Italy, as well as an interactive modelling section where the user could modify a given set of free parameters in order to explore data correlations or specific questions. The website was developed by Fabio Miletto Granozio with the collaboration of Mario Barra, Emiliano Di Gennaro and Francesco Taurino.

May 2020

CNR-SPIN Salerno delegate meets Mayor of Fisciano

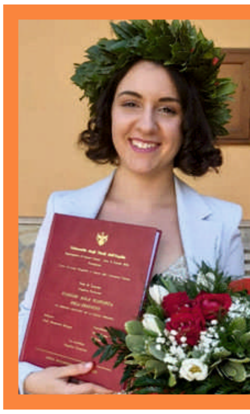
Mario Cuoco, deputy director of CNR-SPIN research unit of Salerno, met the Mayor of Fisciano Dr. Vincenzo Sessa, acknowledging the prompt support that municipality offered in providing personal protective equipment and supporting the research activities in pandemic times.

July 2020

Master in Surface Treatments for Industrial Applications

The University of Padua, with the Legnaro National Laboratories of the National Institute of Nuclear Physics (INFN) and with the significant participation of CNR-SPIN, has organized the 18th edition of the one-year Master in "Surface Treatments for Industrial Applications". The Master consists in theoretical and experimental activities that will provide the specific competences needed for the improvement of the industrial processes related to the film deposition and the surface treatments.

Infinity explained to children



Alessandro Stroppa (CNR-SPIN) and Prof. M. A. D'Arcangeli (Department of General and Social Pedagogy, University of L'Aquila) supervised a Master thesis that explores the possibilities to teach the mathematical concept of infinity to primary school pupils. Master student Angelica Forsinetti devised a didactic yet playful framework for the introduction of such a complex topic to children, including hands-on workshops that build on established primary school curricula and that can be proposed as integrating activities in schools. The matter has attracted interest from local media, in particular the newspaper Il Centro, and it was included in the outreach event "UNIVAQ Street Science 2020".

Workshop on "Fundamentals of magnetoelectricity and how it can boost energy efficiency"

Within the H2020 Marie Curie International Training Network (ITN) entitled *"BeMAGIC - Magnetoelectrics Beyond 2020: A Training Programme on Energy-Efficient Magnetoelectric Nanomaterials for Advanced Information and Healthcare Technologies"* coordinated by Prof. Jordi Sort (Univ. Autonoma de Barcelona) and of which CNR-SPIN is a partner (CNR coordinator: Dr. Silvia Picozzi, CNR-SPIN Chieti), CNR-SPIN has organized the *"1st BeMAGIC Workshop: Fundamentals of magnetoelectricity and how it can boost energy efficiency"*. Given the Coronavirus pandemic, the workshop was held remotely on 9-10 September 2020. The event was addressed to BeMAGIC PhD students as part of their training programme.

August 2020

Genoa bridge is back !

Since the collapse of Morandi Bridge in Genoa on 14 August 2018, with 43 casualties and hundreds of homeless, researchers and employees of the Genoa unit of CNR-SPIN have witnessed the story of the bridge from the Institute windows: from the picture taken soon after the dramatic collapse, to the demolition of damaged pillars, to the inauguration of the new San Giorgio bridge. A due commemoration to the victims of the bridge collapse and a new hope for the future.

September 2020

Undersecretary for the Economic Development visits START 4.0

Gian Paolo Manzella, Undersecretary for Economic Development, visited the Competence Center START 4.0, hosted by CNR-SPIN district of Corso Perrone in Genoa, during his tour of the Liguria Industry and Innovation Ecosystem. START 4.0, comprising 39 companies and research centers in Genoa and led by Executive Director Cristina Battaglia under the support of the Ministry of Economic Development (MISE), is strongly contributing to the digital and technological transition of the innovative enterprises of the Liguria region.

