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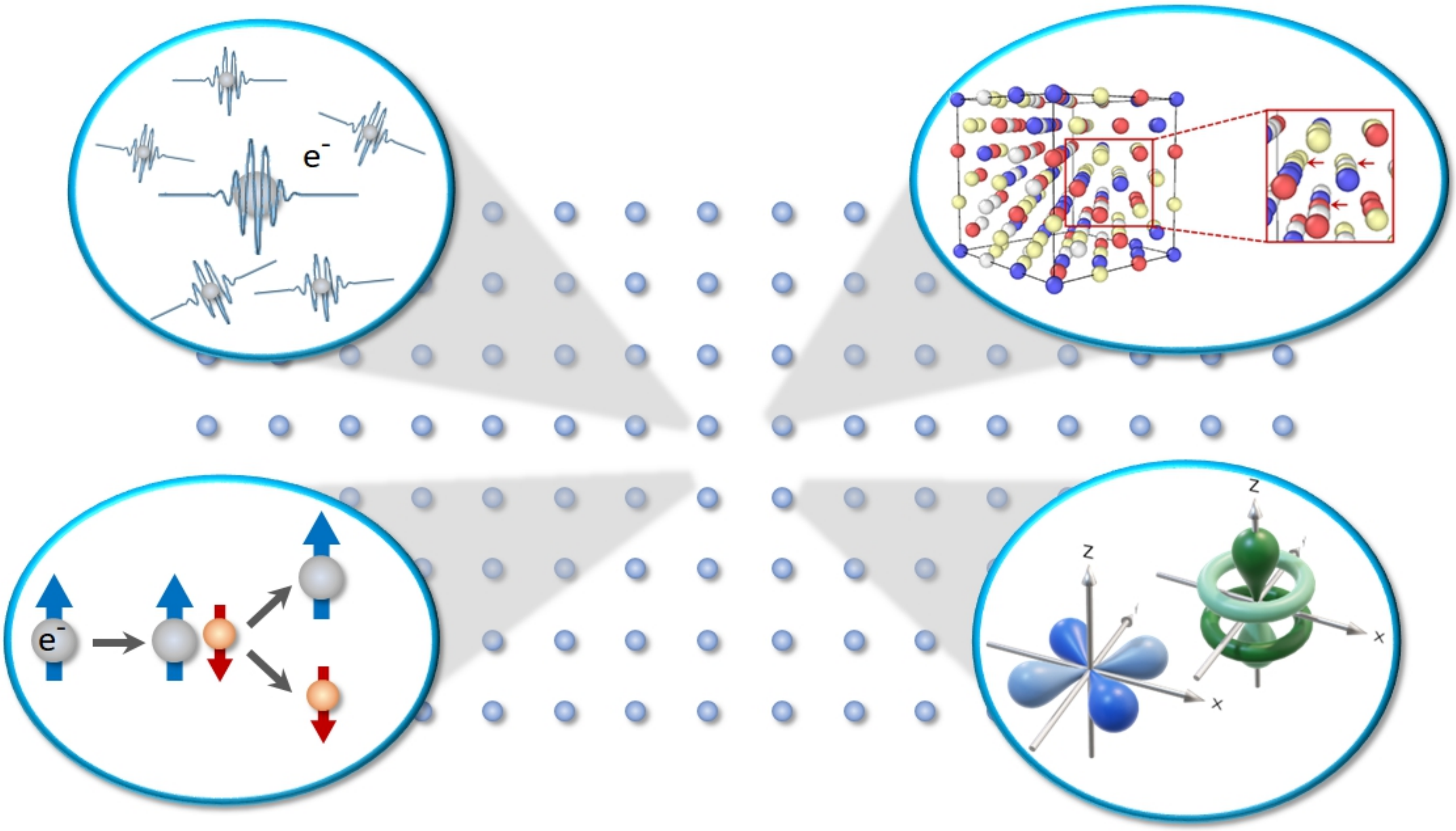

Superconductors, oxides
and other innovative materials and devices

Scientific Report 2022-2023

Consiglio Nazionale
delle **Ricerche**

SPIN

Editorial Project by
CNR - SPIN

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Emilio Bellingeri, Fabio Chiarella, Paola Gentile, Adriana Santroni

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

Graphical and editorial design
Daniela Gaggero, CNR - Public Relations and integrated Communication Unit

Cover Image
Schematic representation of electronic correlations in quantum materials – Frontmatter image of the Workshop "Electronic Correlations, Emergent Phenomena, and Quantum Materials" -Lectiones Amalfitanae- (Amalfi, 10-13 April 2022), by Mario Cuoco

Thanks to
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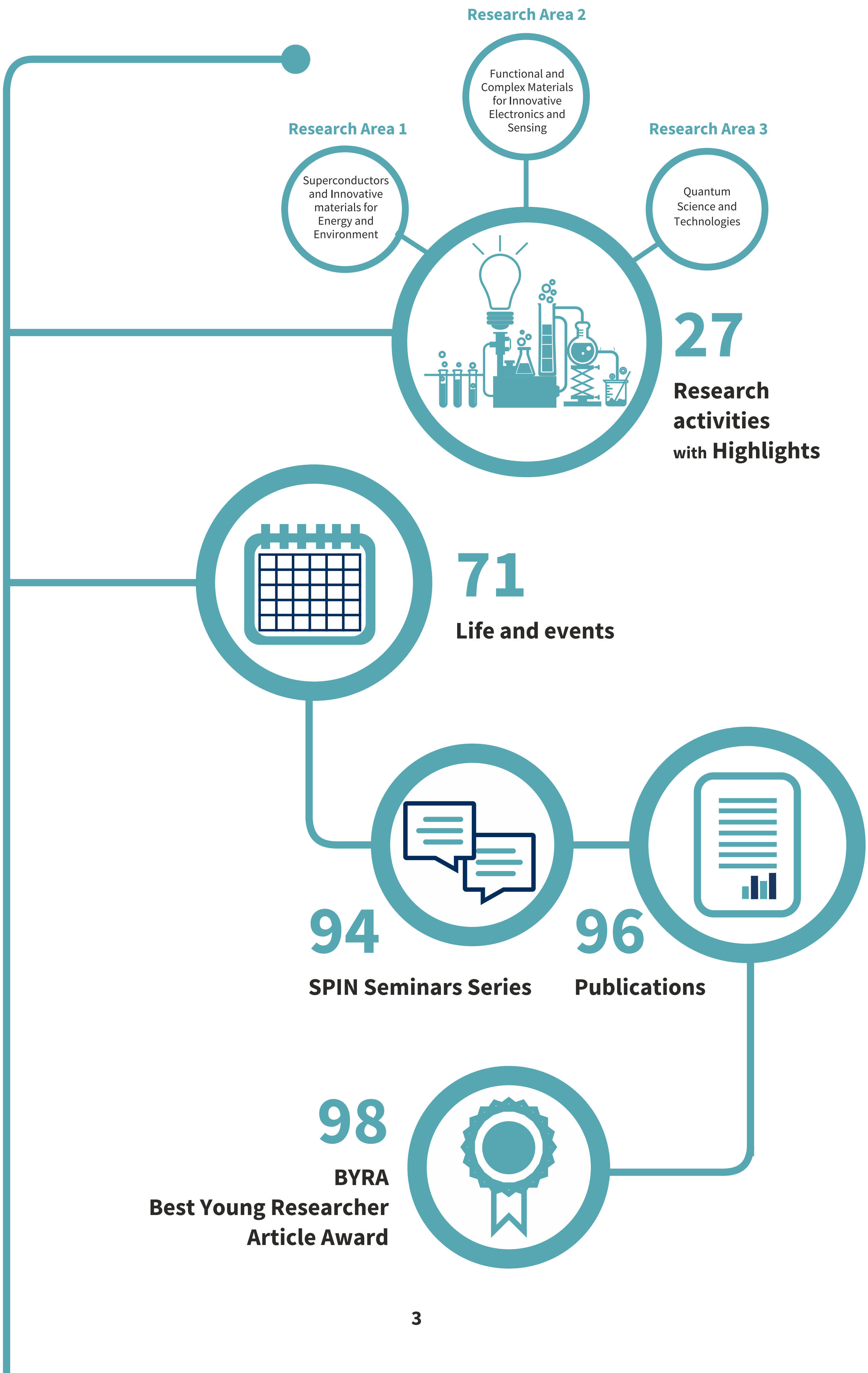
SPIN

Scientific Report 2022-2023

Summary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Foreword

Foreword

It is with great pride and satisfaction that I present the 2022–2023 Scientific Report of the CNR-SPIN Institute. These pages reflect not only the scientific achievements of the past years but also the overall commitment and collaborative spirit of our community across the research units in Genoa, L'Aquila, Naples, Rome, Salerno, Pozzuoli and Chieti.

In a rapidly evolving scientific landscape, our institute continues to position itself at the forefront of research in superconductors, quantum materials, energy materials, innovative electronics, and quantum technologies. At the level of research organization, the two-year period covered by this report has been marked by the successful consolidation of our three newly defined research areas: Superconductors and Innovative Materials for Energy and Environment; Functional and Complex Materials for Innovative Electronics and Sensing; and Quantum Science and Technologies. These pillars now guide our vision, and structure the ambitious research goals we pursue.

Our research efforts have been bolstered by numerous national and international projects, including significant involvement in the PNRR initiatives and Horizon Europe programs. In particular, within the PNRR initiatives, including Research Infrastructures, Extended Partnerships, National Centers and Innovation Ecosystems and Projects of Relevant National Interest (PRIN), SPIN has been awarded financial resources exceeding 12 million euros. PNRR represents a pivotal platform for strengthening our role in the national landscape, aligning our research with the country's technological and industrial priorities, provide a huge boost to the capabilities of our laboratory infrastructure and allow the acquisition of new selected human resources. The actual success of this potentially groundbreaking operation, that is terminating in the successive biennium, will need to be evaluated on a longer timescale.

Besides showcasing our cutting-edge research results through our publication highlights and reporting on our effort in strengthening the Institute through competitive grants and resulting investments, the report highlights the vibrant participation of SPIN researchers in scientific dissemination, public engagement, and educational activities, particularly our initiatives for schools and the broader public, which contribute to fostering a scientifically literate society.

As director, I extend my deepest gratitude to all our researchers, technical staff, and administrative personnel, whose dedication and passion are the foundation of SPIN's success. A special mention is definitively due to the workgroup of editors that worked hard for many months to produce this beautiful and accurate report (Emilio Bellingeri, Fabio Chiarella, Daniela Gaggero, Paola Gentile, Adriana Santroni) and to all the other colleagues that provided the needed documents and information.

Fabio Miletto Granozio
Director, CNR-SPIN Institute

Management

Management

2022-2023

Fabio Miletto Granozio

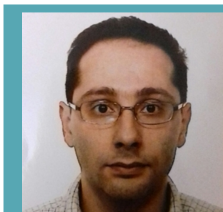
The Director and the Executive Board are the management bodies of the Institute.

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 the management plan and the annual report.

Paolo Barone

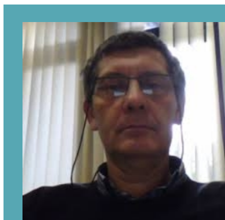
Roberto Felici



Andrea Gerbi

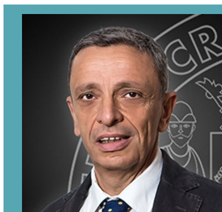
Gaia Grimaldi

Alberto Porzio



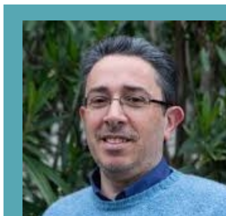
Ettore Sarnelli

Alberto Martinelli

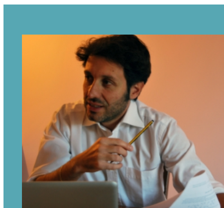


Carmine Attanasio

Vittorio Cataudella

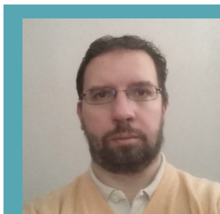


Daniele Marré

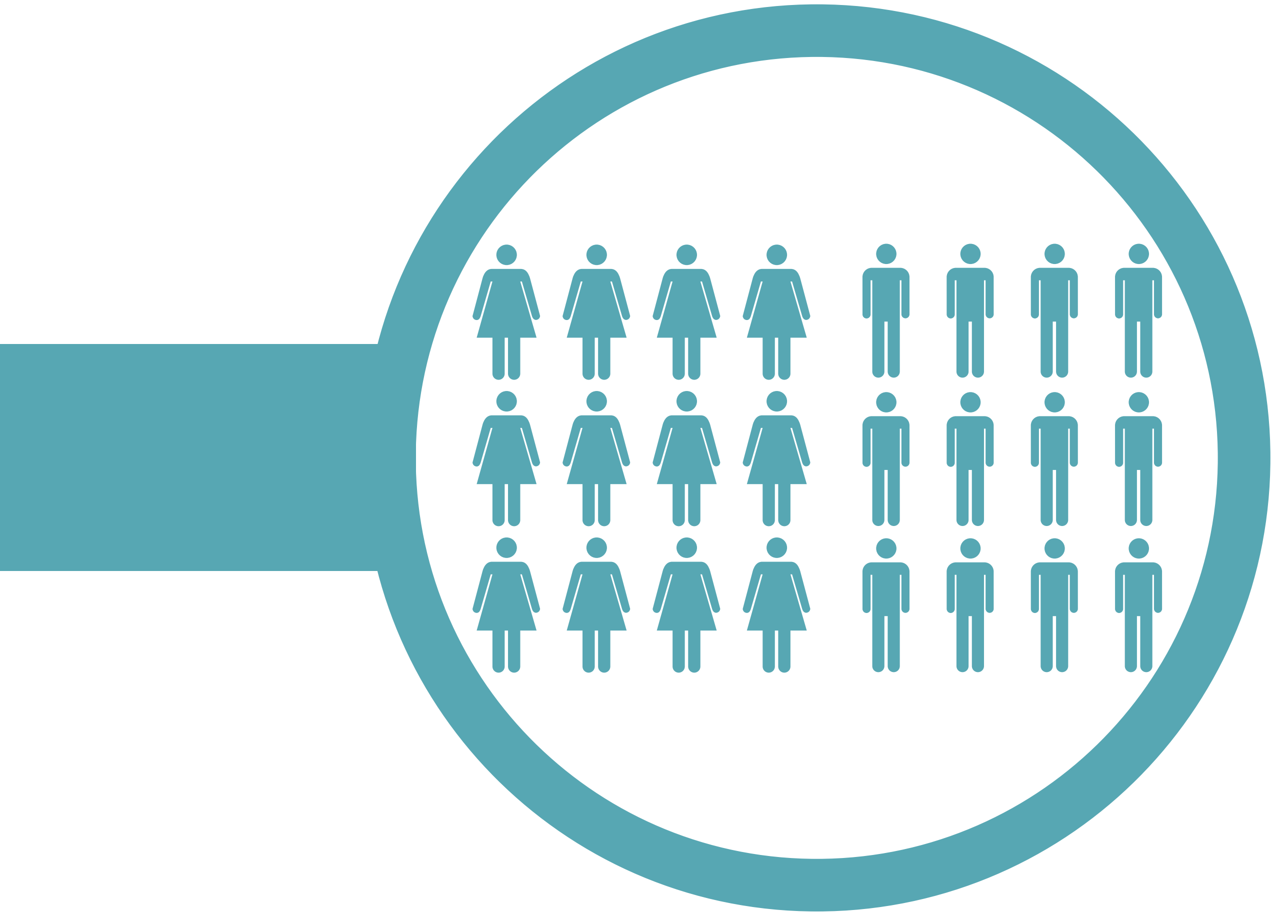


Gianni Profeta

Salvatore Abate



Marco Raimondo



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Locations

Locations

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Deputy director Mario Cuoco

Projects and grants

Projects and grants

Running projects 2022/2023

Type	Coordinator	Title	SPIN leader	Start date	End date	Fund (K€)
ERANET COFUND QUANTERA	CNR SPIN	QUANtum Technologies with 2D-OXides	Marco Salluzzo	23/02/2018	23/02/2022	228.9
ERANET COFUND QUANTERA	CNR-INO	ShoQC – Short-range optical Quantum Connections	Alberto Porzio	01/12/2019	30/11/2023	31.5
PRIN 2017	CNR- ICCOM	Novel Multilayered and Micro-Machined Electrode Nano-Architectures for Electrocatalytic Applications (Fuel Cells and Electrolyzers) Codice PRIN 2017YH9MRK	Roberto Felici	05/06/2019	05/06/2023	20.0
PRIN 2017	CNR SPIN	TWEET: ToWards fErroElectricity in Two-dimensions Codice PRIN 2017YCTB59	Silvia Picozzi	19/08/2019	19/08/2023	320.5
PRIN 2017	Università di Roma La Sapienza	Tuning and understanding Quantum phases in 2D materials - Quantum2D Codice PRIN 2017Z8TS5B	Paolo Barone	19/08/2019	19/08/2023	130.0
PRIN 2017	Università di Genova	"HIBiSCUS - High performance-low cost Iron BaSed Coated condUctorS for high field magnets" Codice PRIN 201785KWLW	Valeria Braccini	19/08/2019	19/08/2023	274.0
PRIN 2017	CNR - SPIN	TOPSPIN: Two-dimensional oxides Platform for SPIN-orbitronics nanotechnology" Codice PRIN 20177SL7HC	Marco Salluzzo	19/08/2019	19/08/2023	268.8
PRIN 2017	Università degli studi di Genova	Understanding and Tuning FRiction through nanOstructure Manipulation (UTFROM) Codice PRIN 20178PZCB5	Renato Buzio	19/08/2019	18/08/2023	101.9
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	29/08/2019	28/08/2023	80.4
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	01/01/2020	31/12/2023	424.3

Projects and grants

Running projects 2022/2023

Type	Coordinator	Title	SPIN leader	Start date	End date	Fund (K€)
EU - H-2020	CNR SPIN	OXIDE NANOELECTROMECHANICAL SYSTEMS FOR ULTRASENSITIVE AND ROBUST SENSING OF BIOMAGNETIC FIELDS - OXiNEMS	Luca Pellegrino	01/05/2019	31/01/2024	742.2
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	01/09/2019	28/02/2024	261.5
PON 2014-2020	CNR - DIITET	ARS01_00405 "OT4CLIMA - Tecnologie OT innovative per lo studio degli impatti del Cambiamento climatico sull'ambiente	Giampiero Pepe	01/09/2018	20/02/2022	45.5
PON 2014-2020	CNR - DSFTM	PON Fotovoltaico BEST4U ARS01_00509	Fabio Miletto Granozio	01/01/2020	31/12/2023	50.0
PON 2014-2020	CNR -DSFTM	PON Quancom ARS01_00734	Coordinatore e referente Napoli: Giampiero Pepe referente Salerno: Carla Cirillo	01/03/2021	31/08/2024	352.6
PON IR	INFN	II.B.S.Co. – PIR01_00011	Giovanni Cantele	01/06/2019	28/02/2022	517.4
ENI research agreement	ENI -CNR	Sottoprogetto 4 - Sviluppo di superconduttività materiali e processi produttivi in particolare per alta Tc	Valeria Braccini	24/03/2019	in corso	110.0
EU - H-2020	UNIVERSITAT KONSTANZ	Gate Tuneable Superconducting Quantum Electronics - SUPERGATES	Mario Cuoco	01/03/2021	28/02/2025	268.7
EU - H-2020 Agreement 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	01/05/2021	30/04/2027	156.0
PRIN 2020	CNR - ISM	attoseCOnd electron dyNamics in QuantUm confinEd SysTems probed by high-order" (CONQUEST) 2020JZ5N9M	Rosalba Fittipaldi	22/03/2022	21/03/2025	123.6

Projects and grants

Running projects 2022/2023

Type	Coordinator	Title	SPIN leader	Start date	End date	Fund (K€)
PRIN 2020	CNR - ISC	Quantum Transition-metal FLUOrides - (QT-FLUO) 20207ZXT4Z”	Marco Saluzzo Paolo Barone	22/03/2022	21/03/2025	124.9
NATO	Università di Roma Torvergata	“ULTRALIGHT WEARABLE SOLAR CELLS AS A PORTABLE ELECTRICITY SOURCE (ESCAPE)” SPS G5936	Filippo Giubileo	02/05/2022	01/05/2025	30.5
UE Horizon 2020 - Eranet Quantera 2021	CNR - SPIN	Superconducting quantum-classical linked computing systems - SuperLink	Giampiero Pepe	01/04/2022	31/03/2025	237.5
UE HEU	KARLSRUHER INSTITUT FUER TECHNOLOGIE	Truly Resilient Quantum Limited Traveling Wave Parametric Amplifiers - TruePA	Martina Esposito	01/12/2022	30/11/2025	354.0
“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	12/05/2021	11/05/2024	100.0
Accordo Progetto MISE	Comune di MATERA	Casa delle Tecnologie Emergenti di Matera CTEMT	Alberto Porzio	04/08/2020	31/12/2024	146.6
UE - Horizon Europe - Research and Innovation Actions	KARLSRUHER INSTITUT FUER TECHNOLOGIE	Truly Resilient Quantum Limited Traveling Wave Parametric Amplifiers (TruePA) GA 101080152	Martina Esposito	01/12/2022	30/11/25	354.0
UE - Horizon Europe - MSCA Postdoctoral Fellowships	CNR - SPIN	Multiferroic Oxide 2DEgs for Reconfigurable nonvolatile memory Nanodevices (MODERN) GA 101108695	Marco Salluzzo	01/10/2023	30/09/25	172.8
UE - Horizon Europe - Research and Innovation Actions	CNR - SPIN	“SpIn-orbitronic QuAntum bits in Reconfigurable 2D-Oxides (IQARO)”, GA 101115190	Roberta Citro - Marco Salluzzo	01/10/2023	30/09/27	726.8

Projects and grants

Running projects 2022/2023

Type	Coordinator	Title	SPIN leader	Start date	End date	Fund (K€)
PNRR - Centri Nazionali		CN00000013 “National Centre for HPC, Big Data and Quantum Computing” - SPOKE 7	Silvia Picozzi	01/09/2022	31/08/2025	173.4
PNRR - Centri Nazionali		CN00000013 “National Centre for HPC, Big Data and Quantum Computing” - SPOKE 10	Mikhail Lisistskiy	01/09/2022	31/08/2025	114.3
PNRR - Partenariati estesi		PE0000023 National Quantum Science and Technology Institute” – NQSTI - SPOKE 2	Silvia Picozzi Mario Cuoco	01/12/2022	30/11/25	590.0
PNRR - Partenariati estesi		PE0000023 National Quantum Science and Technology Institute” NQSTI - SPOKE 4	Mikkel Ejrnaes	01/12/2022	30/11/25	774.2
PNRR - Partenariati estesi		PE0000023 National Quantum Science and Technology Institute” NQSTI - SPOKE 5	Martina Esposito	01/12/2022	30/11/25	526.6
PNRR - Partenariati estesi		PE0000023 National Quantum Science and Technology Institute” NQSTI - SPOKE 6	Marco Salluzzo	01/12/2022	30/11/25	961.7
PNRR - Partenariati estesi		PE0000023 National Quantum Science and Technology Institute” NQSTI - SPOKE 9	Carla Cirillo	01/12/2022	30/11/25	42.7
PNRR - Partenariati estesi		PE0000021 Network 4 Energy Sustainable Transition”, NEST - SPOKE 9	Ilaria Pallecchi	01/12/2022	30/11/25	148.3
PNRR - Ecosistemi dell'innovazione		ECS00000035“Robotics and AI for Socio-economic Empowerment” RAISE SPOKE 2	Gianrico Lamura	01/10/2022	30/09/25	327.0
PNRR - Ecosistemi dell'innovazione		ECS00000035“Robotics and AI for Socio-economic Empowerment” RAISE SPOKE 3	Andrea Gerbi	01/10/2022	30/09/25	766.2
PNRR - Ecosistemi dell'innovazione		ECS00000035 “Robotics and AI for Socio-economic Empowerment” RAISE SPOKE 5	Barbara Cagnana	01/10/2022	30/09/25	23.8