October 2020

"The code of the Universe" exhibition

The exhibition *"The code of the Universe. A photographic journey of discovery"* was held in Genoa as part of a series of events supervised by Emilio Bellingeri (CNR-SPIN) during the International School of Applied Superconductivity, organized by the EASITrain network. The exhibition was conceived and developed by CERN and comprised a series of pictures of research activities and experiments taking place at the international laboratory of Geneva and devoted to the study of high-energy and particle physics. Some of the pictures were focused on the activities developed in Liguria and Genoa, aimed at superconductivity research and applications contributing to the CERN laboratory. The CNR president Massimo Inguscio, the president of "Festival della Scienza" Marco Pallavicini and Guido Tonelli from CERN attended the opening of the exhibition.

EASISchool 3

With the collaboration of Prof. Marina Putti of the University of Genoa, CNR-SPIN organized a two-week postdoctoral school (EASISchool 3) in Genoa from September 28 to October 9. The school, with the support of EASITrain MSCA Project Framework coordinated by CNR-SPIN staff senior researcher Emilio Bellingeri, consisted in a series of long academic seminars on applied superconductivity, with focus on superconducting devices sensing and quantum computation, RF superconductivity and accelerating cavities and design modelling and manufacturing of superconducting magnets. Speakers were chosen among leading experts in the sector belonging to the most important European research infrastructures (CERN, IBM, INFN, ENEA). A two-day Workshop addressed to students took place at the end of the School.

Super! Exhibition at Genoa Science Festival

CNR-SPIN participated to the 2020 edition of the Genoa Science Festival. The series of events dedicated to superconductivity and supervised by Emilio Bellingeri (CNR-SPIN), despite the difficulties related to the COVID-19 pandemic, was concluded by the interactive exhibition Super! The exhibition proposed a number of activities to show the most important and fascinating applications of superconductivity, from superconducting cables to magnetic confinement of plasma and accelerated particles, from trains and flywheel exploiting the magnetic levitation principle, to biomedical applications as neuroimaging magneto-encephalography.

"Wine and Science" at Genoa Science Festival

On October the 31st, CNR-SPIN and Fiammetta Malagoli, member of the organization "Donne del Vino della Liguria", proposed the event "Wine and Science" within the 2020 edition of the Genoa Science Festival. The event consisted in a conversation between Pia Donata Berlucchi (president of the Fratelli Berlucchi winery) and Andrei Varlamov (CNR-SPIN research director). During the event, the history of wine as well as of the development of the scientific analysis, from ancient to modern times, was presented. Several aspects related to chemical and physical properties of different wines and of the winemaking processes were also covered.

November 2020

Naples Science Festival "FUTURO REMOTO 2020"

SPIN contributed to the XXXIV edition (from November 20 to November 29) of Futuro Remoto (Naples Science Festival) with the online tutorial exhibit "Rivelazioni". The online activity, addressed to high secondary school students, served as an introduction to superconducting nano-devices for the detection of single photons, which are essential for innovative applications in the field of quantum technologies. The initiative was part of the outreach activities coordinated by the CREO network, involving all CNR Institutes in Campania, and was realized by Mario Barra, Fabio Chiarella and Mikkel Ejrnaes.

Researchers' Night 2020

CNR-SPIN participated to the Researchers' Night 2020 in Genoa, proposing a webinar for the secondary school students supported by Regione Ligura through the project "Progettiamoci il futuro". The webinar was contributed by Emilio Bellingeri (CNR-SPIN) and Gabriele Bruzzone (CNR-INM, Institute of Marine Engineering). Emilio introduced the students to the past and present history of superconductivity and to its potential applications through a multimedia visit to "Super!" exhibition initially presented at Genoa Science Festival.

Dicember 2020

CNR-SPIN research activity for CERN goes on

The construction of the Future Circular Collider will require an extraordinary economic and technological effort of CERN. CNR-SPIN continues its activities in supporting the technological development of high-temperature superconducting screens for accelerated particles, focusing on a little studied Ta-based superconductor. Films and coatings of this high-temperature superconductor will be synthesized in SPIN labs using electrodeposition and pulsed-laser deposition techniques. The project, that started in 2016, has been renewed for additional three years (2021-2023). Beside CNR-SPIN, that sees Alessandro Leveratto as the local coordinator, it involves University of Roma3 and the *Technische Universität Wien*.

Life and Events

2021

January 2021

An Industrial PHD position for a joint collaboration between CNR-SPIN, PoliMi e STMicroelectronics

In the framework of the agreement between CNR and CONFINDUSTRIA (the main association representing manufacturing and service companies in Italy), the 2020 call for the activation of Industrial PHD courses was finalized with the funding of 38 positions. Among the six positions attributed to the Department of Physics and Technology of Matter of CNR, one was assigned to the joint collaboration involving SPIN, STMicroelectronics and Politecnico di Milano (PoliMi). Under the supervision of Silva Picozzi (CNR-SPIN), this position has been focused on the combination of advanced computational techniques for the design of new multifunctional materials of interest for industrial applications.

SPIN researchers included in the list of the World Top-cited scientists for 2019-2020

The journal PlosBiology published a systematic study about the most cited scientists on the basis of the Scopus data, provided by Elsevier, for the 2019-2020 period. The list of the top 2% most widely cited scientists, in particular, was realized by researchers from Stanford University and other academic institutions in the United States. The list included four SPIN researchers, Silvia Picozzi, Alessandro Stroppa, Filippo Giubileo e Sergio De Nicola, and also the names of Antonio Di Bartolomeo (University of Salerno) and Giacomo Ghiringhelli (Politecnico di Milano), being research associates to the SPIN activities.

February 2021

Webinar "Casa delle Tecnologie Emergenti di Matera"

A webinar was held on 26 February 2021 to introduce the activities of the Laboratory, supported by CNR-SPIN and CNR-INO, dedicated to *Quantum Key Distribution (QKD) & Blockchain* within the framework of "The House of Emerging Technologies of Matera" (Casa delle Tecnologie Emergenti di Matera - CTEMT). CTEMT is a technology transfer center, funded by MISE (Italian Ministry of Economic Development) and dedicated to support research projects involving small and medium-sized enterprises (SMEs) and start-up companies on topics like blockchain, IoT, artificial intelligence and new 5G telecommunication systems.

March 2021

Silvia Picozzi appointed acting Director of SPIN

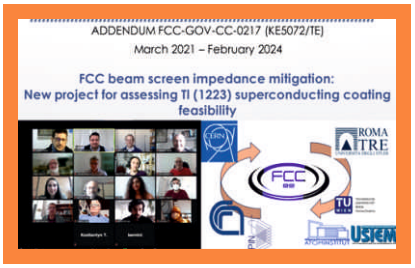
Since April 1^{st} to June 30^{rd} 2021, Silvia Picozzi covered the role of acting Director (Direttore facente funzione) of SPIN until the completion of the CNR official selection for the new Director.

April 2019

Future Circular Collider beam screen impedance mitigation: KICK-OFF MEETING

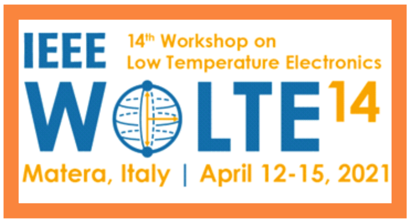
On 23 April, the kick-off meeting of the project renewal for other 3 years for assessing Tl (1223) superconducting coating feasibility took place virtually on the CERN platform Indico. The project foresees the collaboration, besides CERN, with the world's leading experts in radiofrequency measurements in magnetic field and in structural and transport characterization, respectively, at the University of Rome3 and the Technische, Universität Wien (Austria).

In the framework of the project, samples of this high critical temperature superconductor (Tc = 120 K) will be produced at the CNR-SPIN laboratories in Genoa, under the guidance of Alessandro Leveratto. SPIN researchers will try to optimize the material in order to achieve the challenging performances required by FCC.