Projects and grants

Running projects 2022/2023

Type	Coordinator	Title	SPIN leader	Start date	End date	Fund (K€)
PNRR - Ecosistemi dell'innovazione		ECS00000024 “Rome Technopole” SPOKE 1	Carmela Aruta	01/07/2022	30/06/25	212.0
PNRR Infrastrutture di ricerca	Istituto Nazionale di Fisica Nucleare	IR0000003 "Innovative Research Infrastructure on applied Superconductivity" -IRIS	Fabio Miletto Granozio Andrea Malagoli Mario Cuoco	01/11/2022	31/10/25	2416.0
PNRR Infrastrutture di ricerca	CNR - IOM	“Nano foundries and fine analysis - Digital Infrastructure” - NFFA - DI	Fabio Miletto Granozio	01/01/2023	31/12/25	2738.7
PRIN 2022	MUR	Transition metal dichalcogenide thin films for hydrogen generation - TMD4H	Carmela Aruta	28/09/2023	27/09/25	55.1
PRIN 2022	MUR	Sustainable spin generators based on Van der Waals dichalcogenides (SUBLI)	Ilaria Pallecchi	28/09/2023	27/09/25	140.3
PRIN 2022	MUR	Rare-earth single atom MAGnets aNchorEd aT oxIde Surfaces as a platform for new low-consumption magnetic dEvices (MAGNETISE)”	Emilio Bellingeri	28/09/2023	27/09/25	33.6
PRIN 2022	MUR	Two-dimensional chiral hybrid organic-inorganic perovskites for chiroptoelectronics - MIRROR	Alessandro Stroppa	28/09/2023	27/09/25	59.9
PRIN 2022	MUR	From the Nano to the Macro SCale: a deep investigation of Grain Boundaries in High-Tc SuperConducting Wires - NaMaSCale	Valeria Braccini	28/09/2023	27/09/25	50.1
PRIN 2022	MUR	Non-reciprocal supercurrent and topological transitions in hybrid Nb-InSb nanoflags - TopoFlag	Matteo Carrega	28/09/2023	27/09/25	15.0
PRIN 2022	MUR	OMEGA	Fabio Miletto Granozio	28/09/2023	27/09/25	97.0
PRIN 2022	MUR	Spin-ORBit Effects in Two-dimensional magnets (SORBET)	Silvia Picozzi	28/09/2023	27/09/25	96.1
PRIN 2022	MUR	Tribo-Electricity: a New Route for Tribology (TRIEL)	Andrea Gerbi	28/09/2023	27/09/25	62.7
PRIN 2022	MUR	“Advanced Control and Readout of Scalable Superconducting NISQ architectures” (SuperNISQ)	Martina Esposito	28/09/2023	27/09/25	56.5
PRIN 2022	MUR	DARk-mattEr-DEVIces - for -Low-energy-detection: the DAREDEVIL	Cesare Tresca	28/09/2023	27/09/25	10.0

Projects and grants

Running projects 2022/2023

Type	Coordinator	Title	SPIN leader	Start date	End date	Fund (K€)
PRIN 2022	MUR	Photophysics and optoelectronics with TMD/2D Perovskite heterostructures for efficient near-infrared detection	Fabio Chiarella	28/09/2023	27/09/25	84.1
PRIN 2022	MUR	Spin transport in multifunctional oxide nanodevices STIMO	Filomena Forte	28/09/2023	27/09/25	48.0
PRIN 2022	MUR	engineering TOpological quantum phases in hexagonal TErnary coMpounds (TOTEM)	Paola Gentile	28/09/2023	27/09/25	39.7
PRIN 2022	MUR	Materials modelling for energy storage applications	Giovanni Cantele	28/09/2023	27/09/25	50.1
PRIN 2022	MUR	EaRth Abundant and non-toxiC doped metaL oxide-based electro-optIc photonic structures for smarT windows and radiative cOoling (ERACLITO)	Francesco Bisio	28/09/2023	27/09/25	101.4
PRIN 2022	MUR	A lab-on-a-chip integrated with electrochemical transistors for cardiac biomarkers evaluation in human blood (LIFEBLOOD)	Mario Barra	28/09/2023	27/09/25	0.0
PRIN PNRR 2022	MUR	"QUEnch mechanisms STudy In supercONductors for Safe energy and energy Saving QUESTIONs PRIN P2022KWFBH	Gaia Grimaldi	30/11/2023	29/11/25	117.0
PRIN PNRR 2022	MUR	"FOXES - Freestanding OXides Epitaxial Strained micro-heterostructures" PRIN P2022TCT72	Alessia Sambri	30/11/2023	29/11/25	146.6
PRIN PNRR 2022	MUR	SHEEP: Symmetry-broken HEterostructurEs for Photovoltaic applications" PRIN P2022KCYZ7	Cesare Tresca	30/11/2023	29/11/25	50.8
PRIN PNRR 2022	MUR	Superconductivity in KTaO3 Oxide-2DEG Nanodevices for Topological quantum Applications (SONATA) PRIN P2022SB73K	Marco Salluzzo	30/11/2023	29/11/25	112.4
PRIN PNRR 2022	MUR	Development of two-dimensional environmental gas nano-sensors with enhanced selectivity through fluctuation spectroscopy (2DEGAS)" PRIN P2022S5AN8	Filippo Giubileo	30/11/2023	29/11/25	74.9

Projects and grants

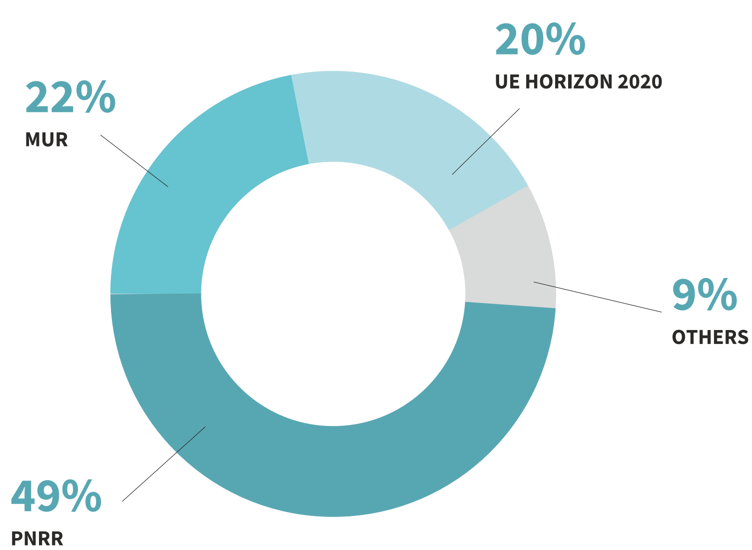
Running projects 2022/2023

Type	Coordinator	Title	SPIN leader	Start date	End date	Fund (K€)
PRIN PNRR 2022	MUR	Development of flexible low-voltage organic phototransistors for visible light communication (OPTICS)" PRIN P20227A8K2	Ettore Sarnelli	30/11/2023	29/11/25	82.6
PRIN PNRR 2022	MUR	Active Radiative COolers (ARCO)" PRIN P2022XTBCW	Francesco Bisio	30/11/2023	29/11/25	100.4
PRIN PNRR 2022	MUR	"Glass-like phonon transport in eco-friendly perOVskitEs foR tHermoelectric Energy generATion - StopHEAT" - PRIN P20223JN27	Alessandro Stroppa	30/11/2023	29/11/25	70.9
PRIN PNRR 2022	MUR	"Design of integrated absorbers for high Efficient solar Energy COnversion in PhotoVoltaic-Thermal devices (EECOPVT)" PRIN- P2022L7X9R	Rosalba Fittipaldi	30/11/2023	29/11/25	23.6
PRIN PNRR 2022	MUR	Atomic-Level Understanding Of Solid Oxide Fuel Cell Processes (A-LENS)	Carmela Aruta	30/11/2023	29/11/25	9.9
MAECI	MAECI	"MAGNETISMO E METALLICITÀ NELL'ISOLANTE DI MOTT CA_2RUO_4: UNA PIATTAFORMA PER FASI QUANTISTICHE INDOTTE DA STRAIN E DROGAGGIO (MAP)"	Rosalba Fittipaldi	01/01/2023	31/12/24	57.3
bilaterale CNR/NRF (Corea)		"Exploring the influence of chirality on angular momentum dynamics of elementary excitations and the emergence of chiral hybrid magnet: A theoretical investigation"	Alessandro Stroppa	01/01/2024	31/12/24	10.0
bilaterale CNR/NSFC(CINA)		"Ferroelectric and Chiral Hydrid orgnic inorganic perovskites"	Alessandro Stroppa	01/01/2024	31/12/24	10.0
PNRR - Ecosistemi dell'innovazione		ECS00000041 Innovation, digitalisation and sustainability for the diffused economy in Central Italy"	Silvia Picozzi	01/07/2022	31/06/2015	123.7
Piano triennale 2019-2021 della Ricerca di sistema elettrico nazionale	MITE (ex MASE)	nuovi Concetti, mAteriali e tecnologie per l'iNtegrazione del fotoVoltAico negli edifici in uno scenario di generazione diffuSa	Alessia Sambri Silvia Picozzi	01/03/2023	28/2/26	48.8
Reseach Agreement	CERN	Tlbased supercondocting Beam screen developement for FCC	Alessandro Leveratto	01/03/2021	28/02/2025	174.0

Projects and grants

Running projects 2022/2023

Type	Coordinator	Title	SPIN leader	Start date	End date	Fund (K€)
Reseach Agreement	CERN	HIGH FIELD MAGNET (HFM)	Andrea Malagoli	09/011/2023	31/10/2027	1’140
Cooperative Agreement Award	AIR FORCE OFFICE OF SCIENTIFIC RESEARCH - AFOSR	Award FA8655-23-1-7014 contributo all'organizzazione della Conferenza ICCGE20	Rosalba Fittipaldi	05/04/2023	04/08/2023	22.5
Commercial order	PIAGGIO AEROSPACE	Severa contract for structural caratterization of aircraft components	Cristina Bernini	2022	2023	2.5
Consulting	Dipartimento di Medicina di Precisione, Università della Campania	Indagine e selezione tra diverse tipologie di sensori elettrochimici	Mario Barra	10/07/2023	30/09/2023	10.0
Commercial order	ASG	Caratterizzazione della corrente critica in campo magnetico di 5.7 T e temperatura di 4.2 K di N. 2 campioni di filo superconduttore a base di Niobio-Titanio	Andrea Malagoli	26/10/2023	28/11/2023	2.0



Collaborations

Collaborations

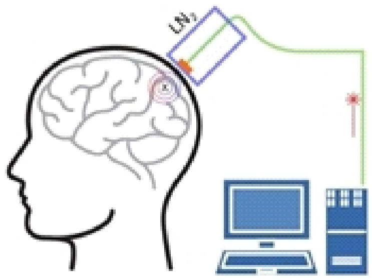
Institution/Company	Title	Responsible	CNR Institute
	2023		
Associazione Studi Ornitologi Italia Meridionale - ASOIM ODV	Accordo di collaborazione tecnico-scientifico per la realizzazione di percorsi didattici per le scuole sull'utilizzo di sensori e sistemi di acquisizione low cost nel campo dell'educazione ambientale	Salvatore Abate	SPIN Salerno
Istituto Comprensivo Cornigliano	collaborazione tecnico-scientifica tra CNR-SPIN e IC Cornigliano finalizzata a realizzare le attività previste dalla FIRST® LEGO® League Challenge 2022/2023	Emilio Bellingeri	SPIN Genova
CERN - European Organization for Nuclear Research	Project on preliminary research and development works related to the development of Iron Based Superconducting wire (IBS) produced with the Powder In Tube (PIT) technology for the HIGH FIELD MAGNET (HFM)	Andrea Malagoli	SPIN Genova
Department of Physics, Pohang University	Theoretical studies of new materials ranging from hybrid perovskites to 2D materials and other innovative materials	Alessandro Stroppa	SPIN Genova
Qianweichang College, Shanghai University	Theoretical studies based on Density Functional Theory, model Hamiltonian and symmetry analysis to support and complement experimental results on innovative materials ranging from hybrid perovskites to 2D materials	Alessandro Stroppa	SPIN Genova

Collaborations

Institution/Company	Title	Responsible	CNR Institute
	2022		
Istituto Nazionale di Fisica Nucleare Dipartimento di Fisica, Università di Genova	Accordo di partnership per l'istituzione di un laboratorio congiunto di ricerca (Lab.Cor)	Andrea Malagoli	SPIN Genova
Istituto Comprensivo "Don Enrico Smaldone"	Progetto "Eduambiente - Laboratorio diffuso di educazione ambientale"	Sergio Pagano, Salvatore Abate	SPIN Salerno
Liceo "Don Carlo La Mura"	Progetto "Eduambiente - Laboratorio diffuso di educazione ambientale"	Sergio Pagano, Salvatore Abate	SPIN Salerno
Scuola Secondaria "Galvani-Opromolla"	Progetto "Eduambiente - Laboratorio diffuso di educazione ambientale"	Sergio Pagano, Salvatore Abate	SPIN Salerno
SISSA	"Superconducting quantum-classical linked computing systems"	Giovanni Pepe	SPIN Napoli
Dept. Of Applied Physics, Hong King Polytechnic University	Collaboration on the joint theoretical and experimental studies of new materials ranging from hybrid perovskites to 2D materials and other innovative materials	Alessandro Stroppa	SPIN L'Aquila
Center for Theoretical Physics of Complex Systems, Institute for Basic Science	Collaboration to promote opportunities to cooperate in scientific acitivities in the broad area of quantum thermodynamics, quantum batteries, quantum many-body systems by conducting cutting edge research at the interface of comptational quantum physics, condensed matter physics and machine learning methods	Matteo Carrega	SPIN Genova

Technology transfer

SPIN's filed patents



Title: A device for sensing a magnetic field
Status: granted on December 2022
Patent no. US11415642
The invention described and claimed in this patent is part of the results of the FET-Open project "OXiNEMS" coordinated by CNR - SPIN.
The patent application, filed on 15 April 2020, has been granted after only 2 years from its filing. Moreover, the patent for this invention is also close to be granted by the European Patent Office.
The patent describes a novel type of mechanical magnetometer based on a superconducting nanostructure and a vibrating magnetic microresonator whose readout is made using an optical detector. The targeted application of this sensor concerns the field of biomagnetism, i.e. the measure and study of very small fields (~1-100 fT) generated by biological processes such as brain or muscle activity, as in magnetoencephalography (MEG) or magnetocardiography (MCG), or by magnetized tissue, as in Ultra Low Field MRI, even in strong (~1T) applied fields as in Transcranial Magnetic Stimulation (TMS).
Inventors: Pellegrino Luca (CNR - SPIN), Maspero Federico, Bertacco Riccardo, Manca Nicola, Kalaboukhov Alexei, Hilschenz Ingo, Della Penna Stefania, Venstra Warner Jurrien, Remaggi Federico, Marre' Daniele, Lombardi Floriana
Applicants: Consiglio Nazionale delle Ricerche, Quantified Air, Università di Chieti-Pescara
Application: EP20169544A·2020-04-15
Publication: EP3896470A1·2021-10-20

Research Area B

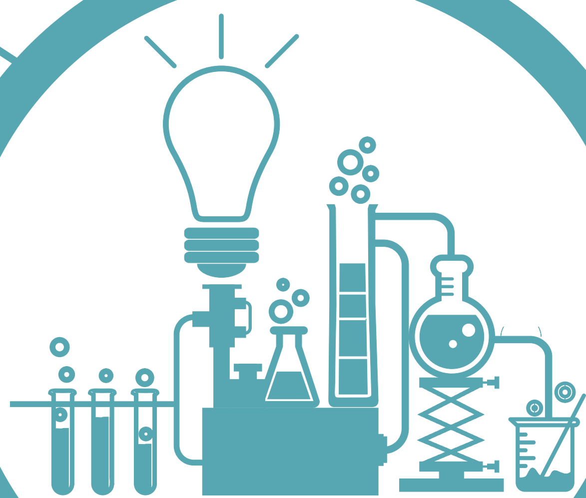
Functional and Complex Materials for Innovative Electronics and Sensing

Research Area A

Superconductors and Innovative materials for Energy and Environment

Research Area C

Quantum Science and Technologies



Research activities with Highlights

Research activities

SPIN reorganization

The previous SPIN Director, Dr. Carlo Ferdeghini, in formulating the 2021 Objectives of the SPIN Institute for the purposes of Performance Evaluation, pointed out the necessity to redefine and refocus the organization of the SPIN Institute, which was structured that time 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.

Following the timeline of the 2021 Institute Objectives, in Autum 2021 there was a meeting between the SPIN Executive Board, the six Research Activity Coordinators and the Unit Deputy Directors. In that occasion, the Research Activity Coordinators illustrated the strengths and the weaknesses in the management of their own Research Activity. The results of this discussion highlighted some critical issues. Some months later, the Executive Board defined in broad terms the steps necessary for the identification and implementation of the new scientific organization.

The first step addressed the identification of a series of alternative proposals, on the basis of which to then consult the entire scientific base of the SPIN Institute. The results of this process had predefined the framework in a more stringent way than expected. All the proposals received essentially mapped SPIN's research into three main Research Activities, or Scientific Areas.
In good agreement with each other, all the proposals included a research area related to **energy** (R1), one dedicated to **electronics/sensors** (R2) and one dedicated to **Quantum Sciences and Technologies** (R3). As expected, the three areas had as a common denominator above all the materials and then the devices, in line with the scientific nature of the Institute.

The finally chosen denominations for the Research Areas were:
Area R1: Superconductors and Innovative materials for Energy and Environment
Area R2: Functional and Complex Materials for Innovative Electronics and Sensing
Area R3: Quantum Science and Technologies

The third stage was then the choice of the person responsible for each Area. All SPIN researchers and technologists had the possibility to submit to the Executive Board their availability to take on the role of Area Coordinator. A CV and a very short programmatic document, including a proposal for division of the Area of interest into sub-areas (or activities), were asked to each candidate. The submitted applications were evaluated by the Institute Executive Board, extended to the Unit Deputy Directors. The evaluation committee was asked to use an evaluation form proposed by the Director and approved with some modifications by the Executive Board.
The evaluation committee finally identified the following Area Coordinators:

Area R1: Valeria Braccini
Area R2: Nicola Manca
Area R3: Marco Salluzzo

The fourth step consisted in the definitive identification of the sub-areas. The decision had been made by consulting the SPIN "scientific base", under the coordination of the Area Coordinators and under the supervision of the Executive Board.
The final structure of the SPIN Institute has been thus defined as in following:

Area R1 - Superconductors and Innovative materials for Energy and Environment
Coordinator: Valeria Braccini

- ***Sub-Area R1.1*** - **Superconductors towards Energy Production, Transport and Storage, and High Magnetic Fields**
  Coordinator: Gaia Grimaldi
- ***Sub-Area R1.2*** - **Materials for Energy and Environment**

Research activities

Area R2 - Functional and Complex Materials for Innovative Electronics and Sensing
Coordinator: Nicola Manca

- ***Sub-Area R2.1* - 2D and Topological Materials for Device Applications**
  Coordinator: Carino Ferrante
- ***Sub-Area R2.2* - Complex Oxides for Novel Electronics and Transducers**
  Coordinator: Rosalba Tatiana Fittipaldi
- ***Sub-Area R2.3* - Organic and Hybrid Sensors, and Complex Systems**
  Coordinator: Mario Barra

Area R3 - Quantum Science and technologies
Coordinator: Marco Salluzzo

- ***Sub-Area R3.1* - Novel Materials and methods for quantum science and technology**
  Coordinator: Matteo Carrega
- ***Sub-Area R3.2* - Optical and microwave photonics for quantum science and technology**
  Coordinator: Mikkel Ejrnaes
- ***Sub-Area R3.3*- Novel ideas for superconducting and spin-based devices for quantum information science and sensing**
  Coordinator: Mikhail Lisitskiy

Research activities

Research Area 1: Superconductors and Innovative materials for Energy and Environment

Area Coordinator: Valeria Braccini

The global challenges of climate and energy require new technologies for renewable energy sources, methods of energy storage and efficient energy use. Innovative systems for energy transport, storage and conversion and their development and demonstration through improved materials and technologies represent undoubtedly strategic issues for the scientific policy of the SPIN institute. This project addresses the challenge of discovering and providing new, innovative materials required for the transition to a sustainable energy system: materials for harvesting energy from renewable sources, transporting and storing energy and converting it into other forms of energy. Different functional properties (as ion conductivity, photovoltaic, catalysis, piezoelectricity) are exploited to design the next generation of materials for green energy applications. Superconductors are exemplary quantum materials that can be employed to study fundamental properties of the quantum world as well as their functionality for accelerating the energy transition. From nanostructured materials to large-scale devices, superconductors offer a playground for developing new enabling technologies in many applications, from medical imaging, transportation, to magnetic confinement for nuclear fusion, particle accelerators, quantum and supercomputing, for instance, aiming to the development of superconducting materials for clean, safe and saving energy.
According to the well-recognized experience of the SPIN scientific community in the cited fields and aiming to intercept such a challenging perspective, within this Area various new improved superconductors and other functional materials will be studied – from the discovery and investigation of new materials towards the development of new technological applications to the realization of prototypes in collaboration with industrial partners.
Nowadays, the SPIN institute has well established competences for computational modelling of new superconductors to guide their synthesis and exploit the quantum nature of advanced materials for device design.

This Area has been splitted into two sub-areas:

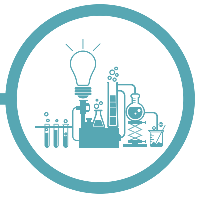
- Superconductors towards Energy Production, Transport and Storage, and High Magnetic Fields
- Materials for Energy and Environment

1.1 Superconductors towards Energy Production, Transport and Storage, and High Magnetic Fields

Sub-area coordinator: Gaia Grimaldi

Room temperature superconductivity has driven the search for new materials and compounds so far, but nowadays superconductivity at cryogenic temperatures is already an enabling technology in several real world applications. From material science to practical devices on the large scale of high field magnets as well as on the small scale of quantum world, there is still the need to achieve a comprehensive knowledge of this fascinating state of matter, its unique characteristics and functionality. Advanced and powerful methods of material design and modelling, high-resolved imaging of their quantum nature, structural, magnetic, thermo-electrical and transport characterisations, synthesis and architectures of innovative materials can bring superconductors towards a sustainable energy system. In particular, we study several forms of superconducting materials: single crystals and bulk/polycrystalline samples, from ultra-thin to thick films grown on crystalline and metallic substrates, mono and multi-filamentary wires, coated conductors and tapes, nanostructures, artificially engineering superconductors, so on and so forth. Materials are fabricated with different techniques such as Pulsed Laser Deposition or DC/RF sputtering, chemical routes, Powder-In-Tube technique. We deal with all classes of superconductors to assess and demonstrate also through a profitable technology transfer they can bring our society closer to an overall decarbonisation and healthy life.

Research activities



A non-exhaustive list of the materials we study is the following.

- Low Temperature Superconductors: Nb, NbN, NbTiN, MoGe, Al, MgB_2, Hg
- High Temperature Superconductors: REBCO with RE=Y, Sm, Eu, Gd; BiSCCO; TBCCO, NCCO
- Iron Based Superconductors: 11-family; 122-family; 1144-family; 1111-family
- Hydrides: H_3S, LaH_{10}, XH_{15} with X=Ca, Sr, La, Y
- Heavy Fermion Superconductors: UPt_3, $CeCu_2Si_2$

Research Topics

- Chemical physics of materials
- Development of superconducting materials in view of large scale applications
- Study of materials defects at nanoscale
- Unconventional superconductivity and vortex physics at extreme conditions

1.2 Materials for Energy and Environment

Sub-area coordinator: Carmela Aruta

CO_2 emissions, energy consumptions, limited resources, climate change, pollution are all challenges to be faced for a more sustainable future. The rationale material design is particularly important to increase the development and utilization of clean energy. Our approach is based on the study of the materials properties at the fundamental level. The materials mainly in thin film form, also as heterostructures or thin membranes, are produced by pulsed laser deposition, sputtering, evaporation and chemical routes and are extensively investigated both at home laboratories and at large scale facilities for the advanced and in-operando characterizations. Theoretical calculations are used to understand the correlation between electronic properties and functionality of materials.

The main aim is to obtain indication on how we can make more efficient and competitive materials for the technological applications in the field of energy harvesting, storage and conversion, as well as environmental field. We investigate new materials and structures for the energy harvesting by exploring different functional properties, as thermoelectricity, piezoelectricity and ferroelectricity, as well as by exploiting solar energy. As for the latter, materials for the conversion by photovoltaic and thermal processes to directly convert into electricity are studied, but also for the photo-assisted environmental pollution abatement. Our field of research involves materials for the conversion and storage of the solar energy into a chemical fuel, like hydrogen, by different processes as electro- and photo-catalytic or photoelectrochemical processes. The next step is the energy storage and conversion of the chemical energy into electricity. For this purpose, ionic, electronic or mixed electronic/ionic materials are investigated as innovative constituents of electrochemical devices, such as batteries and solid oxide fuel cells, which in reverse configuration can in turn produce green fuel.

A partial list of investigated materials is:

- Doped and undoped ceria
- Graphene and Transition metal dichalcogenides
- $LiMn_2O_4$
- $BaFe_2O_4$, Bi_2FeCrO_6, $BiFeO_3$
- Doped and undoped $KNbO_3$
- Other oxide materials such as TiO2, SnO2, SrTiO3, ZnO

Research Topics

- Energy production, conversion, storage and harvesting
- Environmental pollution abatement

Research Area 2: Functional and Complex Materials for Innovative Electronics and Sensing

Area Coordinator: Nicola Manca

In recent years, several classes of novel compounds have attracted the attention of the research community for their uncommon characteristics. This interest is not only related to a curiosity-driven scientific attitude, aiming to better understand the basic physical mechanisms underneath their complex behaviour, but also to take full advantage from their properties to develop smart devices for next-generation electronics, sensors, and transducers.