WOLTE14 2021

The 14th edition of the Workshop on Low Temperature Electronics (WOLTE-14) was held in Matera, a unique historical town on the patronage of UNESCO world heritage. Due to the restrictions related to the COVID19 pandemic, the WOLTE-14 edition was organized in a "hybrid" configuration: a scientific program on a virtual platform was accompanied by the presentations and events held in Matera. The 2021 edition opened to emerging topics including low temperature devices for quantum communication, computation and spintronics, space electronics and sensing, cubesat based communication, optoelectronics, hybridization of semi-, super-conductor, magnetic and photonic devices (both detectors and sources) working at low temperatures. The WOLTE-14 was organized by the University of Napoli Federico II (Giampiero Pepe), CNR-SPIN (Mikkel Ejrnaes) and ASI (Mario Siciliani de Cumis), with the support of the IEEE CSC Italian Chapter (Enrico Silva).



May 2021

Fabio Miletto Granozio selected as new Director of SPIN

During the CNR Management Committee Meeting on May 27th, 2021, the interviews for the choice of the Institute Director were held and Fabio Miletto Granozio was selected as a new Director of SPIN. Fabio began his mandate on July 1st.

June 2021

MaX School on Advanced Materials and Molecular Modelling with Quantum ESPRESSO

The first-principles school on electronic-structure calculations and materials modeling based on Quantum ESPRESSO (QE) software was held (entirely online) from 17 to 28 May. The school was aimed to introduce students and young researchers to materials and molecular modelling with Quantum ESPRESSO, covering basic concepts and recent advances, with emphasis on density-functional-theory (DFT) based methods and High-Performance Computing

(HPC). Starting from a record-breaking number of applicants (1292), for technical reasons only about 120 participants were selected to attend the online school, with special attention to gender and nationality balance. However, applicants being not selected as participants could attend the school in streaming through youtube channel.
The school was organized by Stefano Baroni (SISSA), Ralph Gebauer (ICTP), Anton Kokalj (Jožef Stefan Institute), Wei Ren (Shanghai University), Alessandro Stroppa (CNR-SPIN), with a strong support by the local organizers Ivan Girotto (ICTP) and Ivan Carnimeo (SISSA).

July 2021

Energy transition and circular economy

Alessandro Stroppa (CNR-SPIN) attended the "Summer School" organized by the high school Institute "Algeri Marino" and dedicated to the subject of the "circular economy". The intervention of Alessandro took place during the first day (July 20) and started with a general introduction about the institutional mission of CNR. The attention was then focused on the scientific activities of SPIN and, in particular, on those related to the energy conversion systems. Thus, an accurate description of the general physics underlying the operation of photovoltaic devices, with special attention to the use of innovative materials such as the hybrid perovskites, was the main part of the presentation for the young participants of the summer school.

Master in "Surface treatments for industrial applications"

Following the success of the previous edition, the University of Padua has organized a new edition of the one-year Master in "Surface Treatments for Industrial Applications", with the Legnaro National Laboratories of the National Institute of Nuclear Physics (INFN) and with the significant participation of CNR-SPIN. The Master is aimed at providing the specific competences needed for the improvement of the industrial processes related to the film deposition and the surface treatments.

International Workshop DSTDM

The workshop "DSTDM - Device science of 2D organic and inorganic materials: from fundamentals to applications" was held online on July 5, 2021.
It was organized as a joint initiative of the Research Institute for Interdisciplinary Science of Okayama University, Japan (chairman Prof. Yoshihiro Kubozono) and of the Physics Department of the University of Naples, Italy (chairman Prof. Antonio Cassinese). The DSTDM workshop was aimed at providing a highly-specialized forum to discuss about a wide variety of scientific topics focused on two-dimensional layered organic and inorganic compounds and on their application for innovative device development.

September 2021

European Researchers' Night 2021

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.

An educational video for primary school students

Under the supervision of Alessandro Stroppa (CNR-SPIN), Giulia Dionisi, an under-graduated student of the Department of Human Sciences (DSU) of the University of L'Aquila, realized the video “From Geometry to Geo-matter” to describe, with the help of real images and cartoon aminations, the role of the geometrical shapes in the microscopic world and, in particular, in the structure of several innovative electronic materials. The video was part of the master's thesis of Giulia and was one of the elements of an entire educational planning conceived for primary school students within the DSU activities. The video was published also on the CNR outreach website.

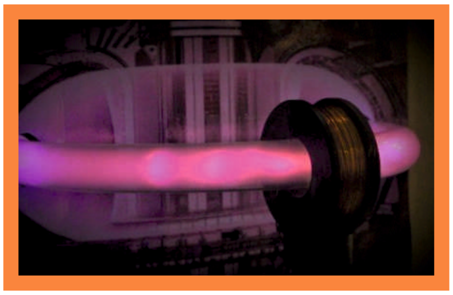
October 2021

51^{st} edition of the Journees des Actinides (JdA51)

The 51^{st} edition of the Journées des Actinides, held in Santa Margherita Ligure (GE) in April 10-14 2022, was announced. The conference was organized by the University of Genova (chairman: Prof. Mauro Giovannini), INFN and CNR-SPIN (A. Martinelli).
The Journées des Actinides is an international conference series providing an informal and interdisciplinary forum for the discussion of current advances on the physical and chemical properties of actinide elements, their alloys and compounds, from fundamental to applied research.

Main topics of the 2022 meeting included strongly correlated systems, superconductivity, quantum criticality, inorganic and organometallic chemistry, materials and nanomaterials, theory and band structure, actinide production and handling, safety of the nuclear fuel cycle, nuclear safeguards and security, radiation protection, environment contamination, remediation, and decommissioning.

Super! Exhibitions returns to the Genoa Science festival



SPIN took part to the 2021 edition of the Genoa Science Festival with the virtual edition of the “Super!”, an exhibition on the present and future applications of superconductivity.
“Super!” was included as a Digitour for schools with guided tours (curated by Emilio Bellingeri), every Friday from 29 October to 12 November 2021, and as a virtual exhibition with free access for the general public. The exhibition in its virtual edition was really successful with more than 1500 participants.

Life and Events

2021

27th edition of International Workshop on Oxide Electronics (iWOE)

The International Workshop on Oxide Electronics (iWOE), organized by CNR-SPIN and University of Genova (chairman: Prof. Daniele Marré), was held in Genoa, in the wonderful setting of the historical Palazzo Ducale, from 13 to 15 October 2021.

The aim of the workshop, which was held in hybrid form with the possibility of attending also remotely because of the limitations related to the COVID-19 pandemic, was to provide an interdisciplinary forum for researchers - theorists as well as experimentalists - on understanding the fundamental electronic and structural properties and also on the design, synthesis, processing, characterization, and applications of (epitaxial) functional oxide materials.

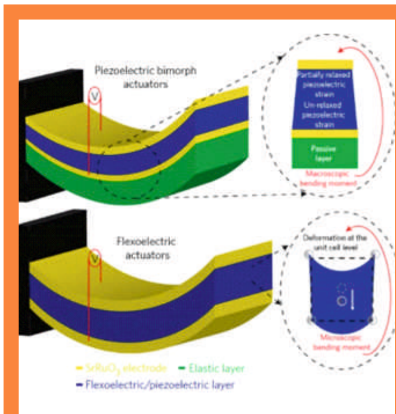
November 2021

Workshop Oxide Superspin 2021 (OSS2021)

Within the Core-to-core "Oxide Superspin (OSS)" Project, CNR-SPIN (M. Cuoco, R. Fittipaldi, P. Gentile and A. Vecchione) supported the organization of the Workshop "Oxide Superspin 2021 (OSS2021)" which was held in Kyoto from December 13rd to 17th 2021.

The aim of the workshop was to introduce and discuss the research progress on novel superconductivity at oxide superconductor interfaces with magnetic materials and in nanodevices, as well as in related subjects. Main topics included: superconducting spintronics and magnetism, novel phases at oxide interfaces, unconventional superconductivity, non-equilibrium phenomena in oxides, topological superconductivity, frontiers in quantum materials.

"Towards Oxide Electronics: a Roadmap" as highly cited paper



According to Web of Science, the manuscript "Towards Oxide Electronics: a Roadmap" by M. Coll et al., published in Applied Surface Science (Vol. 482, July 2019), was included in a list of top-cited papers.

Fabio Miletto Granozio, Director of SPIN since July 2021, was leading and corresponding author for this review dealing with the search of 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, the oxide films and heterostructures are key players to contribute to this timely challenge.