CNR-SPIN has a strong expertise in all the processes related to growth, characterization, theoretical modelling, and integration into prototypical devices of novel compounds. Its varied community covers the most advanced fields of materials science, this includes transition metal oxides, 2D materials, and organic and hybrid materials. These different scientific directions rely on a wide set of common experimental characterizations (structural, optical, scanning-probe, magneto-transport, thermo-electrical, mechanical), and theoretical modelling comprising numerical and first-principles analysis. On top of this, advanced design and micro/nano-fabrication protocols allow to develop devices and prototypical systems for in-lab/in-field testing.

The Research Area is divided into three sub-areas:

- 2D and Topological Materials for Device Applications
- Complex Oxides for Novel Electronics and Transducers
- Organic and Hybrid Sensors, and Complex Systems

2.1 2D and Topological Materials for Device Applications

Sub-area coordinator: Carino Ferrante

The physics of low dimensional materials is one of the primary research directions among the condensed matter community. Triggered by the seminal studies on graphene, this field now expanded to include a wide variety of layered compounds, such as MXenes, transition metal dichalcogenides, and topological insulators. Most of them derive their properties from the reduced dimensionality, particularly through the confinement of electrons in two and even one dimension, achieved via atomic engineering of the interfaces and lateral confinement obtained by synthesis and by nano-patterning.

In CNR-SPIN we investigate novel low-dimensional materials and their heterostructures, with the goal of designing and developing nanodevices that exhibit unconventional and/or unprecedented performance. To this purpose, our research activity includes the fundamental understanding of charge, structural and spin dynamics in low-dimensional systems by integrating diverse and complementary theoretical and experimental approaches. Specifically, the research fields are: 1) the advanced synthesis of innovative 2D materials and their relative heterostructures, with the control of interfaces and surfaces, 2) ultrafast investigation (on the ~100 fs timescale) of out-of-equilibrium phenomena via pump-probe techniques, 3) theoretical and experimental investigation of nonlinear light-matter interaction, 4) the study of transport phenomena through magnetic, electric, thermal and optical characterization, 5) the theoretical investigation of such systems and phenomena through theoretical modelling and ab-initio calculations.

Research topics:

- “Synthesis of 2D and topological materials”
- “2D materials for sensing”
- “Magneto/Electro/Thermal transport in Van der Waals materials”
- “Theoretical modelling of 2D materials and heterostructures”
- “Optical and ultra-fast characterizations of 2D systems”
- “Scanning probe microscopy characterizations of 2D materials”

2.2 Complex Oxides for Novel Electronics and Transducers

Sub-area coordinator: Rosalba Tatiana Fittipaldi

Research efforts all over the world have plainly indicated that complex oxides, exhibiting intriguing properties such as ferroelectricity, magnetism, or superconductivity, are cutting-edge materials for the development of novel electronic devices and transducers. Composites containing different complex oxide materials can provide a wealth of interesting physics and novel functionality for applications. Combining the different physical properties of single oxide materials in one multicomponent heterostructure, both as bulk and thin films, opens an enormous possibility for technological applications as well as fundamental science.

CNR-SPIN's research activities on complex oxides follow a multidisciplinary approach aimed at advancing the field through several integrated steps: 1) synthesizing novel oxide materials in bulk, thin film, and nanostructured forms; 2) investigating these materials and their heterostructures at the micro- and nanoscale using advanced characterization techniques; 3) designing and developing prototype devices based on oxide materials; 4) exploring novel states of matter, such as chiral currents and altermagnetism; and 5) employing diverse theoretical frameworks to model equilibrium and non-equilibrium phenomena in solid-state systems.

Research topics:

- "Synthesis of complex oxides polycrystals, single crystals, thin-films, heterostructures, and nanoparticles"
- "Oxides-based MEMS and membranes"
- "Multi-scale characterization of complex oxides by scanning probe, electron microscopy, optical, and electronic transport"
- "Theoretical modelling of equilibrium and out-of-equilibrium phenomena in oxide systems"

2.3 Organic and Hybrid Sensors, and Complex Systems

Sub-area coordinator: Mario Barra

Today, one of the growing trends in material science is the development of new compounds combining enhanced opto-electronic properties with the possibility to be easily processed by low temperature/low-cost techniques.

In this framework, CNR-SPIN researchers deal with organic (semi)conductors and 2D/3D hybrid organic/inorganic materials which, owing to their responsiveness to physical and (bio)chemical external stimuli and peculiar physics, enable the development of innovative devices for energy and information manipulation. Examples include flexible organic detectors of ionizing particles (protons, X-rays, gamma rays) for medical therapies, systems for the wideband visible light communications, or sensing devices working in liquid environment. The properties of the investigated materials are analysed down to nanoscale through a wide number of experimental approaches such as advanced microscopy and spectroscopy techniques.

The experimental efforts are strongly integrated with accurate modelling activities devoted to gain new knowledge and to stimulate the development of new sensing systems. These are mainly focused on the study of 2D hybrid organic-inorganic perovskites displaying intriguing new phenomena (e.g. chiroptoelectronic and spintronic properties) and to elaborate effective models and/or simulations of complex systems at the interface between material physics and biology.

Research topics:

- "Organic electronics and charge-transport phenomena"
- "Hybrid organic-inorganic perovskites"
- "Modeling of complex systems"

Research activities

Research Area 3: Quantum Science and technologies

Area Coordinator: Marco Salluzzo

Quantum technologies are today at the frontier of an interdisciplinary research on which academic, SME and large industries are dedicating worldwide efforts towards the establishment of quantum revolution. In spite of fast technological advancements in the different Quantum technologies pillars, several challenges are far to be solved, namely: the realization of fault-tolerant quantum-bits for the attainment of a real quantum advantage in quantum computing; the development of a platform for Quantum key distribution (QKD) devices and systems for Quantum telecommunication; the deployment of integrated quantum sensors and imaging systems with metrology standards in Quantum Sensing and metrology.

CNR-SPIN in last few years is contributing through national and international projects, to the Quantum technology research at several levels. This area will contribute to the fields of fundamental and applied research in quantum physics and materials, in quantum computing based on superconducting electronics and on spintronics, quantum photonics and quantum sensing taking advantage of an interdisciplinary approach, which collects competences available of Area 3 in the fields of:

- Material Science and technology (growth of single crystals and complex heterostructures)
- Low-temperature quantum-transport phenomena
- Josephson physics
- Nano-fabrication/nano-characterization technologies
- Qubit fabrication and characterizations
- Single photon detectors
- Travelling Wave Parametric Amplifier (TWPA)
- Microwave photonics and microwave technology
- Theory of quantum transport in mesoscopic/nanoscopic systems
- Theoretical modeling and numerical simulation of quantum coherent phenomena in realistic devices

The three sub-areas of research are:

- Novel Materials and methods for quantum science and technology
- Optical and microwave photonics for quantum science and technology
- Novel ideas for superconducting and spin-based devices for quantum information science and sensing

3.1 Novel Materials and methods for quantum science and technology

Sub-area coordinator Matteo Carrega

The development of new quantum technologies requires the investigation of both innovative materials and device designs, in order to fully exploit quantum phenomena from the nano- to the macro- scale towards new applications and industrial impact. Thus, a synergetic approach between experimental and theoretical SPIN researchers in modelling, fabrication, and characterization of new materials is needed covering a wide range of cutting-edge scientific topics and materials, alike 2D heterostructures, oxide interfaces, high-mobility semiconductors, strong spin-orbit materials, hybrid semiconductor/superconductor devices, high temperature superconductors, and topological materials. The institute competences include state of the art fabrication techniques (such as epitaxial growth of complex systems), low temperature magneto-transport, advanced electron and advanced spectroscopy methods and condensed matter theoretical studies (including analytical and numerical ab initio methods). The investigation of quantum transport phenomena in nanoscale devices based on low dimensional systems (e.g oxide interfaces, 2D flakes and semiconductors, topological insulators) and in unconventional superconductors provide new insights in fundamental aspects, such as the emergence of new states of matter, that can open new-pathways for future applications. A deep understanding of fundamental aspects, such as the role of electronic correlations, spin-orbital degree of freedom, superconducting proximity effects, is a primary goal of this area. In parallel, novel methods and concepts beyond conventional ones are targeted, including the study of non-equilibrium phenomena (also in presence of time dependent sources) and the investigation of thermodynamic aspects in quantum devices. Dealing with nanoscale technologies, the unavoidable impact of quantum mechanics on thermodynamic properties, such as heat and energy exchanges, represent a relevant issue with potential impact on new thermoelectric devices with improved performances and in the pursuit for low-power and energy cost effective quantum information and computing applications.

A synthetic list of research domains and keywords related to activity 3.1 follows:

- Materials for quantum devices and topological states of matter: epitaxial growth of complex materials, e.g. oxide interfaces and topological insulators; Growth of Topological insulator and single crystals; growth of Al, Nb, NbRe, MoSi, High-Tc superconductors

- Advanced Spectroscopies on novel materials: Synchrotron based spectroscopies: RIXS, XAS, ARPES, RESPES, time resolved experiments using free-electron lasers on unconventional superconductors; Scanning tunnelling spectroscopies; MOmentum and position REsolved mapping Transmission Electron energy loss Microscope
- Quantum transport in hybrid superconductor-semiconductor devices and low-dimensional systems: Fractional quantum Hall effects and interferometry of edge states; Topological insulators and interaction effects; Topological Josephson junctions and anomalous Josephson effect in mesoscopic junctions: Topological SC at oxide interfaces and in Hybrid SC/semiconductor devices; Study of non-reciprocal superconducting (supercurrent diode) and normal transport; Topological states and novel quantum effects in materials with nanoscale curved geometries; 2D quantum phenomena.
- Non-equilibrium open quantum systems and quantum thermodynamics: Novel methods and concepts, including the study of non-equilibrium phenomena and the investigation of thermodynamic aspects in quantum devices, are targeted. Dealing with nanoscale technologies, the unavoidable impact of quantum mechanics on thermodynamic properties, such as heat and energy exchanges, represent a relevant issue with potential impact on new thermoelectric devices with improved performances and in the pursuit for low-power and energy cost effective quantum information and computing applications.

3.2 Optical and microwave photonics for quantum science and technology

Sub-area coordinator Mikkel Ejrnaes

The light-matter interaction science is the core of the activities of this research area, which focuses on how the application of innovative materials and devices can advance quantum sciences and technologies. The understanding of a controlled light/matter interaction will lead to a wave of new functionalities and technologies based on quantum components that on one hand uses solid state devices to control the quantum nature of light and on the other hand uses light to control the quantum nature of solid state devices. Our research activity is multidisciplinary in what combines condensed matter physics and materials science with microwave quantum optics and laser physics. In this sense, it helps pushing the boundaries of what can be envisaged in emerging fields and technologies that are based on new materials and microwave quantum optics as well as on devices with novel functionalities. A synthetic list of research domains and keywords related to activity 3.2 follows:

- Quantum Detection: Fabrication of ultrathin SC microstrips for single photon detection and characterization. Study of dark count mechanisms and photon detection. Superconducting single-photon and THz detectors for the most demanding applications that encompass quantum information and communication, atmospheric remote sensing and LIDAR, metrology, ultra-sensitive imaging and spectroscopy of faint emission sources in medicine and biology.
- Microwave photonics: Quantum Microwave Photonics with Superconducting Circuits and next generation of superconducting TWPA; Travelling Wave Parametric Amplifiers for quantum noise limited amplification of weak microwave signals, readout of solid-state qubits and quantum optics experiments in the microwave regime; High Q-resonators for qubits read-out and sensing. Superconducting parametric devices for quantum-noise-limited amplification of weak microwave signals.

3.3 Novel ideas for superconducting and spin-based devices for quantum information science and sensing

Sub-area coordinator Mikhail Lisitskiy

Quantum device development is proceeding in the last few years at a very high-speed pace. Yet the development of quantum systems providing a real quantum advantage still requires strong advancements in the fundamental and applied research.
For examples, superconducting qubits are still fighting with the large degrees of quantum error-rate, with the need to implement error-correction methods to overcome the current limitations.
Together with Al-AlOx Josephson junction qubit technology, several other promising approaches are being pursued worldwide, which include Silicon- or semiconducting spin-orbit qubits, spin-qubits based on nitrogen vacancies in diamond, Josephson Junction based on other materials and concepts (like FM based JJs), and/or the intrinsically fault tolerant topological qubits. While very long coherence times were recently achieved using spin-based qubits (including purified Silicon qubits), still the research in this field suffer from scaling to multiqubit operation (coupling of single qubits) and more difficulties in the read-out.
The Area 3.3 focuses on the study of novel qubit platform which are potentially able to overcome some of the limitations of current state of art technology.
A synthetic list of research domains and keywords related to activity 3.3 follows:

- Quantum devices based on non-conventional superconductors: Gate controlled SC devices for SC-logics. Topological superconductors and SC/FM hybrids for novel topological qubits.
- Superconducting qubits and SC quantum networks: SQNs of interacting Josephson junctions and superconducting flux-qubits arranged in various quasi-1D and 2D vertex-sharing frustrated lattices embedded into a microwave resonator. Detection of single microwave photons with coherent quantum network of superconducting qubits.
- Spin-orbit qubit based on unconventional 2D-systems: Spin-orbit qubits based on oxide and/or semiconducting quantum dots, topological nanowires. Integration of Qubits with Silicon.

"Investigation of transport mechanisms induced by filament-coupling bridges-network in Bi-2212 wires"

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SUPERCOND. SCI. TECHNOL. 35 (2022) 035002

Bi-2212/Ag wires exhibit a unique feature: a network of grain bridges within the Ag matrix during the partial-melt heat treatment process. While these bridges enhance current distribution and critical current density, they also represent a strong electrical coupling between filaments themselves. This coupling amplifies AC losses, a significant drawback for applications like DC magnets and power transmission. In this work, through transport and magnetic measurements and their comparison, we study the behavior of these bridges as a function of applied magnetic field (up to 7 T) and temperature (up to 60 K) and the implications they have on the electrical coupling. The experiment has been performed on multifilamentary wires prepared by Groove-Die-Groove (GDG) Powder-In-Tube process. The reported results show that the effective length scale on which the filaments are coupled is dependent on the field and temperature, passing from the filaments-bundle diameter regime at low field and temperature to single filament diameter regime at high field and temperature. The proposed combination of dc and magnetic JC measurements will be useful in the identification of bridges behavior and thus our findings can be of support for future works on AC losses evaluation and magnet design.

The authors thank INFN that co-funded the described work in the framework of the CSN5 project BISCOTTO and Dr Valeria Braccini for the fruitful discussion.

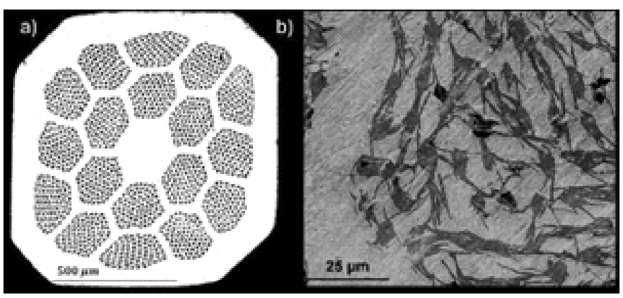
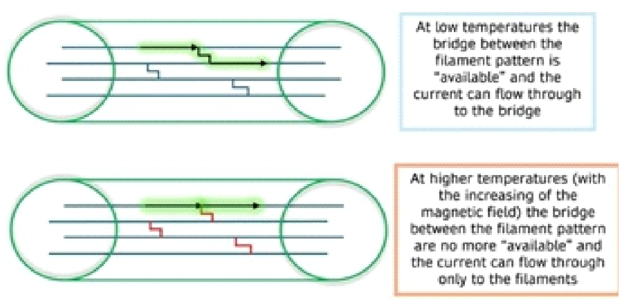


Fig. 1: optical image of the green wire (a) and SEM micrograph of the filaments connection induced by the growth of Bi-2212 across the Ag-matrix after the heat treatment.



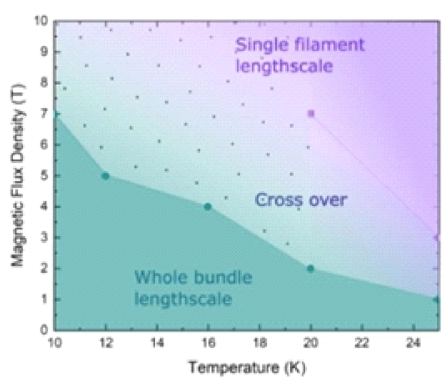


Fig. 2: a) Explanation sketch of the two different transport regimes (whole bundle or single filament);
b) in the space *temperature–magnetic field* we observe, through the comparison between magnetic and transport measurements, the behavior reported in the diagram where, in function of T and B, one can decide and choose the preferred working regime.

"Why mercury is a superconductor"

Cesare Tresca[1,2,3], Gianni Profeta[1,3], Giovanni Marini[1], Giovanni B. Bachelet[2], Antonio Sanna[4], Matteo Calandra[5,6], Lilia Boeri[2]

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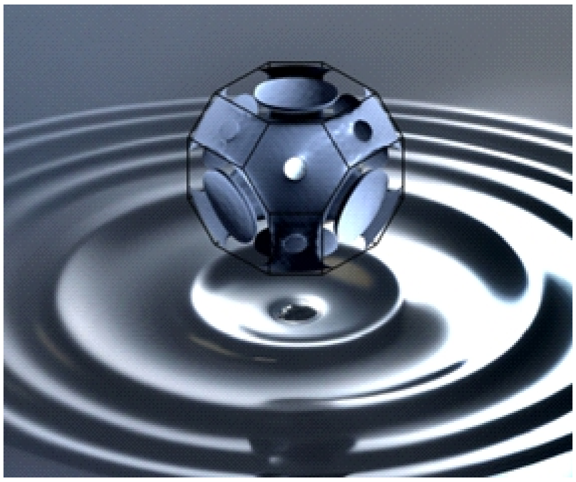
PHYS. REV. B 106 (2022) L18050

Despite being the oldest known superconductor, solid mercury is mysteriously absent from all current computational databases of superconductors. The theoretical prediction of its critical temperature (Tc) and full understanding of its unique superconducting behavior remained elusive for over a century. Now, 111 years later, researchers have revisited mercury's properties in a detailed study based on state-of-the-art superconducting density functional theory (DFT).

In fact, mercury is an exception among conventional superconductors, most of which can be accurately described by state-of-the-art DFT calculations. To address mercury's specific challenges, we closely examined all physical properties essential to conventional superconductivity, which is driven by electron-phonon coupling.
Specifically, we included previously overlooked relativistic effects that impact phonon frequencies, refined the treatment of electron-correlation effects influencing electronic bands, and demonstrated that mercury's d-electrons provide an unusual screening effect that enhances superconductivity by reducing Coulomb repulsion among superconducting electrons.

With these refinements, our calculations yielded a prediction for mercury's Tc that is just 2.5% below the observed experimental value. This new understanding on the first-known superconductor not only holds textbook significance but also offers important guidance for future superconductivity research.



Highlights

Area 1 - Superconductors and Innovative materials for Energy and Environment - 2022

“Superconductivity induced by structural reorganization in the electron-doped cuprate $Nd_{2-x}Ce_xCuO_4$”

Anita Guarino,[1,2] Carmine Autieri,[3,2] Pasquale Marra,[4,5] Antonio Leo ,[1,2,6] Gaia Grimaldi ,[1,2] Adolfo Avella ,[1,2,7] and Angela Nigro [1,2]

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PHYSICAL REVIEW B 105 (2022) 014512

Electron-doped and hole-doped superconducting cuprates exhibit a symmetric phase diagram as a function of doping. This symmetry is, however, only approximate. Indeed, electron-doped cuprates become superconductors only after a specific annealing process: This annealing affects the oxygen content by only a tiny amount but has a dramatic impact on the electronic properties of the sample. Here we report the occurrence of superconductivity in oxygen-deficient $Nd_{2-x}Ce_xCuO_4$ thin films grown in an oxygen-free environment after annealing in pure argon flow (type A samples). As verified by x-ray diffraction, annealing induces an increase of the interlayer distance between CuO_2 planes in the crystal structure. Since this distance is correlated to the concentration of oxygens in apical positions, and since oxygen content cannot substantially increase during annealing, our experiments indicate that the superconducting phase transition has to be ascribed to a migration of oxygen ions to apical positions during annealing. Moreover, as we confirm via first-principles density functional theory calculations, the changes in the structural and transport properties of the films can be theoretically described by a specific redistribution of the existing oxygen ions at apical positions with respect to CuO_2 planes, which remodulates the electronic band structure and suppresses the antiferromagnetic order, allowing the emergence of hole superconductivity.

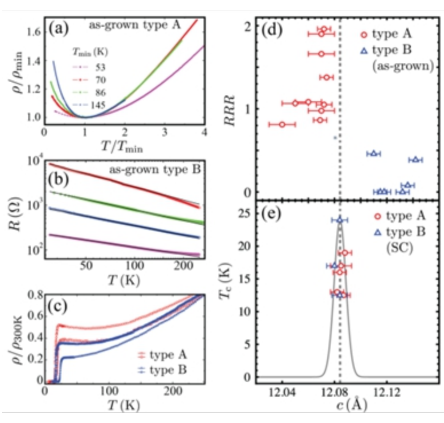

FIG. 2. (a) Resistivity as a function of temperature for type A samples plotted on a log-log scale and normalized to the resistivity minimum. (b) Resistance as a function of temperature for type B samples plotted on a log-log scale. Continuous lines $R(T) \propto T^{-\alpha}$ are the best fit to the data. (c) Normalized resistivity as a function of temperature for type A and B samples after annealing showing the superconducting transition at $Tc \approx 24K$. (d) Residual resistivity ratio *RRR* for as-grown samples (both types) and (e) superconducting critical temperature *Tc* of samples after annealing as a function of the *c*-axis parameter. The dashed gray line is the average value of c_{SC} and the continuous smooth curve is a guide for the eye. The annealing process was optimized for the sample reaching $Tc \approx 24K$.

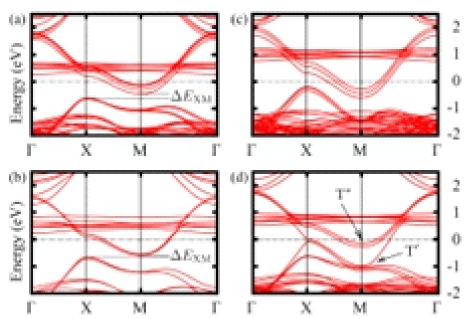

FIG. 3. DFT electronic band structure of NCCO for (a) T' structure with $x = 0.125$, (b) T' structure with $x = 0.25$, (c) T' structure with $x = 1/6 \approx 0.17$, and (d) $T_{SC} = 2T^* + T'$ structure with $x = 1/6$, where we highlighted the dominant T' and T^* bands with larger contributions. The Fermi level is set to zero. The flat bands at 0.5–1.5 eV above the Fermi level are the cerium $4f$ bands. All other lower-energy bands are copper $3d$ bands.

"Electrical conduction and noise spectroscopy of sodium-alginate gold-covered ultrathin films for flexible green electronics"

Carlo Barone[1,2,3], Piera Maccagnani[4], Franco Dinelli[5], Monica Bertoldo[6,7], Raffaella Capelli[8,9,10], Massimo Cocchi[7], Mirko Seri[11], Sergio Pagano[1,2,3]

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SCIENTIFIC REPORTS 12 (2022) 9861

Green electronics is an emerging topic that requires the exploration of new methodologies for the integration of green components into electronic devices. Therefore, the development of alternative and eco-friendly raw materials, biocompatible and biodegradable, is of great importance. Among these, sodium-alginate is a natural biopolymer extracted from marine algae having a great potential in terms of transparency, flexibility, and conductivity, when functionalized with a thin gold (Au) layer. The electrical transport of these flexible and conducting substrates has been studied, by DC measurements, from 300 to 10 K, to understand the interplay between the organic substrate and the metallic layer. The results were compared to reference bilayers based on polymethyl-methacrylate, a well-known polymer used in electronics. In addition, a detailed investigation of the electric noise properties was also performed. This analysis allows to study the effect of charge carriers fluctuations, providing important information to quantify the minimum metallic thickness required for electronic applications. In particular, the typical noise behavior of metallic compounds [Fig. 1 (a)] was observed in samples covered with 5 nm of Au, while noise levels related to a non-metallic conduction [Fig. 1 (b)] were found for a thickness of 4.5 nm, despite of the relatively good DC conductance of the bilayer.Fig. 1: The amplitude of the 1/f noise component is shown as a function of temperature and of bias current, in a three-dimensional plot, for metallic (a) and for non-metallic (b) sodium-alginate films.