The roadmap was the final outcome of a wide four-year project, named Towards Oxide-Based Electronics (TO-BE), that was coordinated by SPIN in the person of Fabio Miletto Granozio and has seen the involvement of several hundred scientists from 29 EU countries as participants.

Intellectual Property Award 2021: Spin involved in one of the eight selected CNR technologies

The international patent application WO2021209891 “Magnetic Field Sensor” from CNR passed the first selection of the “Intellectual Property Award 2021”, a competition promoted by the General Directorate for the protection of Industrial Property - Italian Patent and Trademark Office - of the Ministry of Economic Development in collaboration with Netval.

The patent deals with a new MEMS magnetometer that can be manufactured with standard industrial processes, has high resolution, small size and low power consumption, designed for consumer electronics and applications in many sectors, such as automotive/drones. The patent was part of the project OXINEMS being funded by the European Union's Horizon 2020 program.

The inventors, F. Maspero, R. Bertacco, S. Cuccurullo, L. Pellegrino, D. Marré, N. Manca, are employees or associated members of CNR-SPIN and CNR-INF working at PoliFAB, the micro and nanotechnology facility of Politecnico di Milano.

Naples Science Festival “Futuro Remoto” 2021

SPIN attended the 2021 edition (from November 23 to December 3) of Futuro Remoto (Naples Science Festival) with two online activities for high secondary school students. The former was entitled *“Superconductivity: a transition toward the future”* and was realized by Gaia Grimaldi and Salvatore Abate (CNR-SPIN), Antonio Leo, Angela Nigro and Masood Rauf Khan from Dep. of Physics University of Salerno.

The second activity *“The ferroelectric transition: will the future be ferroelectric?”* was proposed by Alessia Sambri (CNR-SPIN) and Andrea Rubano (Dep. Physics, University of Naples), being part of the outreach activities planned within the PRIN project TWEET.

December 2021

Italy-China science, technology and innovation week

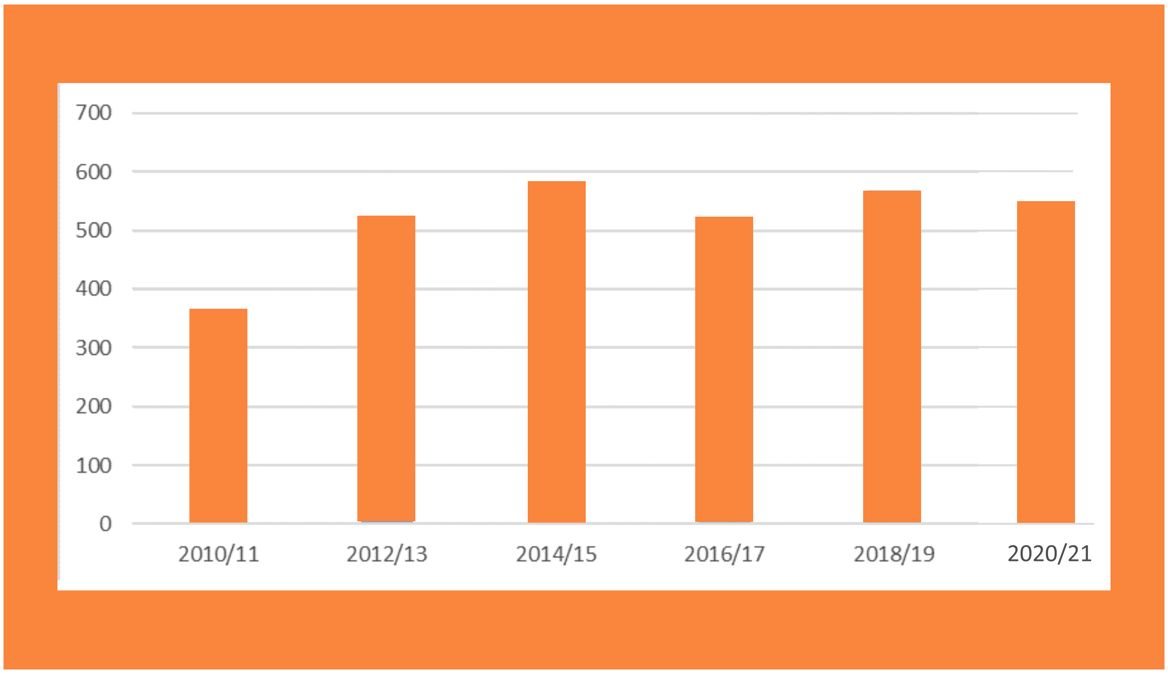
The 11th edition of the “Italy-China science, technology and innovation week” was held online from 1 to 3 December 2021. This initiative was part of a bilateral program of scientific cooperation, promoted by the Italian Ministry of University and Research and by the Chinese Ministry of Science and Technology, and was coordinated in Italy by Città della Scienza with the collaboration of CNR.

The “week” was characterized by a rich program of meetings and round tables held by Italian and Chinese experts and dealing with topics of shared interest such as high energy physics, advanced materials for a sustainable society and energy transition process. Alessandro Stroppa (CNR-SPIN) was one of the participants at the event also in light of his long-term scientific collaborations with various Chinese Universities (Fudan, Shanghai, Nankai, South-East University).

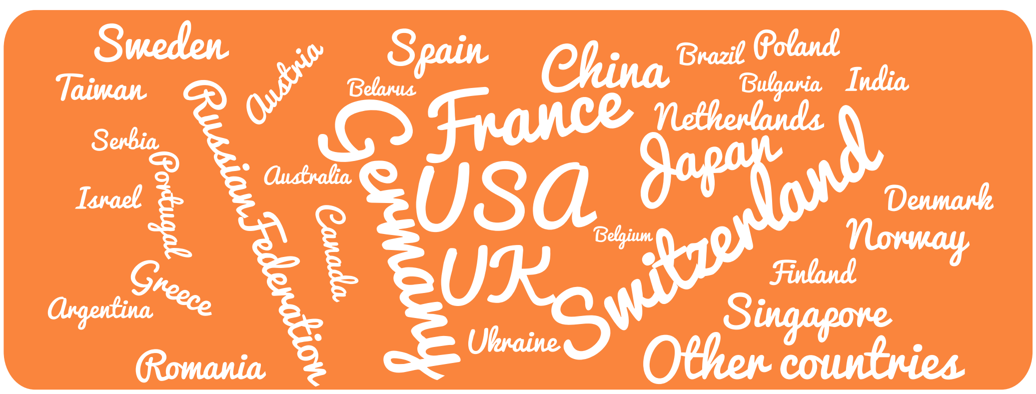
Publications

SPIN published **552 articles** in the two-years period.
The complete list can be found at **https://www.spin.cnr.it/research/publications**

Pubblication per biennium



International collaborations



Publications

Best young researcher SPIN article Award

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

2020

Spontaneous skyrmionic lattice from anisotropic symmetric exchange in a Ni-halide monolayer

Coauthors: P. Barone, S. Picozzi

Nature Communications 11 (2020), 5784

Motivation

The paper reports the prediction of the existence of a spontaneous network of anti-biskyrmions in a two-dimensional centrosymmetric magnet. The topic is at the cutting edge of the research field on the magnetic properties of low-dimensional systems, as highlighted by the high impact factor of the journal on which the paper was published. The role of the candidate is recognizable and relevant, both for the technical contribution (simulations) and for the interpretation of the results, and their placement in the reference scientific landscape.