University of Salerno has partially supported this work through grants 300391FRB19PAGAN and 300391FRB20BARON. INFN is also gratefully acknowledged through experiments SIMP, Qub-IT, and DARTWARS

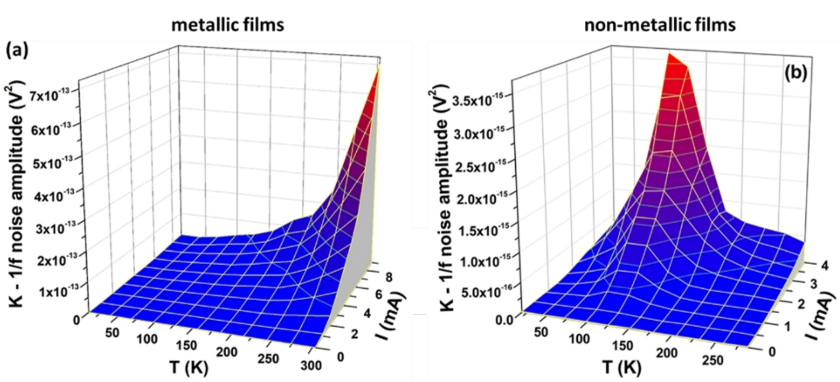

Fig. 1: The amplitude of the 1/f noise component is shown as a function of temperature and of bias current, in a three-dimensional plot, for metallic (a) and for non-metallic (b) sodium-alginate films.

"Roles of Defects and Sb-doping in the Thermoelec-tric Properties of Full-Heusler Fe_2TiSn"

Ilaria Pallecchi [1], Daniel I. Bilc [2], Marcella Pani [3,1], Fabio Ricci [4], Sébastien Lemal [4], Phi-lippe Ghosez [4], Daniele Marré [5,1]

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ACS APPLIED MATERIALS & INTERFACES 14 (2022) 25722

The potential of Fe_2TiSn full-Heusler compounds for thermoelectric applications has been suggested theoretically, but not yet grounded experimentally, due to the difficulty of obtaining reproducible, homogeneous, phase pure and defect free samples. In this work, we study $Fe_2TiSn_{1-x}Sb_x$ polycrystals (x from 0 to 0.6), fabricated by high-frequency melting and long-time high-temperature annealing. We obtain fairly good phase purity, homogeneous microstructure and good matrix stoichiometry. Although intrinsic p-type transport behavior is dominant, n-type charge compensation by Sb doping is demonstrated. Calculations of formation energy of defects and electronic properties carried out in the density functional theory formalism reveal that charged iron vacancies V_{Fe}^{2-} are the dominant defects responsible for the intrinsic p-type doping of Fe_2TiSn in all types of growing conditions except Fe-rich. Additionally, Sb substitutions at Sn site give rise either to Sb_{Sn}, Sb_{Sn}^{1+} which are responsible for n-type doping and magnetism (Sb_{Sn}) or to magnetic Sb_{Sn}^{1-} which act as additional p-type dopants. Our experimental data highlight good thermoelectric properties close to room temperature, with Seebeck coefficients up to 56 μV/K in the x=0.2 sample and power factors up to $4.8x10^{-4}$ W m^{-1} K^{-2} in the x=0.1 sample. Our calculations indicate the appearance of a pseudogap in Ti-rich conditions and large Sb doping, possibly improving further the thermoelectric properties.

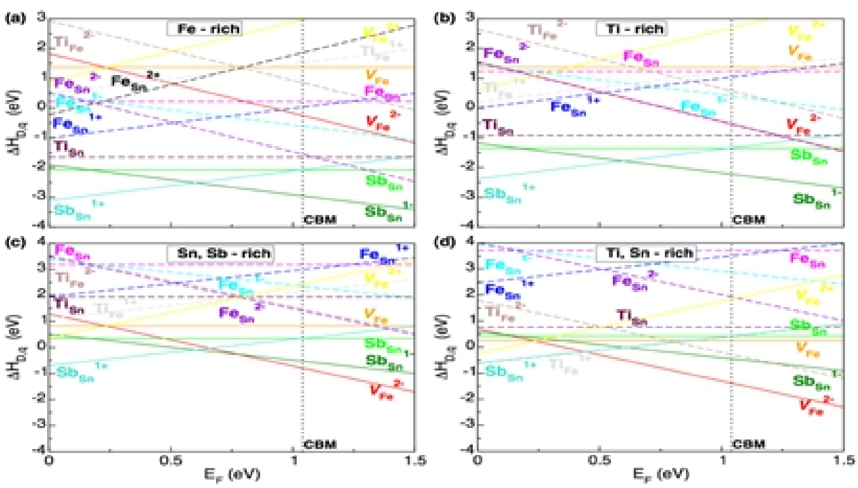

Fig. 1: Fermi energy dependence of formation energy of different types of atomic defects

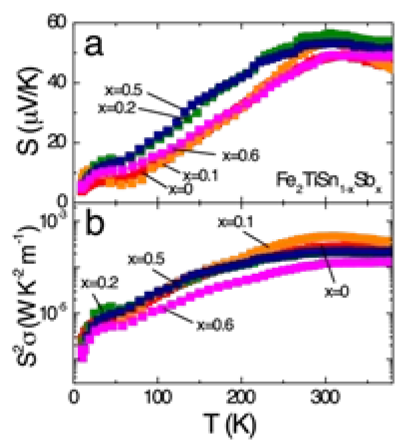

Fig. 2: Seebeck coefficient (a) and thermoelectric power factor (b) measured in $Fe_2TiSn_{1-x}Sb_x$ (x = 0.0, 0.1, 0.2, 0.5 and 0.6) samples.

“Evidence for a single-layer van der Waals multiferroic”

Qian Song [1,2,9], Connor A. Occhialini [1,9], Emre Ergeçen [1,9], Batyr Ilyas [1,9], Danila Amoroso [3,4], Paolo Barone[5], Jesse Kapeghian [6], Kenji Watanabe[7], Takashi Taniguchi[8], Antia S. Botana[6], Silvia Picozzi[3], Nuh Gedik[1], Riccardo Comin[1]

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NATURE 602 (2022) 601

Multiferroic materials have attracted wide interest because of their exceptional static and dynamical magnetoelectric properties. In particular, type-II multiferroics exhibit an inversion-symmetry-breaking magnetic order that directly induces ferroelectric polarization through various mechanisms, such as the spin-current or the inverse Dzyaloshinskii–Moriya effect. This intrinsic coupling between the magnetic and dipolar order parameters results in high-strength magnetoelectric effects. Two-dimensional materials possessing such intrinsic multiferroic properties have been long sought for to enable the harnessing of magnetoelectric coupling in nanoelectronic devices. Here we report the discovery of type-II multiferroic order in a single atomic layer of the transition-metal-based van der Waals material NiI2. The multiferroic state of NiI2 is characterized by a proper-screw spin helix with given handedness, which couples to the charge degrees of freedom to produce a chirality-controlled electrical polarization. We use circular dichroic Raman measurements to directly probe the magneto-chiral ground state and its electromagnon modes originating from dynamic magnetoelectric coupling. Combining birefringence and second-harmonic-generation measurements with theoretical modelling and simulations, we detect a highly anisotropic electronic state that simultaneously breaks three-fold rotational and inversion symmetry, and supports polar order. The evolution of the optical signatures as a function of temperature and layer number surprisingly reveals an ordered magnetic polar state that persists down to the ultrathin limit of monolayer NiI2. These observations establish NiI2 and transition metal dihalides as a new platform for studying emergent multiferroic phenomena, chiral magnetic textures and ferroelectricity in the two-dimensional limit.

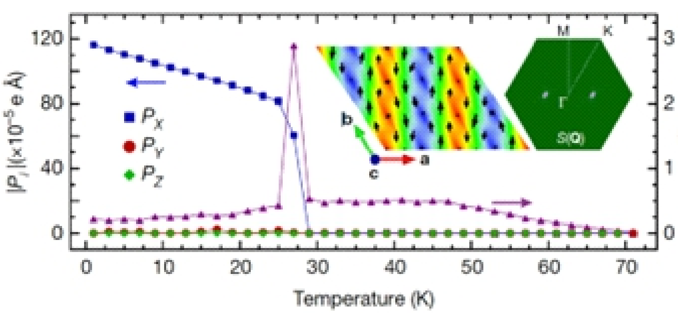

Fig. 1 - Electrical polarization components |Pi| in units of 10−5 e . (absolute value, closed squares) and specific heat (CV, triangles) as a function of temperature, relative to the proper-screw spiral order represented in the insets (for the spin texture, the black arrows represent in-plane components of the spins and the colour map indicates the out-of-plane spin component with red (blue) denoting sz = +(−)1, S(Q) represents the spin structure factor, corresponding to the single-Q helical spin configuration Q).

“Curved Magnetism in CrI_3”

Alexander Edström[1,2], Danila Amoroso[3,4], Silvia Picozzi[3], Paolo Barone[5], Massimiliano Stengel[1,6]

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PHYSICAL REVIEW LETTERS 128 (2022) 177202

Curved magnets attract considerable interest for their unusually rich phase diagram, often encompassing exotic (e.g., topological or chiral) spin states. Strain gradients can strongly impact magnetism via a curvature-induced modification of the spin coupling parameters, commonly referred to as flexomagnetism. Micromagnetic simulations are playing a central role in the theoretical understanding of such phenomena; their predictive power, however, rests on the availability of reliable model parameters to describe a given material or nanostructure. We used noncollinear magnetic calculations within Density Functional Theory (DFT), with and without spin-orbit coupling (SOC), to investigate the interplay of curvature and magnetism in monolayer CrI_3. Besides revealing a crossover between two spin states of distinct symmetry, our calculations demonstrate that the effects of SOC are essential for a quantitatively (and sometimes even qualitatively) accurate description of the flexomagnetic coupling parameters.

This work has been supported by the Swedish Research Council (Grant no. 2018-06807), MICINN-Spain (Grant no. PID2019–108573GB-C22), Severo Ochoa FUNFUTURE center of excellence (CEX2019-000917-S), Generalitat de Catalunya (Grant No. 2017 SGR1506), the EU Horizon 2020 program ERC (Grant no. 724529), PRIN-MIUR projects (Grant No. 2017Z8TS5B and Grant No. 2017YCTB59) and NFFA-MIUR Italy project.

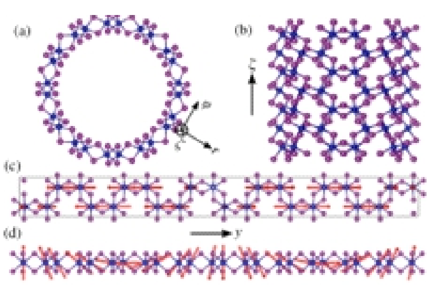

Fig. 1: Curvature effects are studied in CrI_3 nanotubes using cylindrical coordinates (a), (b). A ferromagnetic state in the nanotube takes the form of a spiral in this reference frame, as when unrolling the nanotube (c),(d).

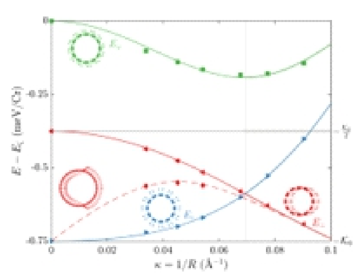

Fig. 2: Energies of magnetic states with spins along radial, tangential and azimuthal direction as a function of curvature. Points are DFT energies, lines display the continuum model results. Dashed line shows the energy of a two-domain state.

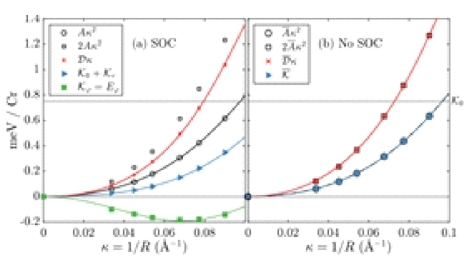

Fig. 3: Energy contributions of spin-coupling parameters $A\kappa^2$ (exchange), $D\kappa$ (Dzyaloshinskii-Moriya), κ (anisotropy) obtained by mapping DFT results with (a) and without SOC (b) onto the continuous model, revealing the impact of relativistic effects on the curvilinear spin Hamiltonian.

“Memory effects in black phosphorus field effect transistors”

Alessandro Grillo[1,2], Aniello Pelella[1,2], Enver Faella[1,2], Filippo Giubileo[2], Stephan Sleziona[3], Osamah Kharsah[3], Marika Schleberger[3] and Antonio Di Bartolomeo[1,2]

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2D MATERIALS 9 (2022) 015028

Black phosphorus (BP) is a layered material in which, similarly to graphite, individual atomic layers are held together by van der Waals interactions. In the single-layer limit, BP is also known as phosphorene and has a numerically predicted direct band gap of ~2 eV at the Γ point of the first Brillouin zone. With increasing number of layers, the interlayer interactions reduce the bandgap to a minimum of 0.3 eV for bulk BP moving the direct gap to the *Z* point. The presence of a finite bandgap makes BP suitable for the realization of field-effect transistors (FETs), and the thickness-dependent direct bandgap may lead to applications in optoelectronics, especially in the infrared region. A remarkable application of BP has been in the field of memory devices. Common non-volatile FET-based memories use a charge-trapping layer to accumulate and retain the electric charge induced by a gate pulse. Fig. 1(a) shows the crystal structure of BP where the layered structure is composed of sheets with the phosphorus atoms arranged in a puckered honeycomb lattice. Ultrathin BP flakes were exfoliated from bulk BP single crystals using a standard mechanical exfoliation method by adhesive tape. The flakes were transferred onto degenerately doped p-type silicon substrates, covered by 90 nm thick SiO_2, on which they were located through optical microscopy. A standard photolithography process followed by electron beam evaporation was used to deposit electrodes, as shown in Fig. 1(b).

The standard electrical characterization shows a large hysteresis width, which can be exploited for memory applications. The hysteresis width has been investigated as a function of the voltage sweep duration and during recovery after irradiating the device with a super-continuous white laser source, revealing that the slow intrinsic trap states are the main responsible for the hysteretic behaviour (Fig. 2). It has also been demonstrated that it is possible to realize BP-based non-volatile memory devices without adding a dedicated charge-trapping layer to accumulate and retain the electric charge. Finally, encapsulating BP with a PMMA protective layer has been used as a simple way to preserve the electrical properties of the memory over a month. These results may pave the way for the realization of simple-to-make memory-type devices based on BP or other 2D materials with intrinsic defects.

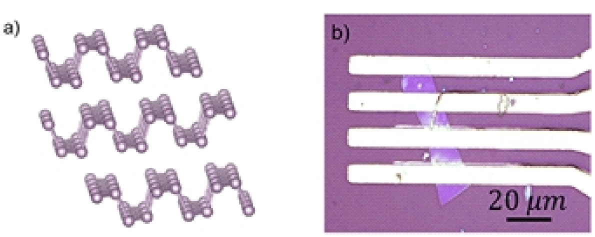

Fig. 1: Figure 1. (a) Crystal structure of few-layer BP. (b) Optical image of the device showing a BP flake covered by four Cr/Au contacts.

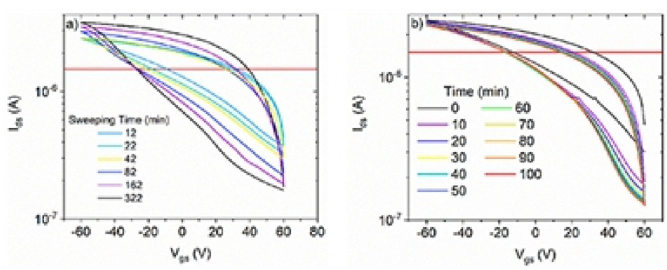

Fig. 2: (a) Transfer characteristics recorded at different sweeping times. (b) Transfer characteristics measured under supercontinuous white laser illumination (black line) and in the dark every 10 min after the laser was switched off.

Highlights

Area 2 - Functional and Complex Materials for Innovative Electronics and Sensing - 2022

“γ-BaFe2O4: a fresh playground for room temperature multiferroicity”

Fabio Orlandi[1] , Davide Delmonte[2] , Gianluca Calestani[3] , Enrico Cavalli[3] , Edmondo Gilioli[2] , Vladimir V. Shvartsman[4] , Patrizio Graziosi[5] , Stefano Rampino[2], Giulia Spaggiari[2,6], Chao Liu[7,8], Wei Ren[7] , Silvia Picozzi[8], Massimo Solzi[6] , Michele Casappa[2,3] & Francesco Mezzadri[2,3]

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NATURE COMMUNICATIONS 13 (2022) 7968

Multiferroics, showing the coexistence of two or more ferroic orderings at room temperature, could harness a revolution in multifunctional devices. However, most of the multiferroic compounds known to date are not magnetically and electrically ordered at ambient conditions, so the discovery of new materials is pivotal to allow the development of the field. In this work, we show that $BaFe_2O_4$ is a previously unrecognized room temperature multiferroic. X-ray and neutron diffraction allowed to reveal the polar crystal structure of the compound as well as its antiferromagnetic behavior, confirmed by bulk magnetometry characterizations. Piezo force microscopy and electrical measurements show the polarization to be switchable by the application of an external field, while symmetry analysis and calculations based on density functional theory reveal the improper nature of the ferroelectric component. Considering the present findings, we propose $BaFe_2O_4$ as a Bi- and Pb-free model for the search of new advanced multiferroic materials.

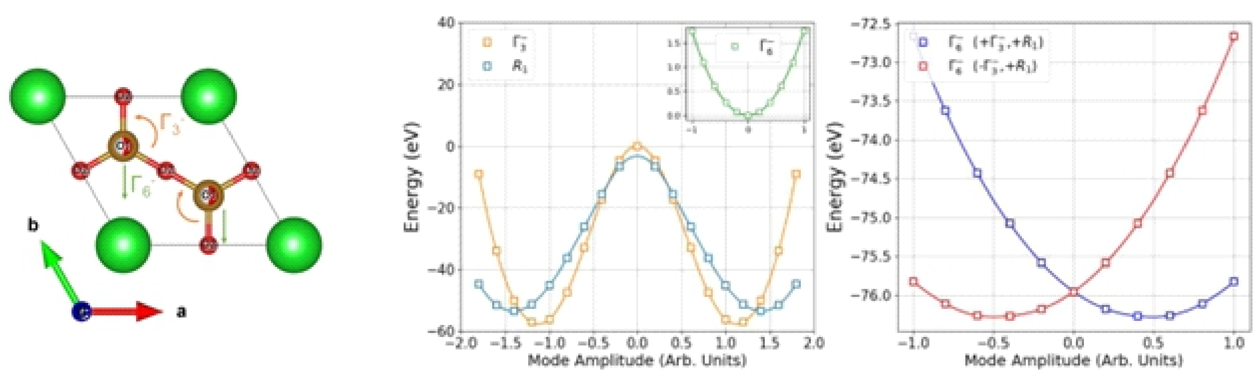

Fig.1 - Left panel: The orange and green arrows denote the displacements due to the Γ3- and Γ6 - modes. Central panel: DFT total energies as a function of mode amplitudes, considering only the Γ3− (orange line) and R1 (blue line) modes. The inset shows the total energy behavior, when activating only the Γ6− mode. Right panel: DFT total energies obtained by changing the Γ6− amplitude, in the presence of the R1 mode amplitude frozen to its positive minimum and the Γ6- mode frozen to the positive minimum (blue points) and to the negative minimum

“Stress Analysis and Q-Factor of Free-Standing (La,Sr)MnO_3 Oxide Resonators”

Nicola Manca[1], Federico Remaggi[2,1], Alejandro E. Plaza[1], Lucia Varbaro[2], Cristina Bernini[1], Luca Pellegrino[1], and Daniele Marré[2,1]

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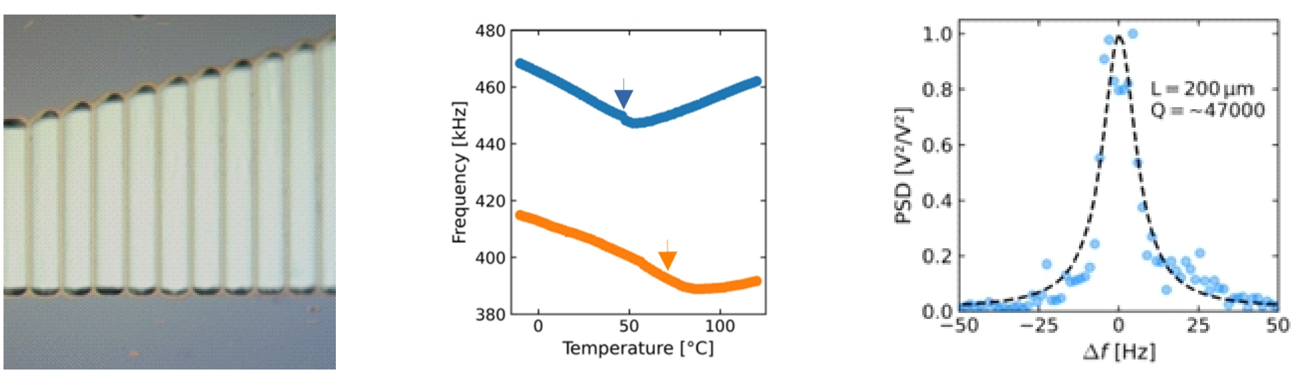
SMALL 18 (2022) 2202768

High-sensitivity nanomechanical sensors are mostly based on silicon technology and related materials. The use of functional materials, such as complex oxides having strong interplay between structural, electronic, and magnetic properties, may open possibilities for developing new mechanical transduction schemes and for further enhancement of the device performances. The integration of these materials into micro/nano-electro-mechanical systems (MEMS/NEMS) is still at its very beginning and critical basic aspects related to the stress state and the quality factors of mechanical resonators made from epitaxial oxide thin films need to be investigated. Here, suspended micro-bridges are realized from single-crystal thin films of $(La_{0.7},Sr_{0.3})MnO_3$ (LSMO), a prototypical complex oxide showing ferromagnetic ground state at room temperature. These devices are characterized in terms of resonance frequency, stress state, and Q-factor. LSMO resonators are highly stressed, with a maximum value of ≈260 MPa. The temperature dependence of their mechanical resonance is discussed considering both thermal strain and the temperature-dependent Young's modulus. The measured Q-factors reach few tens of thousands at room temperature, with indications of further improvements by optimizing the fabrication protocols. These results demonstrate that complex oxides are suitable to realize high Q-factor mechanical resonators, paving the way toward the development of full-oxide MEMS/NEMS sensors.

This work was carried out under the OXiNEMS project (www. oxinems.eu). This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 828784. The authors acknowledge financial support from the Università di Genova through the Fund for promoting European projects (BIPE).



(left) Array of microbridge resonators made of 100nm-thick LSMO deposited on $SrTiO_3$(110) substrate.(center) Temperature dependence of the resonance frequency of LSMO bridge resonators showing the effect of the magnetic transition on the mechanical response (Curie temperature is marked by arrows). (right) Spectral response of a 250µm-long LSMO bridge, mechanical quality factor is obtained from Lorentzian fit

"A Two-Dimensional Superconducting Electron Gas in Freestanding $LaAlO_3/SrTiO_3$ Micromembranes"

Ricci Erlandsen[1], Rasmus Tindal Dahm[1], Felix Trier[1], Mario Scuderi[2], Emiliano Di Gennaro[3], Alessia Sambri[4], Charline Kaisa Reffeldt Kirchert[1], Nini Pryds[1], Fabio Miletto Granozio[4], Thomas Sand Jespersen[1]

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NANO LETTERS 22 (2022) 4758

Freestanding oxide membranes constitute an intriguing material platform for new functionalities and allow integration of oxide electronics with technologically important platforms such as silicon. Sambri et al. recently reported a method to fabricate freestanding $LaAlO_3/SrTiO_3$ (LAO/STO) membranes by spalling of strained heterostructures. Here, we first develop a scheme for the high-yield fabrication of membrane devices on silicon. Second, we show that the membranes exhibit metallic conductivity and a superconducting phase below ≈ 200 mK. Using anisotropic magnetotransport we extract the superconducting phase coherence length $\xi \approx 36-80$ nm and establish an upper bound on the thickness of the superconducting electron gas $d \approx 17-33$ nm, thus confirming its two-dimensional character. Finally, we show that the critical current can be modulated using a silicon-based backgate. The ability to form superconducting nanostructures of LAO/STO membranes, with electronic properties similar to those of the bulk counterpart, opens opportunities for integrating oxide nanoelectronics with silicon-based architectures.

This work has been supported by the project QUANTOX (QUANtum Technologies with 2D-OXides) of QuantERA ERA-NET Cofund in Quantum Technologies (Grant Agreement No. 731473) implemented within the 10th European Union's Horizon 2020 Programme and MIUR PRIN 2017 (Grant Nos. 20177SL7HC "TOPSPIN" and 2017YCTB59 "TWEET")

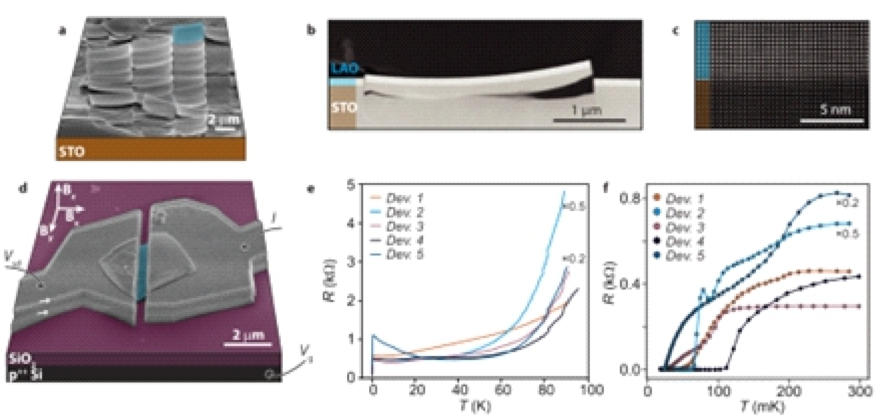

Fig 1: (a) Tilt-view scanning electron microscope (SEM) image of the as-grown LAO/STO micromembranes. (b) Low-magnification scanning transmission electron microscope (TEM) image of a cross section of the growth substrate. The LAO layer (blue) appears with a lighter contrast in comparison the STO (brown). A partially released LAO/STO micromembrane is apparent with curving due to a LAO/STO lattice mismatch. (c) High-resolution image of the epitaxial LAO/STO interface. (d) Artificially colored SEM of a finished LAO/STO membrane device fabricated on a p++ Si/SiO2 substrate. The degenerately doped substrate acts as a backgate electrode in the measurements. (e) Two-terminal resistance vs temperature for five devices showing metallic behavior. (f) Low-temperature regime of (e) showing superconducting transitions. In (e) and (f), the resistance of the cryostat filters and the membrane/metal interface have been subtracted (see text) and results for Dev. 2 and 5 have been scaled by factors of 0.5 and 0.2, respectively, for clarity.