2021

Anyons in Quantum Hall Interferometry

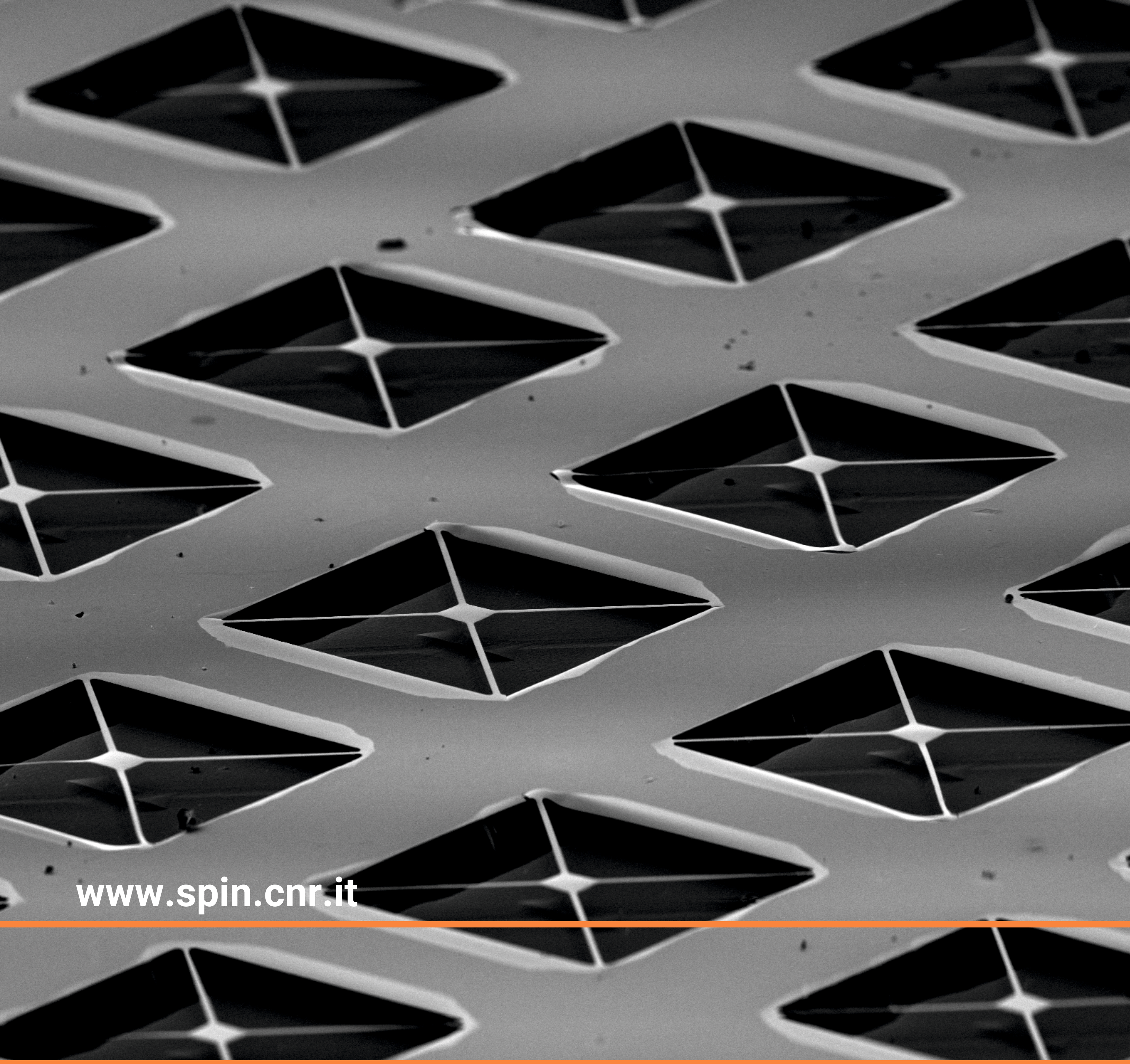
Cohautors: L. Chirolli, S. Heun, L. Sorba

Nature Review Physics 3 (2021), 698

Motivation

In this paper, Carrega el al. review the recent theoretical and technological advances in Quantum Hall interferometry. Beside representing the first example of topological quantum matter, the quantum Hall effect in the fractional regime involves excitations with fractional statistics whose detection and manipulation represent key milestones in view of topologically protected quantum computation schemes. The review paper, the first comprehensive one in this cutting-edge research field, clearly highlights the important contributions of the candidate and his expertise and mastery of the topic

Last modified: February 16. 2023



www.spin.cnr.it

Consiglio Nazionale
delle Ricerche

SPIN