"In-Operando Optical Spectroscopy of Field-Effect-Gated Al-Doped ZnO"

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ACS APPLIED MATERIALS & INTERFACES 15 (2023) 3112

Transparent conductive oxides (TCO) have the unique characteristics of combining optical transparency with high electrical conductivity; such a property makes them uniquely alluring for applications in visible and infrared photonics. One of their most interesting features is the large sensitivity of their optical response to the doping level. We performed the active electrical manipulation of the dielectric properties of aluminum-doped ZnO (AZO), a TCO-based on Earth-abundant elements. We actively tuned the optical and electric performances of AZO films by means of an applied voltage in a parallel-plate capacitor configuration, with $SrTiO_3$ as the dielectric, and monitored the effect of charge injection/depletion by means of in-operando spectroscopic ellipsometry (Fig.1 right). Calculations of the optical response of the gated system allowed us to extract the spatially resolved variations in the dielectric function of the TCO and infer the injected/depleted charge profile at the interface (Fig.1 center, right). We observed that good agreement between experimental data and calculations is achieved assuming an exponential decay of the injected charge density with a characteristic decay length of 4 nm.

This work demonstrates the possibility of accessing "in operando" the out-of-plane charge-density profiles in insulator/semiconductor interfaces under field effect by means of advanced optical spectroscopy.

This project has received financial support from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement no. 799126.

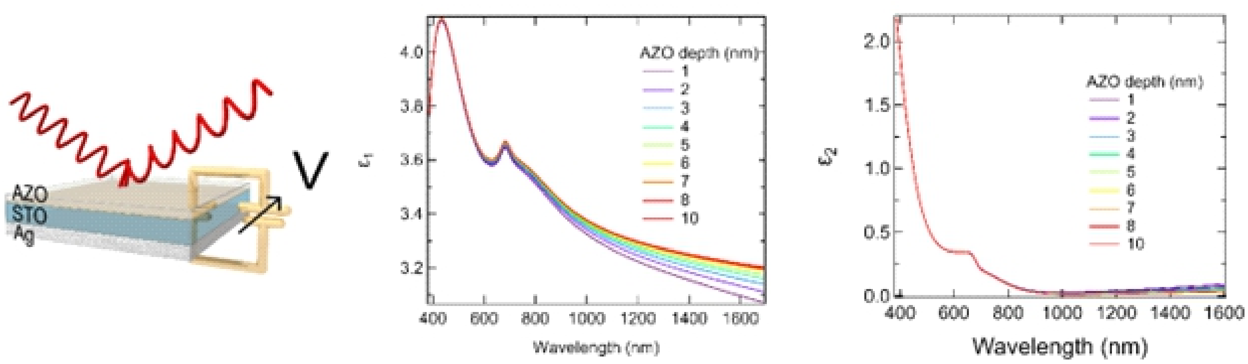

Fig. 1: Left: Schematic drawing of the field-effect device geometry for in-operando optical characterization. Center: the dielectric constants ε_1 and ε_2 of 0.2 at. % AZO film at various depth values from the AZO/BTO interface.

"Ultrafast laser surface irradiation of silicon: Effects of repetition rate in vacuum and air"

M. Hu[1], J. JJ Nivas[1,2,3], M. Valadan[3,4], R. Fittipaldi[5], A. Vecchione[5], R. Bruzzese[1,2], C. Altucci[3,4], S. Amoruso[1,2,3]

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APPLIED SURFACE SCIENCE 606 (2022) 154869

Ultrashort pulse lasers offer many possibilities in applications related to the processing of a solid target surface, such as materials drilling, cutting, marking and texturing. They have also been able to impart new functionalities to a material surface through the generation of laser induced periodic surface structures (LIPSS), e.g. and studies exploiting energetic laser pulses of few tens of µJ, at repetition rates of tens to hundreds kHz have shown new features of fs laser surface irradiation and texturing processes. Our study reports a thorough investigation on the crater morphology and surface texture of silicon irradiated with fs pules in air and vacuum, at various repetition rates. The subject is of particular interest, and great practical impact, since in many applications the process occurs at atmospheric pressure and our previous experimental findings evidenced a clear variation of the features of the irradiated samples at about 10 kHz, that was ascribed to plume shielding induced by the confinement of the ablated material at atmospheric pressure. Hence, we were stimulated to analyse the effects of surface irradiation of a silicon target also in vacuum conditions, at repetition rates varying from 0.01 to 200 kHz, and in static conditions. The outcomes were compared with results obtained in air in similar experimental conditions. Both the threshold fluence for the formation of a shallow crater, and the morphological characteristics of the surface structures generated inside the crater were analysed, for a fixed sequence of *N* laser pulses, as a function of the pulse repetition rate, f_p. Strong differences were observed for processing in vacuum and air, that allow also addressing the change in laser-target energy coupling in the two cases, at repetition rates larger than 10 kHz. The observed behaviour was eventually rationalized in terms of the different effects of the nanoparticle debris covering the target surface, and of the occurrence of plume *This work has been supported the PRIN 2020 project Conquest funded by the Italian Ministry of University and Research (Prot. 2020JZ5N9M) and by the China Scholarship Council through the financial support to the PhD grant of M.Hu.*

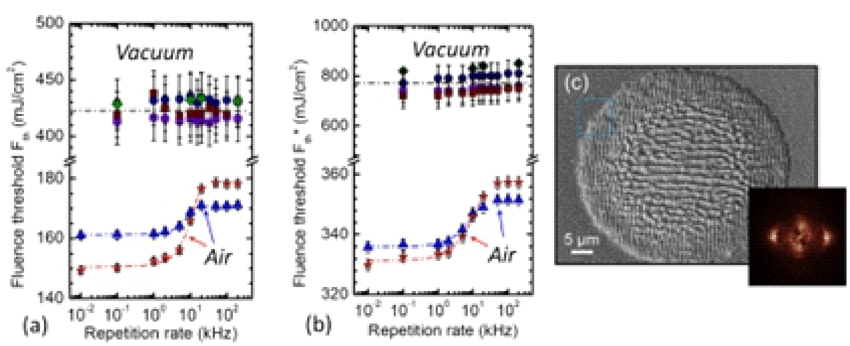

Fig. 1. Variation of the threshold fluences F_{th} (a), and F^*_{th} (b) as a function of the repetition rate, for irradiation in air, with a sequence of *N* = 100 (triangles), and *N* = 200 (stars), at a laser peak fluence F_p = 0.84 J/cm², and in vacuum, for ^{N} = 100, at four different values of F_p, namely 0.78 (hexagons), 0.84 (squares), 0.91 (circles) and 0.97 (rombs) J/cm2. The lines are guides to the eye. The panel (c) displays an example of the surface structures formed in the crater for irradiation in air at 1 kHz and its inset shows the 2D-FFT spectra generated from the SEM image.

"Origin of Ferroelectricity in Two Prototypical Hybrid Organic−Inorganic Perovskites"

Kai Li[1], Zhi-Gang Li[1], Jun Xu[1], Yan Qin[1], Wei Li[1], Alessandro Stroppa[2], Keith T. Butler[3], Christopher J. Howard[4], Martin T. Dove[5], Anthony K. Cheetham[6], and Xian-He Bu[1]

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JOURNAL OF THE AMERICAN CHEMICAL SOCIETY 144 (2022) 816

Hybrid organic−inorganic perovskite (HOIP) ferroelectrics are attracting considerable interest because of their high performance, ease of synthesis, and lightweight. However, the intrinsic thermodynamic origins of their ferroelectric transitions remain insufficiently understood. Here, we identify the nature of the ferroelectric phase transitions in displacive $[(CH_3)_2NH_2][Mn(N_3)_3]$ (Fig. 1) and order−disorder type $[(CH_3)_2NH_2][Mn(HCOO)_3]$ via spatially resolved structural analysis and ab initio lattice dynamics calculations. Our results demonstrate that the vibrational entropy change of the extended perovskite lattice drives the ferroelectric transition in the former and also contributes importantly to that of the latter along with the rotational entropy change of the A-site (Fig. 2). This finding not only reveals the delicate atomic dynamics in ferroelectric HOIPs but also highlights that both the local and extended fluctuation of the hybrid perovskite lattice can be manipulated for creating ferroelectricity by taking advantages of their abundant atomic, electronic, and phononic degrees of freedom.

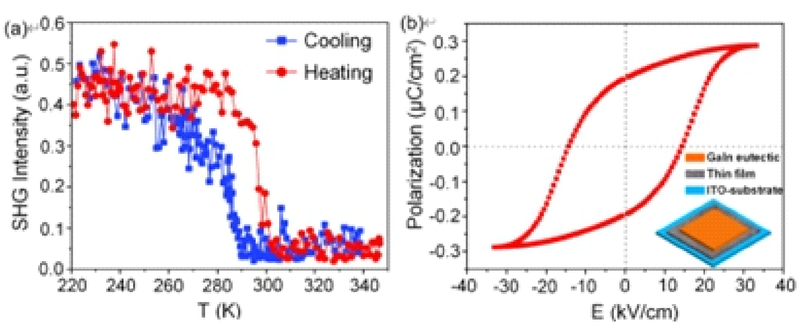

Fig. 1: SHG and ferroelectric characterizations of $[DMA][Mn(N_3)_3]$.
(a) Temperature-dependent SHG upon both heating and cooling. (b) The macroscopic polarization versus external voltage hysteresis loop. The inset in (b) shows the GaIn/$[DMA][Mn(N_3)_3]$ thin film/ITO capacitor architecture.

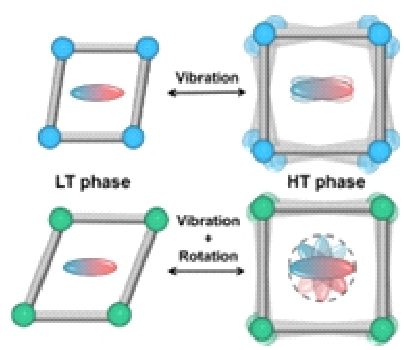

Fig. 2: Angular dependence Jc(θ) in semi-log scale (a) and pinning force (b), at 8 K and in fields of 2 and 16 T. The huge peak at H//ab is the signature of the pinning mechanism related to the 2D GB // ab defects. The small peak detectable at 16 T correlates with the 2D GB □ ab observed defects, and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

"Organic electrochemical transistors as novel biosensing platforms to study the electrical response of whole blood and plasma"

Valentina Preziosi[1], Mario Barra[2], Giovanna Tomaiuolo[1], Pasquale D'Angelo[3], Simone Luigi Marasso[3,4], Alessio Verna[4], Matteo Cocuzza[3,4], Antonio Cassinese[2,5] and Stefano Guido [1,6,7]

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JOURNAL OF MATERIAL CHEMISTRY B 10 (2022) 87

In this paper, for the first time, organic electrochemical transistors (OECTs), based on PEDOT:PSS active channels and driven by gold or platinum gate electrodes, were employed to investigate the electrical behaviour of human blood, plasma and alternative buffer solutions that inhibit red blood cell (RBC) aggregation. While the OECT response with the platinum gate was found to be completely dominated by the strong ionic concentration related to plasma, with gold electrodes we identified distinctive features of the steady state and transient OECT behaviour in blood and plasma. In a second set of experiments, we observed a clear dependence of the OECT response, in terms of the current modulation and the trans-conductance values as extracted from the transfer curves, on the concentration of RBCs suspended in Anticoagulant Citrate Dextrose (ACD) solutions supplemented with albumin. The role of negative charges distributed on the RBC surface was considered to explain the main findings observed in this study. Finally, RBC morphology was monitored just after the withdrawal and during the electrical experiments, with optical microscopy observations showing that the application of voltages lower than 1 V does not provide significant cell lysis or other structural modifications. Overall, this study demonstrates that OECTs can be applied as non-destructive analysis tools in combination with blood-based solutions.

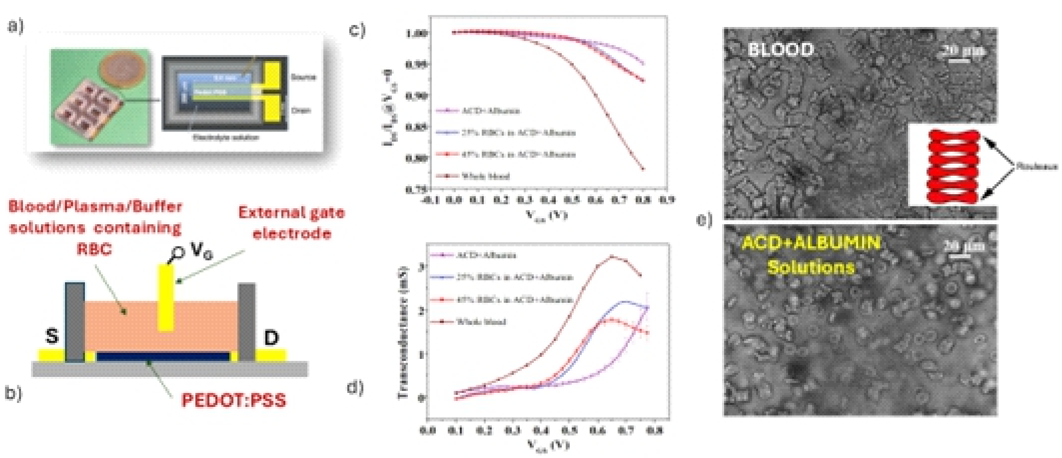

Fig. 1: a) Layout of the PEDOT:PSS OECTs; b) A schematic side view of the device configuration; c) OECT normalized transfer-curves (V_{DS}=-0.1V) and (d) transconductance values as a function of V_{GS} achieved for whole blood, ACD plus albumin, and RBCs at 45% and 25 % in ACD plus albumin; e) RBC morphology observed after the electrical tests in blood and ACD plus albumin solutions.

“Electron-Phonon Interaction and Longitudinal-Transverse Phonon Splitting in Doped Semiconductors”

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PHYSICAL REVIEW LETTERS 129 (2022) 185902

Electron-phonon interactions (EPI) shape many physical properties of condensed matter, from transport and optical properties to superconductivity. In polar semiconductors, the long-range Coulomb-mediated Fröhlich interaction dominates in the long wavelength limit, causing a splitting of longitudinal (LO) and transverse (TO) optical phonon modes and strongly affecting charge-carrier lifetimes. We study the impact of electron screening on the Fröhlich interaction in doped semiconductors by introducing a momentum-dependent generalization of Born effective charges (BECs), measuring the dipole moments of optical phonons. Our linear-response formulation, rooted in Density Functional Perturbation Theory, enables to treat screening effects via controlled approximations on the dielectric function, while evaluating ab initio in the undoped setup all other quantities contributing to the dielectric response. As an illustrative case, we study EPI and the LO-TO splitting of doped cubic silicon carbide. We further evaluate the electronic lifetime due to the EPI with LO phonons, often limiting intrinsic carrier mobility of polar doped semiconductors. Our work highlights the need of including free-carriers screening for a proper assessment of transport properties in doped semiconductors. The proposed approach for dealing with electronic screening lays the foundation for further extensions tackling other less conventional types of electron-phonon interactions, as well as giving access to the vibrational contribution to the full macroscopic dielectric function that shapes the dynamical structure factor probed in inelastic scattering experiments.

This work has been supported by the
EU Horizon 2020 program Graphene Core3 Grant No. 881603 and ERC-Synergy “MORE-TEM” project Grant No. 951215

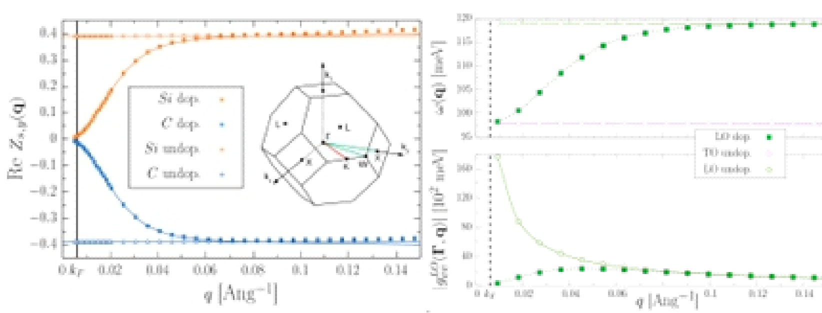

Fig. 1: (Left) Momentum-dependent BECs of Si and C in 3C-SiC along the high-symmetry red line displayed in the Brillouin zone for the undoped (empty circles) and doped case for a hole carrier concentration of p = 4.827 × 10^{15} cm^{-3} (full squares). (Right) LO and TO phonons and EPI in undoped (empty circles) and doped (full square) setup, highlighting the strong screening effect onto LO quantities. The vertical black line is drawn at the effective Fermi momentum k_F.

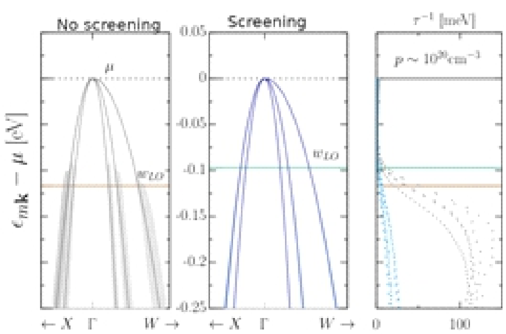

Fig. 2: Inverse lifetime scattering due to LO phonons evaluated with (light blue) and without (light gray) including screening effects for a hole concentration p ~10^{20} cm^{-3}, shown as linewidths in left and central panel and in absolute magnitude in right panel.

“Charge and Spin Order Dichotomy in $NdNiO_2$ Driven by the Capping Layer”

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PHYSICAL REVIEW LETTERS 123 (2022) 027002

Superconductivity in infinite-layer nickelates holds exciting analogies with that of cuprates, with similar structures and 3d-electron count. Using resonant inelastic x-ray scattering, we studied electronic and magnetic excitations and charge density correlations in Nd_1-xSrxNiO$_2$ thin films with and without an $SrTiO_3$ capping layer. We observe dispersing magnons only in the capped samples, progressively dampened at higher doping. We detect an elastic resonant scattering peak in the uncapped x=0 compound at wave vector (≈⅓,0), remindful of the charge order signal in hole doped cuprates. The peak weakens at x=0.05 and disappears in the superconducting x=0.20 film. The role of the capping on the electronic reconstruction far from the interface remains to be understood.

*This work was funded by the French National Research Agency (ANR) through the ANR MISSION ANR-18-CE- CE24-0008-01. D. P. has benefited from support from the initiative of excellence IDEX-Unistra (ANR-10-IDEX-0002-02) from the French national program Investment for the future. L. M., M. M. S., and G. G. acknowledge support by the project PRIN2017 “Quantum-2D” ID 2017Z8TS5B of the Ministry for University and Research (MIUR) of Italy. The work at NUS is supported by the Agency for Science, Technology, and Research (A*STAR) under its Advanced Manufacturing and Engineering (AME) Individual Research Grant (IRG) (A1983c0034) and by the Singapore Ministry of Education (MOE) under its Tier 2 program. R. A. acknowledges support by the Swedish Research Council (VR) under the Project 2020-04945. The synchrotron experiments were performed at ESRF synchrotron facility in France under proposals no. HC-4166 and HC-4628.*

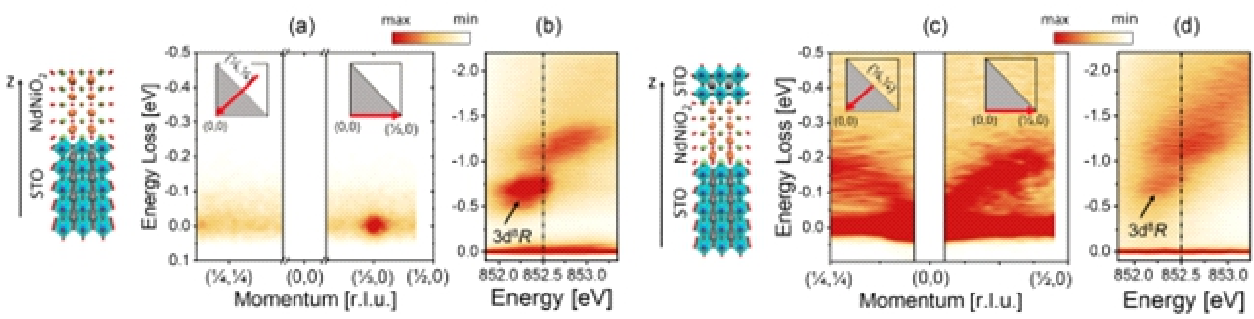

FIG. 1. Summary of the RIXS results for uncapped and STO capped NSNO(0) films. (a),(c) Energy-loss or in-plane-momentum scattering intensity maps along the high symmetry directions indicated in the insets, excited at incident photon energy ~852.5 eV (Ni^{1+} XAS peak) using π polarization. (b),(d) Energy-loss or excitation-energy maps across the Ni L_3 edge at 10° grazing incidence. Lateral panels show sketches of the structure of both (left) uncapped and (right) capped samples.

"Engineering dynamical couplings for quantum thermodynamic tasks"

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PHYSICAL REVIEW X QUANTUM 3 (2022) 01323

The development of quantum technologies requires a deeper understanding of the energetics and thermodynamics of nonequilibrium quantum systems. Key problems for the construction of future quantum machines include optimization of the energetic cost of quantum protocols, efficient heat management, and the development of effective strategies for cooling. The common framework to deal with these problems is to consider open quantum systems weakly coupled to an infinitely large environment, so that any information which has been transferred to the environment is lost and cannot be retrieved by the system, thus excluding memory effects. On the other hand, when dealing with small, nanoscale quantum systems the above assumptions easily break down, and one should develop methods and tools to address regimes beyond that framework, taking into account memory effects and system-environment quantum correlations.
In this work, we address the above questions in systems where the system-environment couplings are periodically modulated in time, and suitably engineered to perform thermodynamic tasks. In particular, asymmetric couplings to two heat baths can be used to extract heat from the cold reservoir and to realize an ideal heat rectifier, where the heat current can be blocked either in the forward or in the reverse configuration by simply tuning the frequency of the couplings modulation. The developed formalism is ideally suited to apply optimal control and machine learning techniques to quantum thermal machines.

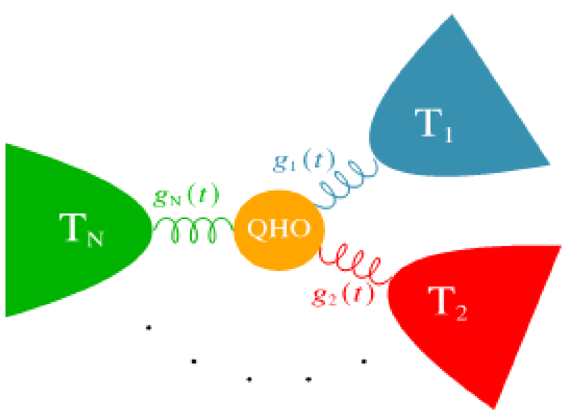

Fig. 1: Sketch of the proposed setup with modulated system/reservoir couplings.

“IBM quantum platforms: A quantum battery perspective”

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BATTERIES 8 (2022) 43

We characterize for the first time the performances of IBM quantum chips as quantum batteries, specifically addressing the single-qubit Armonk processor. By exploiting the Pulse access enabled to some of the IBM Quantum processors via the Qiskit package, we investigate the advantages and limitations of different profiles for classical drives used to charge these miniaturized batteries, establishing the optimal compromise between charging time and stored energy. Moreover, we consider the role played by various possible initial conditions on the functioning of the quantum batteries. As the main result of our analysis, we observe that unavoidable errors occurring in the initialization phase of the qubit, which can be detrimental for quantum computing applications, only marginally affect energy transfer and storage. This can lead counter-intuitively to improvements of the performances. This is a strong indication of the fact that IBM quantum devices are already in the proper range of parameters to be considered as good and stable quantum batteries comparable to state-of-the-art devices recently discussed in the literature.

This paper has been published with the support of Dipartimento di Eccellenza MIUR 2018–22.

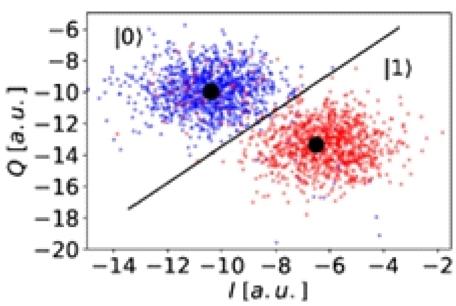

Fig. 1: Example of data distribution associated to the measurements of the state |0⟩ (blue dots) and |1⟩ in the *(I, Q)* plane (in arbitrary units) of the Armonk single-qubit device. Big black dots indicate the centers of the two distributions, while the black line separates them. The efficiency of the considered separation is roughly 97.4% for the ground state and 92.7% for the excited state.

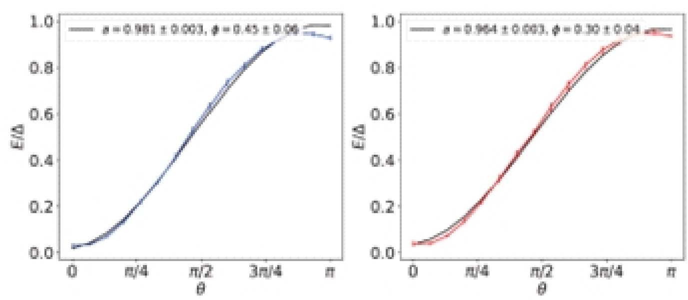

Fig. 2: Best fit of the energy stored into the QB (in units of Δ) as a function of θ (black curves). Data correspond to Gaussian pulses with σ= *tm/*, being *tm* =600ns (blue curve in the left panel) and *tm* =135ns (red curve in the right panels).

“Observation of Two-Mode Squeezing in a Traveling Wave Parametric Amplifier”

Martina Esposito[1,2,*] Arpit Ranadive[1,*] Luca Planat[1] Sebastien Leger[1] Dorian Fraudet[1] Vincent Jouanny[1] Olivier Buisson[1] Wiebke Guichard[1] Cecile Naud[1] Jose Aumentado[3] Florent Lecocq[3] and Nicolas Roch[1]

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PHYSICAL REVIEW LETTERS 128 (2022) 153603

Traveling wave parametric amplifiers (TWPAs) have recently emerged as essential tools for broadband near quantum-limited amplification. However, their use to generate microwave quantum states still misses an experimental demonstration. In this Letter, we report operation of a TWPA as a source of two-mode squeezed microwave radiation. We demonstrate broadband entanglement generation between two modes separated by up to 400 MHz by measuring logarithmic negativity between 0.27 and 0.51 and collective quadrature squeezing below the vacuum limit between 1.5 and 2.1 dB. This work opens interesting perspectives for the exploration of novel microwave photonics experiments with possible applications in quantum sensing and continuous variable quantum computing.

This work is supported by the European Union's Horizon 2020 research and innovation program under Grant Agreement No. 899561. M.E. acknowledges the European Union's Horizon 2020 research and innovation program under the Marie Sklodowska Curie (Grant Agreement No. MSCA-IF-835791). A.R. acknowledges the European Union's Horizon 2020 research and innovation program under the Marie Sklodowska Curie Grant Agreement No. 754303 and the “Investissements d'avenir” (ANR-15-IDEX-02) programs of the French National Research Agency.

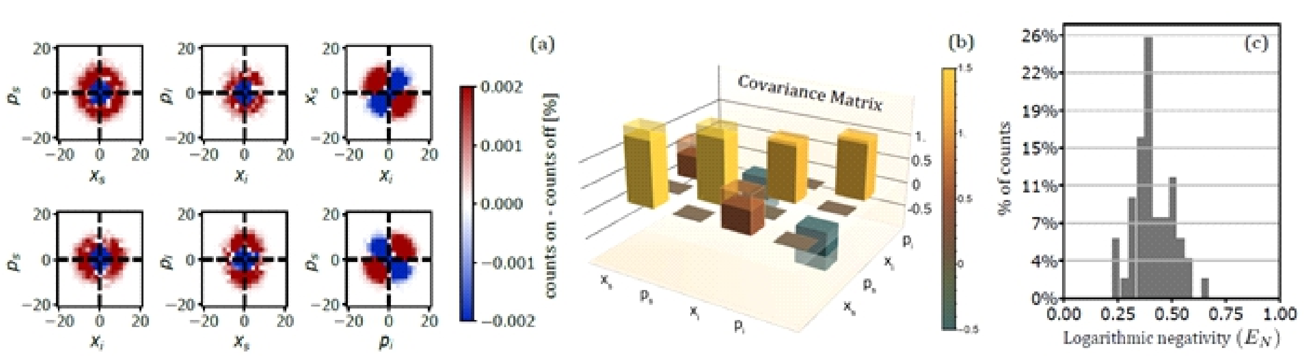

Fig. 1: (a) Measured quadrature phase space distribution (two-dimensional differential histogram plots: difference between pump on and pump off histograms) for 10^8 on-off acquisitions and detuning Δ = 200 MHz; the shape of the differential quadrature distributions in the phase spaces indicates the presence of two-mode correlations. (b) Reconstructed covariance matrix with uncertainty indicated by shaded regions. (c) Entanglement stability over time: histogram of 50 repeated entanglement measurements, each obtained from a set of 2 × 10^6 repeated on-off quadrature acquisitions. Pump frequency f_p = 4.415 GHz.

“Single photon detection in NbRe superconducting microstrips”

Mikkel Ejrnaes[1], Carla Cirillo[2], Daniela Salvoni[3], Federico Chianaese[4], Ciro Bruscino[4], Pasquale Ercolano[4], Antonio Cassinese[4,5], Carmine Attanasio[6], Giovanni Piero Pepe[4] & Loredana Parlato[4]

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APPLIED PHYSICS LETTERS 121 (2022) 262601

Detection of single infrared photons in superconducting microstrips of 4 nm thick disordered $Nb_{0.15}Re_{0.85}$ has been investigated. Microstrips with a critical temperature of 5.15 K and widths from 1.0 to 2.5 mm have been fabricated by optical lithography. We demonstrate single photon detection sensitivity at 1.5 mm wavelength at a temperature of 1.79 K. By investigating the detection process at this temperature, we find that the current bias threshold is at 21% of the depairing current. This threshold is similar to what should be observed in typical amorphous superconductors, which confirms that ultrathin disordered $Nb_{0.15}Re_{0.85}$ is an interesting material for superconducting microstrip single photon detectors that operate above 1 K.

This research was supported by the QUANCOM Project (MUR PON Ricerca e Innovazione No. 2014–2020 ARS01_00734).

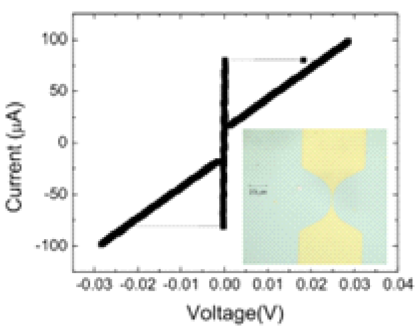

Fig. 1: Current–voltage characteristic at 1.79 K for a typical device. Inset: image of the same microstrip as realized by optical microscope.

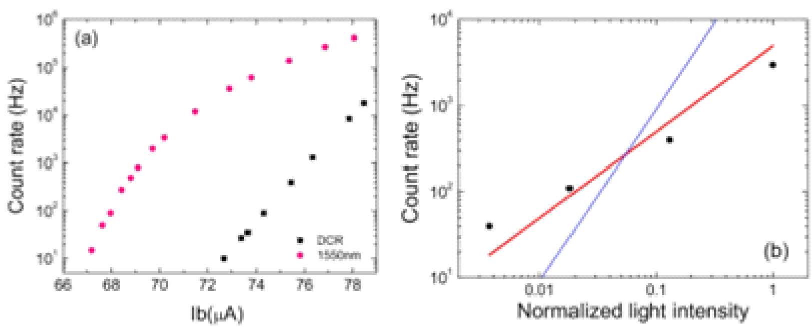

Fig. 2: Single photon detection in NbRe microstrip at 1.79 K. (a) Dark count rates (black squares) and photon count rates (magenta circles) at 1.5 mm. (b) The photon count rate as a function of the light attenuation at a bias current of 69.1 mA (black circles). The best single photon response fit (thick red line) and the best two-photon response (thin blue line) are also shown that affirms the single photon response of the NbRe microstrip.

"Electronic materials with nanoscale curved geometries"

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NATURE ELECTRONICS 5 (2022) 551

As the dimensions of a material shrink from an extended bulk solid to a nanoscale structure, size and quantum confinement effects become dominant, altering the properties of the material. Advances in nanostructuring techniques now allow electronic materials with 3D nanoscale architectures to be constructed from 2D and 1D materials, yielding three-dimensional shapes and configurations that would be impossible to achieve with bulk materials. The pursuit of these structures has largely been driven by the growing demand for next-generation electronics, based on electronic memory and logic devices with improved performance and reliability. Central to these customized appliances is the recognized possibility to modify and fine-tune the physical properties of essentially all electronic materials through a proper exploitation of geometric deformations and curvature effects at the nanoscale. Within this context, a key role turns out to be played by the characteristic radius of curvature associated to the curved geometric shape. In particular, in materials that exhibit long-range order, such as magnets and superconductors, the ground state and elementary excitations can be geometrically tuned when the radius of curvature is comparable to the magnetic length or the superconducting coherence length. Additionally, the interplay between nanoscale deformations and structure inversion asymmetry establishes a deep connection between electronic spin textures, spin transport properties, and the nanoscale shape of the system, making possible to induce novel topological states and modified Cooper pairs structures (Fig.1), thus leading to novel coherent effects for quantum technologies.

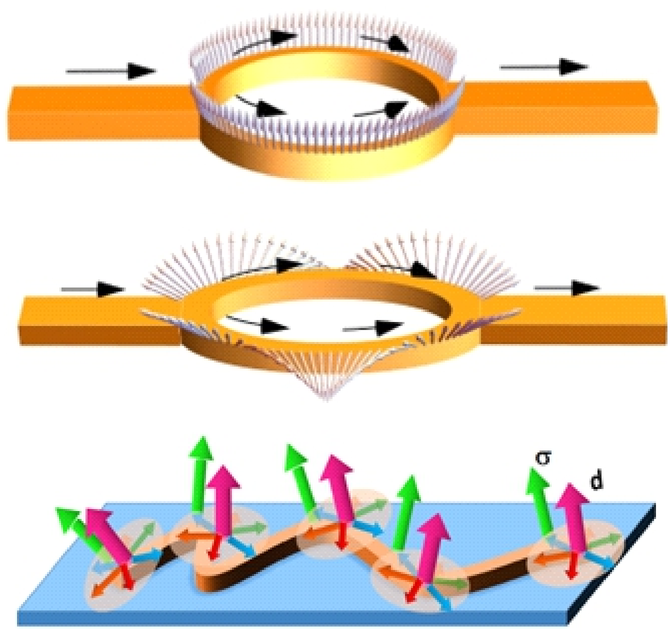

Fig. 1: Schematics of the spin textures realized in circular (top) and shape-deformed (middle) interferometers, as well as of the spin and superconducting d-vector textures in superconducting nanostructures, due to the interplay between inversion asymmetry and geometric shaping.

"Orbital selective switching of ferromagnetism in an oxide quasi two-dimensional electron gas"

R. Di Capua[1,2], M. Verma[3], M. Radovic[4], V. N. Strocov[4], C. Piamonteze[4], E. B. Guedes[4], N. C. Plumb[4], Y. Chen[2], M. D'Antuono[1,2], G. M. De Luca[1,2], E. Di Gennaro[1,2], D. Stornaiuolo[1,2], D. Preziosi[5], B. Jouault[6], F. Miletto Granozio[2], A. Sambri[2], R. Pentcheva[3], G. Ghiringhelli[7,8] & M. Salluzzo[2]

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NPJ QUANTUM MATERIALS 7 (2022) 41

Multi-orbital physics in quasi-two-dimensional electron gases (q2DEGs) triggers intriguing phenomena not observed in bulk materials, such as unconventional superconductivity and magnetism. Here, we investigate the mechanism of orbital selective switching of the spin-polarization in the oxide q2DEG formed at the (001) interface between the $LaAlO_3$, $EuTiO_3$ and $SrTiO_3$ band insulators. By using density functional theory calculations, transport, magnetic and x-ray spectroscopy measurements, we find that the filling of titanium-bands with $3d_{xz}/3d_{yz}$ orbital character in the $EuTiO_3$ layer and at the interface with $SrTiO_3$ induces an antiferromagnetic to ferromagnetic switching of the exchange interaction between Eu-$4f^7$ magnetic moments. The results explain the observation of the carrier density-dependent ferromagnetic correlations and anomalous Hall effect in this q2DEG, and demonstrate how combined theoretical and experimental approaches can lead to a deeper understanding of emerging electronic phases and serve as a guide for the materials design of advanced electronic applications.
This work has been supported by ERA-NET QUANTERA European Union's Horizon H2020 project QUANTOX under Grant Agreement No. 731473, Ministero dell'Istruzione, dell'Università e della Ricerca (MIUR) for the PRIN project TOP-SPIN (Grant No. PRIN 20177SL7HC) and for the PRIN 2010-11 project (Grant No. PRIN 2010-11–OXIDE), the EU COST program CA16218 (Nanocohybri), the German Research Foundation (DFG) within CRC/TRR80 (project number 107745057, subproject C3), CRC1242 (project number 278162697, subproject C02), and Computation time at the Leibniz Rechenzentrum Garching, project pr87ro and supercomputer magnitUDE (DFG grants INST 20876/209-1 FUGG, INST 20876/243-1 FUGG).

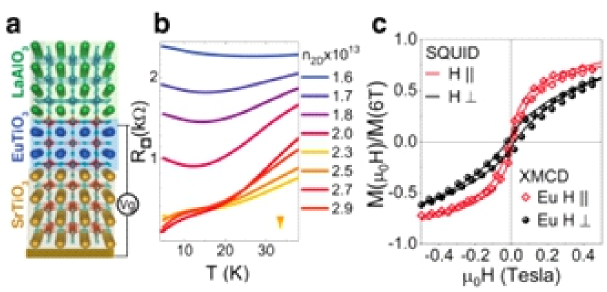

Fig. 1: (a) Sketch of the LAO/ETO/STO heterostructure. (b) Sheet resistance vs. temperature as a function of the gate voltage Vg. The arrow indicates increasing values of Vg from −30 to 30 V and 2D carrier density. © Eu- XMCD (scatter data) and SQUID magnetization (continuous lines) as function of the magnetic field parallel (red) and perpendicular (black) to the interface. The data are normalized to the saturation value.

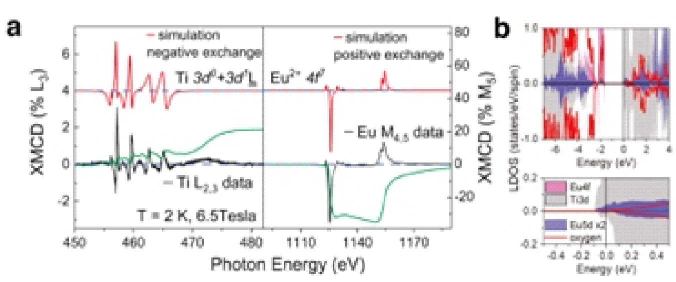

Fig. 1: (a) XMCD data at the Ti-L (left) and Eu-M (right) edges at 6.5 Tesla and 2 K. Red-lines are atomic multiplet simulations, green lines are integrals of the XMCD spectra. (b) Spin-resolved band structure and LDOS in the AFM state from the DFT+U calculations. Element and spin-resolved density of states from the DFT+U calculations for $EuTiO_3$ layers (average) with FM coupling. In the FM solution we do observe a substantial spin-polarization at −2 eV of both Eu-4f (magenta) and Eu-5d (blue) states, and an overlap between Ti-3d states (gray).

"High-performance Fe(Se,Te) films on chemical CeO_2-based buffer layers"

L. Piperno[1], A. Vannozzi[1], A. Augieri[1], A. Masi[1], A. Mancini[1], A. Rufoloni[1], G. Celentano[1], V. Braccini[2], M. Cialone[2], M. Iebole[2,3], N. Manca[2], A. Martinelli[2], M. Meinero[2,3], M. Putti[3] & A. Meledin[4,5]

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SCIENTIFIC REPORTS 13 (2023) 569

The fabrication of a Fe-based coated conductor (CC) becomes possible when Fe(Se,Te) is grown as an epitaxial film on a metallic oriented substrate. Thanks to the material's low structural anisotropy, less strict requirements on the template microstructure allow for the design of a simplified CC architecture with respect to the REBCO multi-layered layout. This design, though, still requires a buffer layer to promote the oriented growth of the superconducting film and avoid diffusion from the metallic template.
This paper reports on the deposition and epitaxial growth of Fe(Se,Te) superconducting films with and without seed layer on Zr-doped CeO_2 chemical buffer layers and their detailed characterization. The aim of this study is also to investigate and clarify the role of the seed layer on the final film structural and superconducting properties.
The chemical solution deposition method MOD was successfully employed and the quality of the obtained buffers was assessed via evaluation of structural and microstructural parameters. Deposition of the Fe(Se,Te) film/seed layer was performed via PLD. The epitaxial growth was successful and the optimal structure was retained from the buffer to the top layer. The seed layer not only favours chemical matching with the buffer, indirectly controlling the Se/Te ratio by allowing for low temperature deposition, but it also compensates for buffer layer roughness and protects the Fe(Se,Te) film layer from oxygen contamination. Superconducting properties of a Fe(Se,Te) film were evaluated via dc measurements, and a deeper characterization of the film was carried out via angular measurements. The sample shows a good in-field behavior at all the investigated temperatures, e. g., at 4.2 K the J_c^{18T} is more that 10% J_c^{sf}, with a negligible anisotropy in transport properties visible as a slight difference in J_c values for θ = 0° and θ = 90° (Fig. 1). The anisotropy parameters calculated as $\gamma_H = H_{irr}^{90°} H_{irr}^{0°}$ is about 1.3 for the whole investigated temperature range with an upturn at high temperature (Fig. 2). For applications at low temperature, thus, the material shows good superconducting properties and low anisotropy, demonstrating the effectiveness and potential of the proposed architecture.

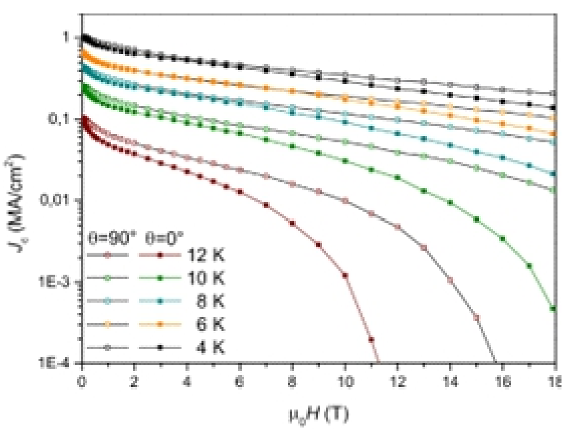

Fig. 1: J_c vs B at different temperatures in a Fe(Se,Te) film deposited on a MOD CZO-buffered YSZ.

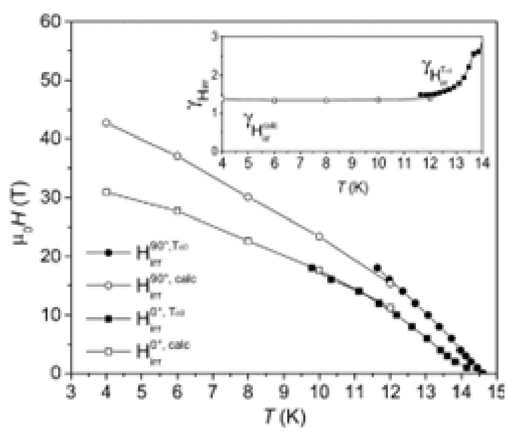

Fig. 2: H_{irr} vs T derived from R vs T measurements (full symbols) and the pinning force fits (empty symbols) in a Fe(Se,Te) film deposited on a MOD CZO-buffered YSZ. Inset: anisotropy of H_{irr}

"Superconductivity induced by gate-driven hydrogen intercalation in the charge-density-wave compound 1T-$TiSe_2$"

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COMMUNICATIONS PHYSICS 6 (2023) 202

The search for a roadmap towards high-temperature superconductivity is one of the hot topics of modern material science. During the last decade, conventional BCS superconductivity at 203 K and 250 K was shown to occur in H_2S [1] and YH_{10} [2] at very high pressures (~200 GPa). These ground-breaking experiments proved that in BCS-conventional superconductors Tc is not upperbounded, provided the proper mixture of high density of states and high phonon frequencies is available. At the same time, such experiments proposed hydrogen as a highly effective way to tune the phononic spectra and, thus, for inducing superconductivity with a high critical temperature.

This work presents the effects of hydrogen intercalation in 1T-$TiSe_2$ via the ionic-liquid gating method. The H-intercalated compound, namely H_xTiSe_2, becomes a superconductor at about 3.6 K and, interestingly, and its intrinsic charge-density-wave state coexists with superconductivity. The H-induced superconducting phase is possibly gapless-like and multi-band in nature, in contrast with those induced in $TiSe_2$ via copper, lithium, and electrostatic doping. This unique behavior is supported by ab initio calculations showing that high concentrations of H dopants induce a full reconstruction of the band structure, although with little coupling between electrons and high-frequency H phonons. Such findings provide a promising approach for engineering the ground state of transition metal dichalcogenides and other layered materials via gate-controlled protonation.

References

[1] A. P. Drozdov, et al, Conventional superconductivity at 203 kelvin at high pressures in the sulphur hydride system. Nature 525, 73 (2015).

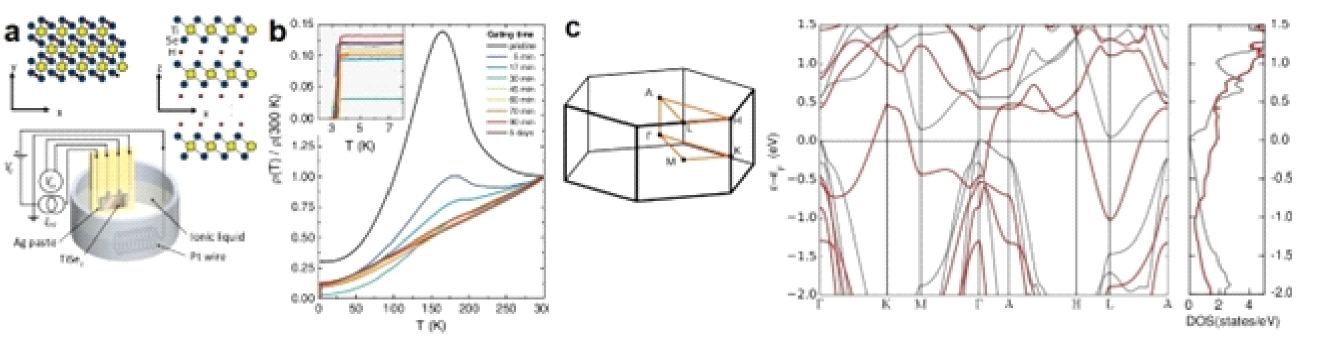

Figure a Sketch of a $TiSe_2$ crystal immersed in the electrochemical cell for ionic liquid gating-induced protonation, including the electrical connections. The side panel shows a ball-and-stick model of the H_x-$TiSe_2$ structure with x⊠1. b Temperature dependence of the electrical resistivity ρ(T) normalized by the value at 300 K of a series of $TiSe_2$ crystals gated for increasing amounts of time. The inset shows a magnification of the T range where the superconducting transitions are observed. c The Brillouin zone with high symmetry points and the electronic band structure and the density of states of 1T-H_1TiSe_2 (red) compared with the pristine 1T-$TiSe_2$ dispersion (gray).

"Calorimetric evidence for two phase transitions in Ba1−xKxFe$_2$As$_2$ with fermion pairing and quadrupling states"

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NATURE COMMUNICATIONS 14 (2023) 6734

In the phase diagram of $Ba_{1-x}K_xFe_2As_2$, many studies claimed the existence of a Lifshitz transition tuned by K doping around x=0.75, which involves the change of the gap structure from the original s± symmetry, to a s- or d- wave symmetry, passing by an intermediate region where time reversal symmetry is broken and the superconducting order parameter becomes complex (s+is or s+id). S+is superconductors exhibit a range of unconventional properties, and the time-reversal symmetry breaking (BTRS) is mostly manifested in spontaneous currents around nonmagnetic impurities, that result in local magnetic fields. The BTRS state sets in at T_c^{Z2}, and beyond the mean field approximation, a situation in which $T_c > T_c^{Z2}$ can arise, implying the existence of a bosonic metallic non-superconducting state above T_c, in which time-reversal symmetry is broken.

In this work, a combination of specific heat and spontaneous Nernst effect measurements have been performed in order to prove the presence of a bosonic BTRS state in Ba-122, at $T_c^{Z2} > T_c$. The specific heat data DeltaCel/T, presented in fig. 1, exhibit the superconducting phase transition at T_c, followed by a step-like anomaly above Tc highlighted by the black arrow. This anomaly cannot be caused by superconducting phases surviving at higher temperatures since no superconducting signal is observed in the magnetic susceptibility (blue curves). To investigate whether this anomaly can be associated with the BTRS state, the specific heat has been compared with spontaneous Nernst effect (SNE) (fig. 2). A SNE signal ≠0 appears at T_c^{Z2}=13.25K, highlighted by the vertical green dashed line, and coincides with the high-temperature anomaly in the specific heat. These observations commonly agree in detecting the breaking of time-reversal symmetry at TcZ2 and allow to confirm the existence of a bosonic metallic state in the range T_c <

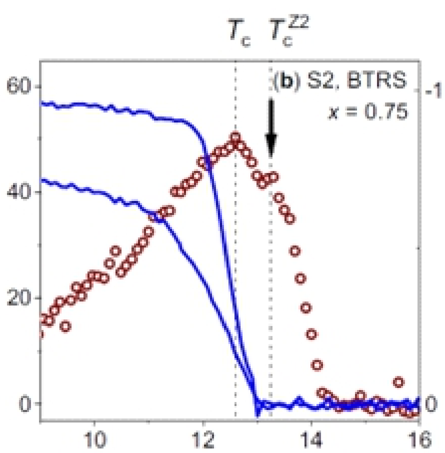

Fig. 1: Specific heat (red dots) and magnetic susceptibility (blue curves) of $Ba_{1-x}K_xFe_2As_2$ with x=0.75. The vertical black arrow indicates T_c^{Z2}.

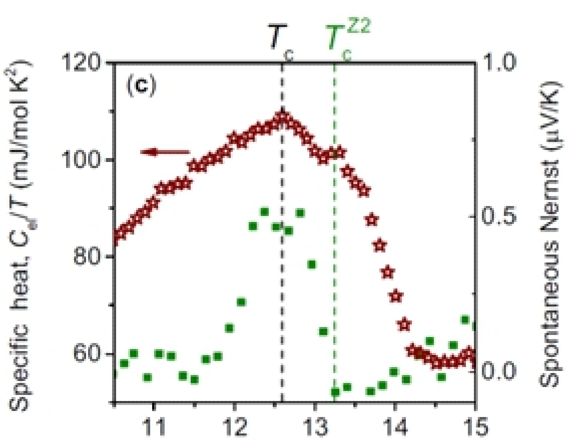

Fig. 2: Specific heat (left-axes) and Spontaneous Nernst effect (right-axes) of $Ba_{1-x}K_xFe_2As_2$ with x=0.75.

"A self-powered CNT-Si photodetector with tuneable photocurrent"

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ADVANCED ELECTRONIC MATERIALS 9 (2023) 2200919

A photodetector with bias-tuneable current is realized by adding a film of single-walled carbon nanotubes (CNT), forming a CNT/Si_3N_4/Si capacitor, to a prefabricated Pt-Ti/Si_3N_4/Si metal-insulator-semiconductor (MIS) diode. Electrical characterization of the entire device is performed to extract the temperature-dependent ideality factor and Schottky barrier height in the framework of the thermionic emission theory. The CNT/Si_3N_4/Si capacitor increases the reverse current of the parallel Pt-Ti/Si_3N_4/Si MIS diode by adding a Fowler-Nordheim tunnelling current at high reverse voltage bias. This feature endows the photodetector with two different photocurrent levels, photoresponsivity up to 370 mA/W and external quantum efficiency up to 50% at 950 nm wavelength. The device also shows a different photoresponse when light is focused on the CNT/Si_3N_4/Si region or around the Pt-Ti/Si_3N_4/Si structure. The photodetector can also be used as an optoelectronic Boolean logic device, in which the applied voltage bias and the incident light are the two input signals, and the photocurrent is the output. Furthermore, light generates a photocurrent at zero volt.

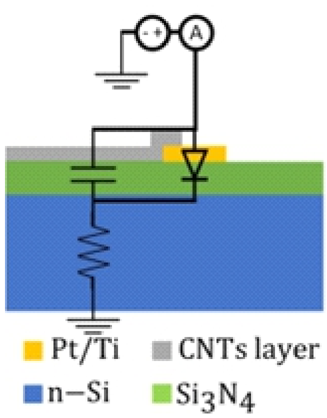
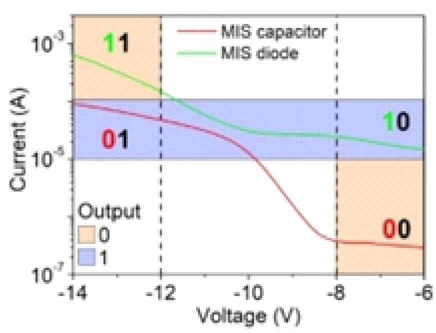


Fig. 1: Cross-section of the device under study.



x (Vbias)	y (Light on)	x ⊕ y
-8V<V<-6V	MIS capacitor	0
-8V<V<-6V	MIS diode	1
-14V<V<-12V	MIS capacitor	1
-14V<V<-12V	MIS diode	0

Fig.2: CNT-Si device IV characteristics under illumination on the MIS diode (green curve) and the MIS capacitor (red curve). Table shows that CNT-Si device suitable for optoelectronic Boolean logic application, working as a XOR.

"Laser-induced periodic surface structuring for secondary electron yield reduction of copper: dependence on ambient gas and wavelength"

Jijil JJ. Nivas [1,2,3], Meilin Hu[2], Mohammadhassan Valadan[1,4], Marcella Salvatore[2,5], Rosalba Fittipaldi[1,6], Marcel Himmerlich[7], Elena Bez[7,8], Martino Rimoldi[7], Andrea Passarelli[1], Stefano L. Oscurato[2], Antonio Vecchione[6], Carlo Altucci[1,4], Salvatore Amoruso[1,2,3], Antonello Andreone[1,2,3], Sergio Calatroni[7], Maria Rosaria Masullo[1]

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APPLIED SURFACE SCIENCE 622 (2023) 156908

One of the main limitations for future high-performance accelerators operating with positively charged particles is the formation of an electron-cloud inside the beam vacuum chamber, giving rise to instabilities. The Secondary Electron Yield (SEY) of the beam-facing surfaces gives a measure of the mechanism which drives this phenomenon. The laser-induced periodic structure formation on Cu surfaces has been demonstrated as a promising process to reduce SEY. We studied the laser process influence on SEY for 515 and 1030 nm wavelength femtosecond pulses on copper in different ambiences (air, nitrogen, vacuum). Depending on used process conditions, the surface composition differs, structures with varying aspect ratio are formed, i.e., periodic ripples and large-scale channels. Treatment in air at 515 nm is the most efficient for the formation of deeper structures allowing SEY maximum reduction first down to 1.6–1.7 and then below unity upon electron irradiation, thereby totally suppressing electron-cloud. Increasing the laser fluence, SEY will further reduce due to surface roughness enhancement via nanoparticle re-deposition. This study reveals the crucial role of laser induced periodic surface structures (LIPSS) treatments to enable surface treatment in large-scale accelerator installations, where particle-free components are desired, and paves the way to potential future applications.

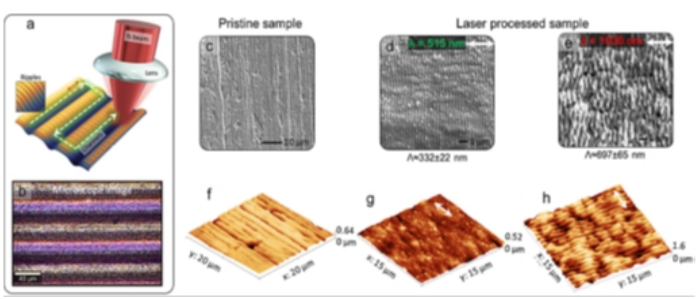

Fig. 1: (a) Graphical representation of the structural surface changes induced by the implemented laser treatment, (b) optical micrograph of a Cu sample processed at sample scanning velocity v=1 mm/s with 515 nm fs pulses. SEM images of the copper surface before laser processing (c), after irradiation in ambient air and v=1 mm/s with at 515 nm (d) and 1030 nm (e). AFM images of the copper surface before (f) and after laser processing at 515 nm (g) and 1030 nm (h).

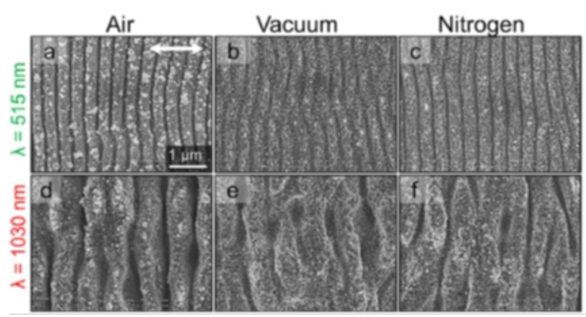

Fig. 2: SEM images of LIPSS generated with two different laser wavelengths (515 and 1030 nm) in three different environments (air, vacuum, and nitrogen ambience) at v=1.5 mm/s. The white double-headed arrow in (a) indicates the laser beam polarization direction.

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“Dissipation Mechanisms and Superlubricity in Solid Lubrication by Wet-Transferred Solution-Processed Graphene Flakes: Implications for Micro Electromechanical Devices”

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ACS APPLIED NANO MATERIALS 6 (2023) 11443

Solution-processed few-layer graphene flakes, dispensed to rotating and sliding contacts via liquid dispersions, are gaining increasing attention as friction modifiers to achieve low friction and wear at technologically relevant interfaces. Vanishing friction states, i.e. superlubricity, have been documented for nearly-ideal nanoscale contacts lubricated by individual graphene flakes. However, there is no clear understanding if superlubricity might persist for larger and morphologically disordered contacts, as those typically obtained by incorporating wet-transferred solution-processed flakes into realistic microscale junctions. Here, we address the friction performance of solution-processed graphene flakes by means of colloidal probe Atomic Force Microscopy (AFM). We use a state-of-the-art additive-free aqueous dispersion to coat micrometric silica beads, which are then sled under ambient conditions against prototypical material substrates, namely, graphite and the transition metal dichalcogenides (TMDs) MoS_2 and WS_2. High resolution microscopy proves that the random assembly of the wet-transferred flakes over the silica probes results into an inhomogeneous coating, formed by graphene patches that control contact mechanics through tens-of-nanometers tall protrusions. Atomic-scale friction force spectroscopy reveals that dissipation proceeds via stick–slip instabilities. Load-controlled transitions from dissipative stick–slip to superlubric continuous sliding may occur for the graphene–graphite homojunctions, whereas single- and multiple-slips dissipative dynamics characterizes the graphene–TMD heterojunctions. Numerical simulations demonstrate that the thermally activated single-asperity Prandtl–Tomlinson (PT) model comprehensively describes friction experiments involving different graphene-coated colloidal probes, material substrates, and sliding regimes. Our work establishes experimental procedures and key concepts that enable mesoscale superlubricity by wet-transferred liquid-processed graphene flakes. Together with the rise of scalable material printing techniques, our findings support the use of such nanomaterials to approach superlubricity in micro electromechanical systems.

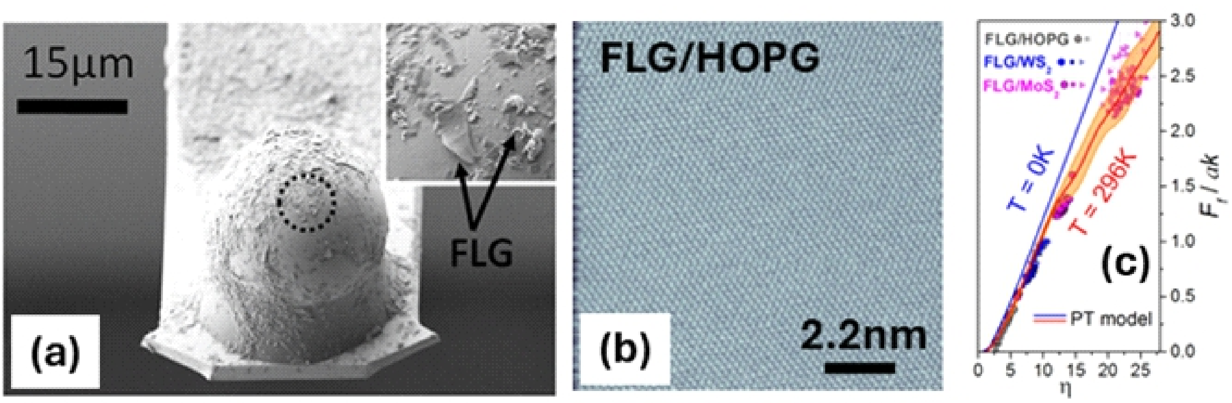

Fig. 1 (a) SEM micrograph of a graphene-coated colloidal AFM probe. At higher magnification, the silica surface appears partially covered by FLG flakes (inset). (b) Atomic-scale lateral force map acquired on HOPG by means of a graphene-coated probe. (c) Comparison of experimental friction data with predictions from the PT model, for graphene-coated probes sled against HOPG, WS_2 and MoS_2. Superlubricity takes place only for the FLG/HOPG interface and for the PT parameter values

"Near-90° Switch in the Polar Axis of Dion–Jacobson Perovskites by Halide Substitution"

Weixin He,[1] Yali Yang,[2] Chuanzhao Li,[3] Walter P. D. Wong,[4] Fanica Cimpoesu,[5] Ana Maria Toader,[5] Zhenyue Wu,[4] Xiao Wu,[4] Zexin Lin,[4] Qing-hua Xu,[4] Kai Leng,[3]* Alessandro Stroppa,[6]* and Kian Ping Loh[1]*

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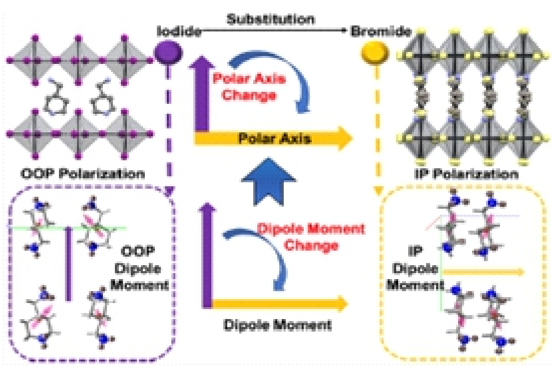
JOURNAL OF THE AMERICAN CHEMICAL SOCIETY 145 (2023) 14044

Ferroelectricity in two-dimensional hybrid (2D) organic–inorganic perovskites (HOIPs) can be engineered by tuning the chemical composition of the organic or inorganic components to lower the structural symmetry and order–disorder phase change. Less efforts are made toward understanding how the direction of the polar axis is affected by the chemical structure, which directly impacts the anisotropic charge order and nonlinear optical response. To date, the reported ferroelectric 2D Dion–Jacobson (DJ) [PbI4]2– perovskites exhibit exclusively out-of-plane polarization. Here, we discover that the polar axis in ferroelectric 2D Dion–Jacobson (DJ) perovskites can be tuned from the out-of-plane (OOP) to the in-plane (IP) direction by substituting the iodide with bromide in the lead halide layer. The spatial symmetry of the nonlinear optical response in bromide and iodide DJ perovskites was probed by polarized second harmonic generation (SHG). Density functional theory calculations revealed that the switching of the polar axis, synonymous with the change in the orientation of the sum of the dipole moments (DMs) of organic cations, is caused by the conformation change of organic cations induced by halide substitution.



The polar axis in ferroelectric 2D Dion–Jacobson (DJ) perovskites can be tuned from the out-of-plane (OOP) to the in-plane (IP) direction by substituting the iodide with bromide in the lead halide layer.

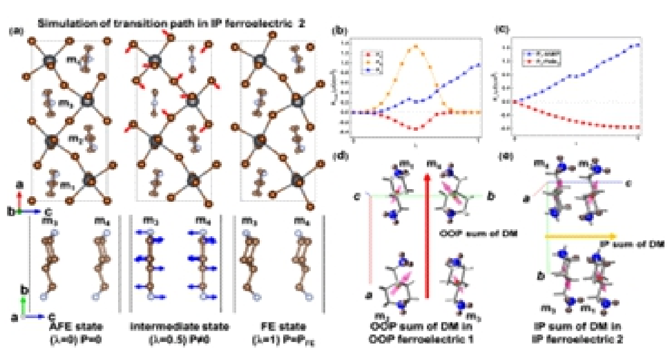


Fig.2 (a) Transition path in IP ferroelectric 2 from AFE (P = 0, λ = 0) to FE (+P, λ = 1) phases, containing the top view (along the b axis) of the perovskite inorganic lattice and side view (along the a axis) of 4AMP cations. m1–m4 indicate the four 4AMP molecules in the unit cell. The red arrows represent the direction of significant atomic displacements. The blue arrows indicate the converted path of 4AMP cations. (b) Total FE polarization as a function of λ in IP ferroelectric 2. (c) Polarization contribution of the 4AMP cations and inorganic lattice in IP ferroelectric 2. (d,e) Scheme of the sum dipole moment (DM) in OOP ferroelectric 1 and IP ferroelectric 2, respectively. Direction and size of the arrows illustrate the dipole orientation and magnitude, respectively.

“Flexible fully organic indirect detector for megaelectronvolts proton beams”

Sabrina Calvi[1,2], Laura Basiricò[3,4], Sara M. Carturan[5,6], Ilaria Fratelli[3,4], Antonio Valletta[1,2], Alberto Aloisio[7,8,9,10], Stefania De Rosa[1], Felix Pino[5,6], Marcello Campajola[8], Andrea Ciavatti[3,4], Luca Tortora[1,2,11], Matteo Rapisarda[1,2], Sandra Moretto[5,12], Matteo Verdi[3,4], Stefano Bertoldo[6], Olivia Cesarini[6], Paolo Di Meo[8], Massimo Chiari[13], Francesco Tommasino[14,15], Ettore Sarnelli[8,9], Luigi Mariucci[1,2], Paolo Branchini[1,2], Alberto Quaranta[15,16] and Beatrice Fraboni[3,4]

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NPJ FLEXIBLE ELECTRONICS 7 (2023) 5

A flexible, fully organic detector for proton beams is presented here. The detector operates in the indirect mode and is composed of a polysiloxane-based scintillating layer coupled to an organic phototransistor, that is assessed for flexibility and low-voltage operation (V = −1 V), with a limit of detection of 0.026 Gy min−1. We present a kinetic model able to precisely reproduce the dynamic response of the device under irradiation and to provide further insight into the physical processes controlling it. This detector is designed to target real-time and in-situ dose monitoring during proton therapy and demonstrates mechanical flexibility and low power operation, assessing its potential employment as a personal dosimeter with high comfort and low risk for the patient. The results show how such a proton detector represents a promising tool for real-time particle detection over a large area and irregular surfaces, suitable for many applications, from experimental scientific research to innovative theranostics.

“Pattern Formation by Electric-Field Quench in a Mott Crystal”

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NANO LETTERS 23 (2023) 7782

The control of the Mott phase is closely linked to the spatial reorganization of electronic states. Out-of-equilibrium driving forces often give rise to electronic patterns that are not present in equilibrium, though their nature can be difficult to discern. In this study, we reveal the formation of nanoscale patterns in the Mott insulator Ca_2RuO_4. We demonstrate how an applied electric field induces a spatial reconstruction of the insulating phase, which, uniquely upon deactivating the electric field, reveals nanoscale stripe domains (Fig. 1). These stripes contain regions with differing octahedral distortions, which we directly observe using high-resolution scanning transmission electron microscopy (Fig. 1). The nanotexture is influenced by the orientation of the electric field, and it is both nonvolatile and rewritable. We also provide theoretical simulations of the charge and orbital reconstruction triggered by the dynamic changes in the electric field, offering a clear mechanism behind the formation of the stripe phase (Fig. 2). Our findings pave the way for the development of nonvolatile electronics.

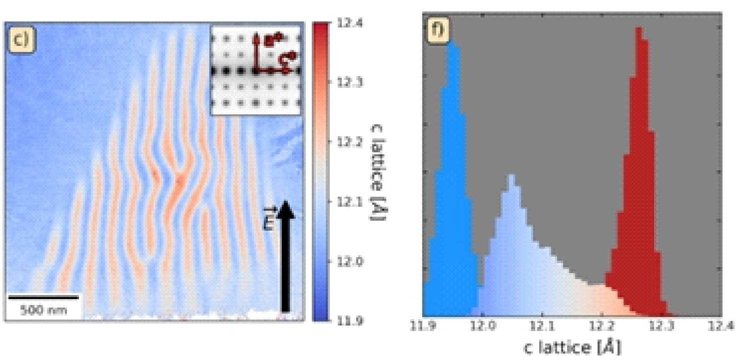

Fig. 1: (a) The real-space map of the c lattice parameter after the voltage is quenched to zero amplitude for a given orientation of the electric field. (b) The histogram of the lattice parameter at zero voltage and maximum applied voltage indicates the distribution of the lattice parameters amplitude for the corresponding voltage configurations. We find that after the quench the distribution exhibits a bimodal line shape reflecting the occurrence of stripes or domains with unit cells having short and long c lattice parameters.

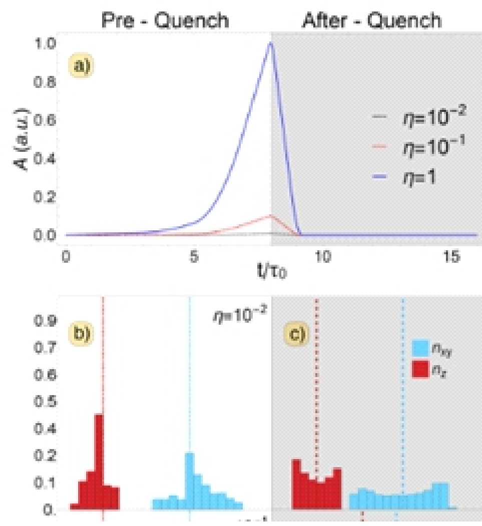

Fig. 2: (a) The electric field is introduced via a time dependent potential that is switched off after a characteristic time interval. The η parameter sets the strength of the electric field. Time distribution of the density of the d_{xy} and (d_{xz}, d_{yz}) orbitals at the ruthenium site before (b) and after the quench (c) demonstrating orbital and structural reconstructions from short to elongated octahedra.

"Hybrid quantum thermal machines with dynamical couplings"

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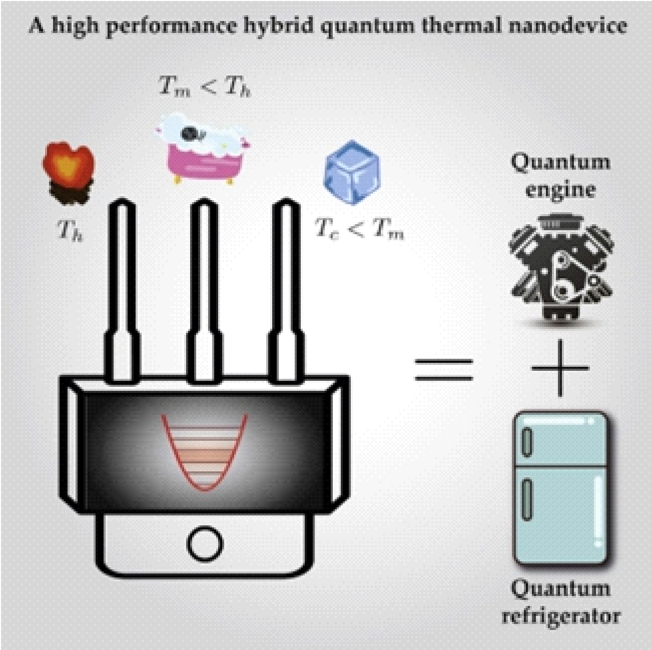
ISCIENCE 26 (2023) 106235

Quantum thermal machines can perform useful tasks, such as delivering power, cooling, or heating. In this work, we consider hybrid thermal machines, that can execute more than one task simultaneously. We characterize and find optimal working conditions for a three-terminal quantum thermal machine, where the working medium is a quantum harmonic oscillator, coupled to three heat baths, with two of the couplings driven periodically in time. We show that it is possible to operate the thermal machine efficiently, in both pure and hybrid modes, and to switch between different operational modes simply by changing the driving frequency. Moreover, the proposed setup can also be used as a high-performance transistor, in terms of output–to–input signal and differential gain. Owing to its versatility and tunability, our model may be of interest for engineering thermodynamic tasks and for thermal management.



"Coexistence and coupling of ferroelectricity and magnetism in an oxide two-dimensional electron gas"

J. Bréhin[1], Y. Chen[2], M. D. Antuono[2,3], S. Varotto[1], D. Stornaiuolo[2,3], C. Piamonteze[4], J. Varignon[5], M. Salluzzo[2], and M. Bibes[1]

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NATURE PHYSICS 19 (2023) 823

Multiferroics are compounds in which at least two ferroic orders coexist, typically ferroelectricity and some form of magnetism. While magnetic order can arise in both insulating and metallic compounds, ferroelectricity is in principle only allowed in insulators, although ferroelectric metals have been proposed and several two-dimensional systems have been reported to behave in this way. However, their combination with and coupling to magnetic order have not been realized thus far. Here we show the coexistence of ferroelectricity and magnetism in an oxide-based two-dimensional electron gas. We report a modulation of the Ti-O polar displacements depending on the ferroelectric polarization direction, and a voltage-induced hysteresis of the sheet resistance that is reminiscent of the ferroelectric polarization loop. The transport properties of the electron gas display an anomalous Hall effect and magnetoresistance that can both be modulated and cycled by switching the remanent polarization, demonstrating a magnetoelectric coupling. Our findings provide new opportunities in quantum matter that stem from the interplay between ferroelectricity, ferromagnetism, metallicity and Rashba spin–orbit coupling.

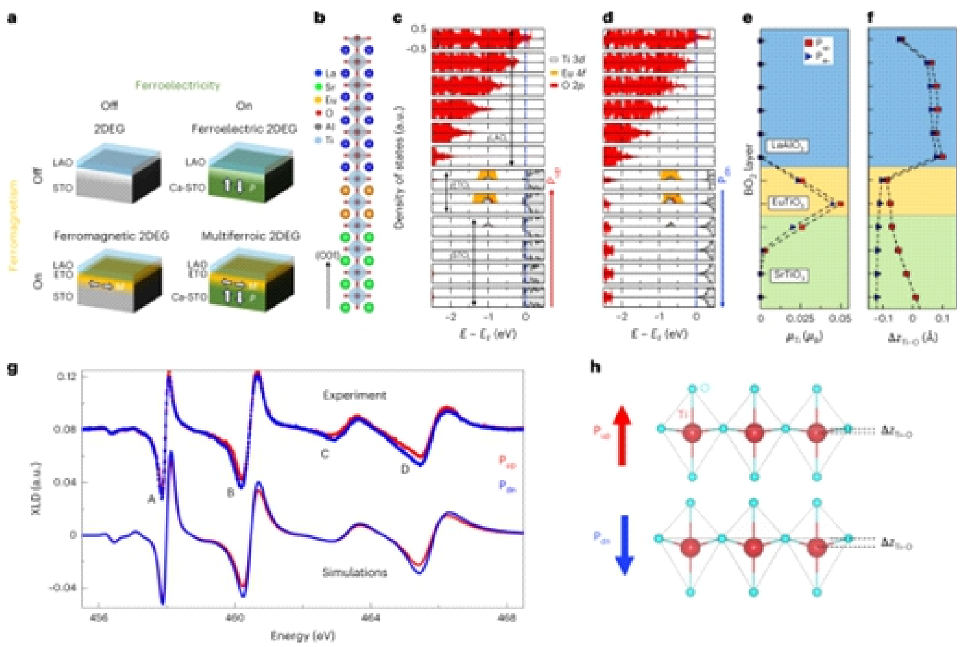

Fig. 1: (a) Multiferroic 2DEG. (b) A sketch of the slab configuration. (c,d) Layer-decomposed projected density of states on O 2p and Ti d states as a function of a polarization pointing toward (c) and outward from (d) the interface. (e) Computed magnetic moments on Ti cations for the two polar states. (f) The relative displacement of the B cation. (g) The X-ray linear dichroism spectra at the Ti L3,2 edge measured at 2 K and the ferroelectric remanence for Pup and Pdn (top) and atomic multiplet simulations (bottom). (h) Sketches of the TiO6 octahedra .

Reference:
[1] J. Bréhin, et. al., Nat. Phys. 19, 823 (2023)
[2] D. Stornaiuolo, et. al., Nat. Mater. 15, 278 (2016)

"Investigation of dark count rate in NbRe microstrips for single photon detection"

P. Ercolano[1], C. Cirillo[2], M. Ejrnaes[3], F. Chianese[4], D. Salvoni[5], C. Bruscino[1], R. Satariano[3], A. Cassinese[1,6], C. Attanasio[7], G.P. Pepe[1] and L. Parlato[1*]

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SUPERCONDUCTOR SCIENCE AND TECHNOLOGY 36 (2023) 105011

Superconducting microstrip single photon detectors (SMSPDs) received great interest since they are expected to combine the excellent performance of superconducting nanostrip single photon detectors with the possibility to cover large active areas using low-cost fabrication techniques. In this work, we fabricated SMSPDs based on NbRe to investigate the role of vortices in the dark counts events in this innovative material and in devices with micrometer size. We realized devices with different layouts, namely single microstrips and pairs of parallel microstrips. The energy barriers related to the motion of single vortices (VS) or vortex–antivortex pairs (VAP), responsible of detection events, have been determined and compared with the ones of similar devices based on different materials, such as MoSi, WSi and NbN. The analysis confirms the high potential of NbRe for the realization of superconducting single photon detectors with large areas.

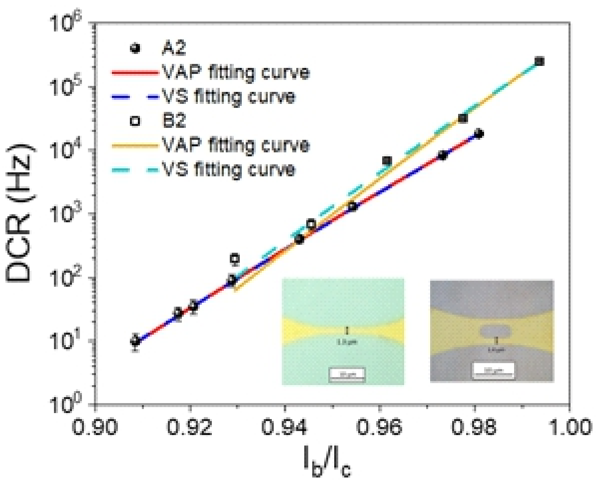


Fig. 1: Dark Count Rate (DCR) vs the normalized bias current for the single strip A2 (black solid circles) and the pair of parallel strips B2 (black open squares), at T = 1.79 K and T = 1.57 K respectively. The solid and dashed lines are the VAP. Inset: microscope photo of the NbRe single strip A2 (left) and of the pair of parallel strips B2 (right) realized by optical lithography.

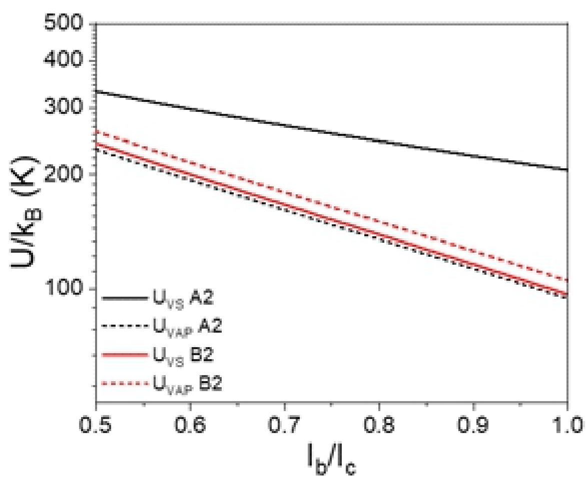
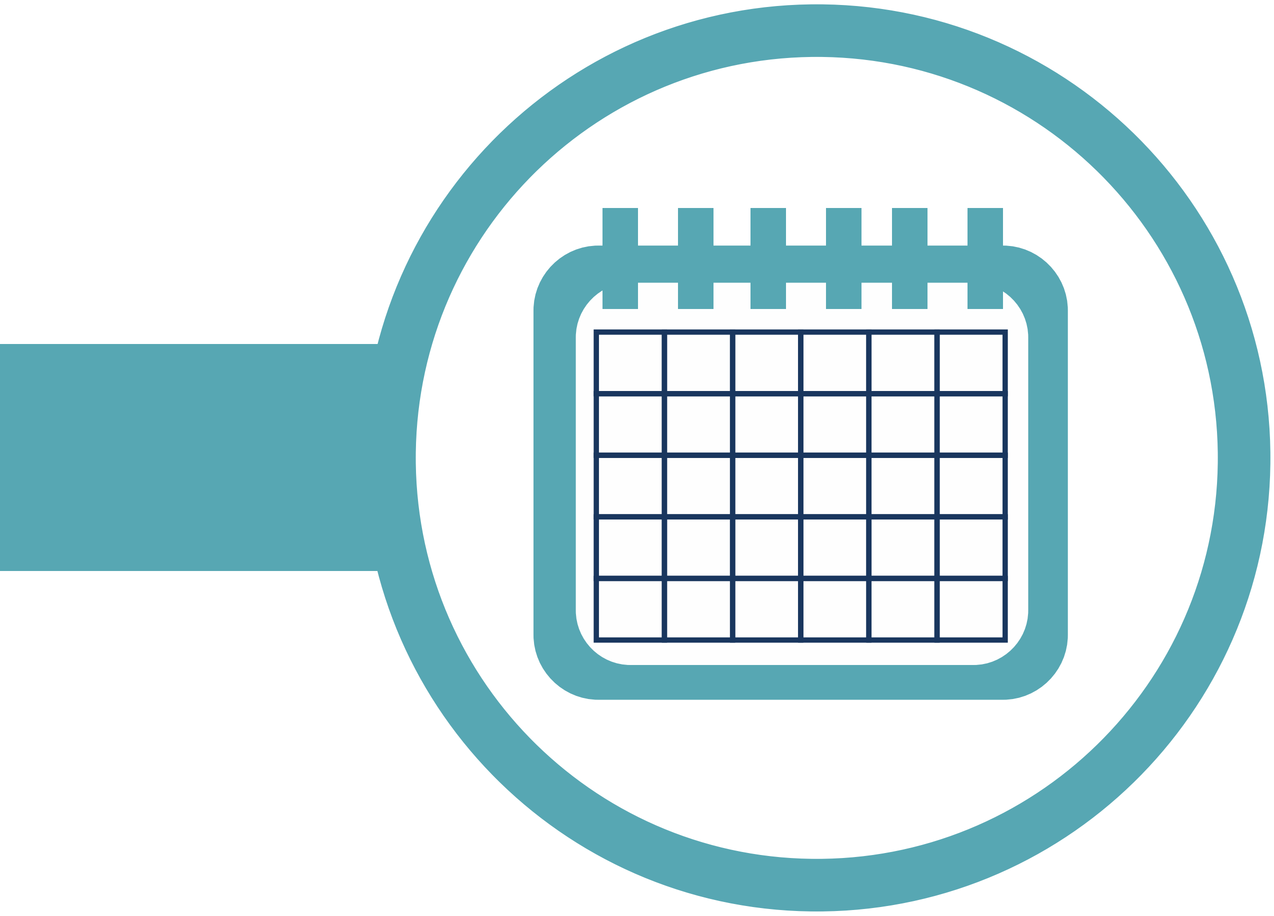


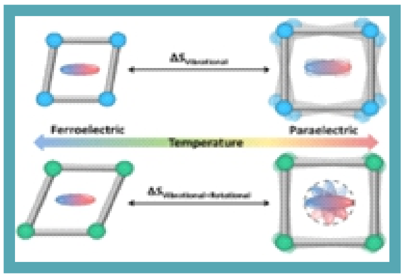
Fig. 2: Energy barriers for the single strip A2 (black lines) and the pair of parallel strips B2 (red lines), at $T = 1.79$ K and $T = 1.57$ K, respectively. Continuous (dashed) lines correspond to VS (VAP) processes.



Life and events

Life and Events

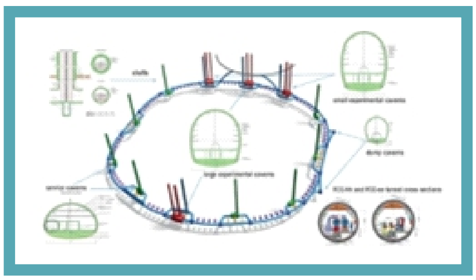
2022



19 January 2022

Unveiled the nature of the ferroelectric phase transition of two prototypical hybrid organic-inorganic perovskites

Dr. Alessandro Stroppa, Profs Xian-He Bu and Wei Li (Nankai University) and collaborators, an international team from Italy, China, UK, and Australia, have unveiled the nature of the ferroelectric phase transition of two prototypical ferroelectric hybrid organic-inorganic perovskites (HOIPs), including displacive $[(CH_3)_2NH_2][Mn(N_3)_3]$ and order-disorder type $[(CH_3)_2NH_2][Mn(HCOO)_3]$. The multidisciplinary study has been published in the Journal of the American Chemical Society.



20 January 2022

A new Memorandum of Understanding for the Future Circular Collider

A new Memorandum of Understanding (MOU) for the Future Circular Collider (FCC) for the new phase of the design of the accelerator was signed by Dr Michael Benedikt, the leader of the study, and Dr Fabio Miletto Granozio, SPIN director, as representative of CNR.

At the same time, Dr Emilio Bellingeri and Dr Alessandro Leveratto were chosen as member and deputy member, respectively, in the FCC International Collaboration Board. Within this MOU, partners will explore the technical and financial feasibility of a future hadron collider at CERN with a centre-of-mass energy of at least 100 TeV and with an electron-positron Higgs and electroweak factory as a possible first stage.

21 January 2022

SPIN Regular Seminar Series

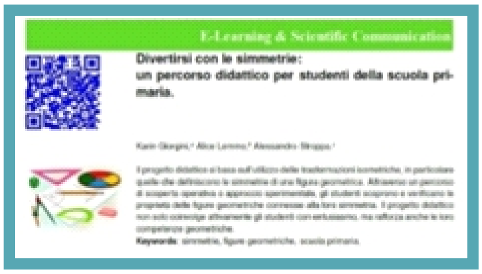
Starting from January 2022, a regular seminar activity of the SPIN Institute has been established. The seminar activity, held every last Thursday of each month in on-line form, has been addressed to young researchers, experienced researchers, Institute associates and to scientists of international recognition.

10 February 2022

New book: "I materiali superconduttori per le applicazioni su larga scala"

"I materiali superconduttori per le applicazioni su larga scala": a book on applied superconductivity, written by Ilaria Pallecchi, Valeria Braccini and Andrea Malagoli, has been published by in riga edizioni. This manual, while maintaining an informative nature, intends to deepen some aspects introducing the reader to the materials used in large-scale applications of superconductivity, e.g. for transport of power, in manufacturing very high field magnets, in the nuclear fusion, etc.

2022


E-Learning & Scientific Communication

Divertirsi con le simmetrie:
un percorso didattico per studenti della scuola primaria.

Keywords

22 February 2022

“Divertirsi con le simmetrie: un percorso didattico per studenti della scuola primaria” a report published in Smart E-lab

Alessandro Stroppa (CNR-SPIN) and collaborators from the Department of Human Science of the University of L'Aquila have recently promoted several didactic projects covering complex topics such as Mathematical Infinity, Geometry and Chemistry, and Symmetry for Primary school children. Starting from the experience of a didactic project focalized on the concept of Symmetry, more recently, Alessandro and co-workers published a detailed report "Divertirsi con le simmetrie: un percorso didattico per studenti della scuola primaria” in the on-line CNR journal, Smart E-lab.


Bernhard Keimer   Giacomo Ghiringhelli   Pengcheng Dai

28 February 2022

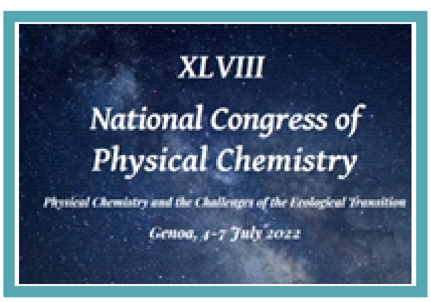
Giacomo Ghiringhelli wins the 2022 Kamerlingh-Onnes Prize

Giacomo Ghringhelli, Professor of Physics at Politecnico di Milano and research associate of SPIN, is one the winners of the 2022 Kamerlingh-Onnes Prize for his “pioneering resonant inelastic X-ray scattering (RIXS) experiments on cuprate superconductors”. Ghiringhelli shared the Kamerlingh-Onnes Prize with Prof. Bernhard Keimer (Max Planck Institute for Solid State Research, Stuttgart, Germany), and Prof. Pengcheng Dai (Rice University, Houston, USA) for their outstanding experimental work on spin and charge correlations in high temperature superconductors using X-ray and neutron scattering.

28 February 2022

“2D-Materials LEGO” has a new component: Evidence for a single-layer van der Waals multiferroic

An international collaboration among the experimental groups led by Prof. Riccardo Comin and Prof. Nuh Gedik at Massachussets Institute of Technology and the theoretical groups led by Dr. Silvia Picozzi at CNR-SPIN and by Prof. Antia Botana at Arizona State University resulted in the discovery of multiferroicity persisting down to the monolayer limit in the transition-metal-based van der Waals material NiI2. These results have been published in the paper: “Evidence for a single-layer van der Waals multiferroic”, Nature 602, 601 (2022).



07 March 2022

XLVIII National Congress of Physical Chemistry

The 48th National Congress of Physical Chemistry (XLVIII CNCF, Genoa 2022), promoted by the Physical Chemistry Division of the Società Chimica Italiana, has been organized by the Physical Chemists of the University of Genoa and hosted at the University facilities (4-7 July). The scientific program included Soft matter, Physical chemistry of life science, Energy, Environment and Ecological transition, Theoretical and computational chemistry, Advanced functional materials, Advanced characterization techniques. The Scientific and Organizing Committees involved SPIN researchers (A. Martinelli) and several SPIN associates.

2022

14 March 2022

SPIN involved in the final session of the Intellectual Property Award 2021 at Expo Dubai 2020

The technology "*Low-power magnetometer for improved sensors integration in future vehicles*", developed by CNR-SPIN and CNR-IFN in the framework of the EU FET-Open OXiNEMS project, funded from the European Union's Horizon 2020 programme under grant agreement No 828784, was presented in the macro area "Future Mobility" for the final session of the "Intellectual Property Award 2021" held at Expo Dubai 2020. Federico Maspero, team delegate and former CNR-IFN research fellow operating at PoliFAB presented the tecnology that led to the Italian patent application No. 102020000007969 and the International patent application No. WO2021209891 A1.

28 March 2022

Interactive exhibition "Colori e Immagini della Scienza"

From Friday 1 to Thursday 21 April 2022, at the University Library of Genoa, the interactive exhibition "Colori e Immagini della Scienza" has been held. It displayed the 88 works created by high school students participating in the Genoa section of the "Art & Science across Italy" project. The project, organized by the INFN and ended in May in Naples with an exhibition at the National Archaeological Museum (MANN), has seen the participation of approximately 270 students welcomed by the INFN section of Genoa, the Departments of Physics and Chemistry of the University of Genoa, the IIT, the SPIN and IMEM Institutes of the CNR. The SPIN researchers contributed to the initiative by disseminating their research activities with seminars.

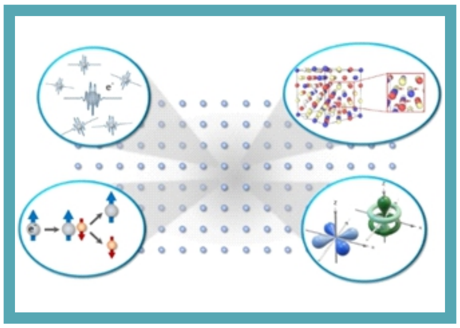
31 March 2022

SPIN participation in the "Italian Quantum Weeks"

SPIN took part in the "Italian Quantum Weeks" project, that was hosted by 17 Italian cities, with events for schools and the general public. SPIN contributed to the development of the program and contents at a national level and was among the promoters of the events held in Naples together with the University of Naples Federico II, CNR-INO and CNR-ISASI.

From 1 to 8 April 2022, the Physics Museum of Polo Museale of University of Naples Federico II hosted the exhibition "Dire l'indicibile – la sovrapposizione quantistica", dedicated to the principle of superposition. The concluding event, on April 8th , was opened by young Neapolitan researchers who discussed "Quantum technologies in the shadow of Vesuvius" and closed by the web-conference "From bit to qbit: the advantage of being quantum". SPIN personnel involved included Salvatore Abate, Mario Barra, Carla Cirillo, Mario Cuoco, Martina Esposito, Gianluca Passarelli, Alberto Porzio.

2022



05 April 2022

Workshop "Electronic Correlations, Emergent Phenomena, and Quantum Materials"

The Institute SPIN-CNR together with the Department of Physics of the University of Salerno, the Flatiron (Simons Foundation, NY, USA), the University of Würzburg (Germany), and the Technische Universität Wien (Austria), organized the Workshop *"Electronic Correlations, Emergent Phenomena, and Quantum Materials"- Lectiones Amalfitanae*, held in Amalfi on April 10-13, 2022, addressing the advancement in theoretical approaches and materials design strategies in functional materials with the aim of providing a perspective on the ways-to-go towards new concepts, effects and materials with an impact particularly in oxide spintronics, spin-orbitronics, two-dimensional (2D) electronics, topotronics, etc..

11 April 2022

The activities of the "Eduambiente" project have been inaugurated

With a series of meetings, scheduled between 11 and 13 April, involving young students, scientists and policy makers, the activities of the "Eduambiente" Project have been inaugurated. The project, approved under Law 6 of 2000 (Contributions to the diffusion of scientific culture), involves the students of the "don Carlo La Mura" high school, the "Galvani-Opromolla" middle school and the "don Enrico Smaldone" IC in the Angri area (SA). The SPIN Institute, coordinated by Salvatore Abate, participated in collaboration with INRIM and CNR-IMAA, by supporting schools in the development of training courses on the study of scientific knowledge on climate, the social impact of climate change, new methodologies for environmental education. SPIN has also supervised the creation of a laboratory for environmental monitoring with the use of low-cost electronics and sensors.

23 May 2022

PCTO 2022 "Le Nanotecnologie e la Meccanica Quantistica"

The SPIN Institute at the Naples Unit has activated a PCTO (Path for Transversal Skills and Orientation) involving the III E class of the Evangelista Torricelli High School of Somma Vesuviana. The students had the opportunity to learn about the aspects of the work of the researcher in Physics and about some of the main challenges of modern Physics of Matter, from the laws of Quantum Mechanics to the development of new materials and innovative devices for applications in electronics, energy, quantum technologies and sensors. The course ended on May 12, with the participation of about 300 students in the event *"A scuola di astroparticelle – In Viaggio verso la Fisica Moderna"*. Mario Barra, Giovanni Cantele, Fabio Chiarella, Mikkel Ejrnaes and Alberto Porzio contributed to this PCTO under the supervision of Ettore Sarnelli.

Life and Events

2022

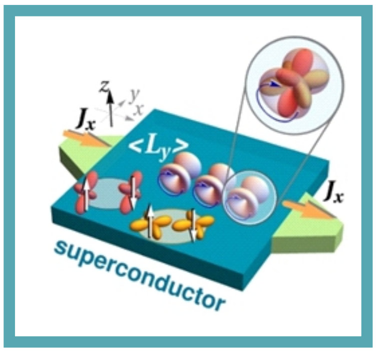
07 June 2022

Conference "Gender asymmetries in STEM"

On Friday June, 17th, Villa Cambiaso in Genoa hosted the conference entitled "Gender asymmetries in STEM". Organized by the Department of Physics of the University of Genoa, in collaboration with the Equal Opportunities Committee of the University, the conference sees the contribution of various institutions, including CNR-SPIN, and the participation in the organizing committee of Marina Putti and Valeria Braccini. The conference, in hybrid format, included three plenary talks and a round table focused on the theme of training in scientific disciplines in relation to the problem of gender. The event was closed by the theatrical performance *"La forza nascosta"*.

07 June 2022

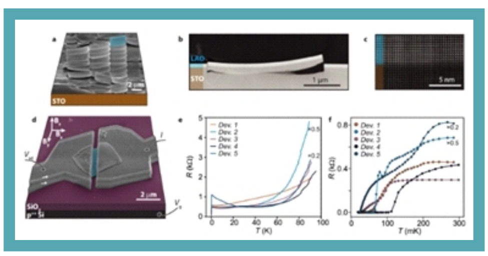
Novel orbitronic effects in superconductors



The research team composed of Mario Cuoco, from the SPIN-CNR, Maria Teresa Mercaldo and Claudio Guarcello from the Physics Department of Salerno University, and Luca Chirolli and Francesco Giazotto from NANO-CNR, in Pisa, recently discovered an effect of converting supercurrent into a current that carries only the orbital information of electrons without dissipation. The effect is colossal given the intensity with which it manifests itself, when compared to the case of the conversion of supercurrent into a spin current. The results have been published in Phys. Rev. Lett. 128, 217703 (2022), and selected as "Editor's Suggestion".

18 June 2022

A Two-Dimensional Superconducting Electron Gas in Freestanding $LaAlO_3/SrTiO_3$ Micromembranes



The research team, composed by CNR-SPIN of Naples, CNR-IMM of Catania, Università degli Studi di Napoli Federico II, Niels Bohr Institute, University of Copenhagen and the Technical University of Denmark, has developed a scheme for the fabrication of conducting $LaAlO_3/SrTiO_3$ (LAO/STO) membrans on a Si/SiO_2 substrate. The demonstrated ability to form superconducting nanostructures of LAO/STO membranes, with electronic properties similar to those of the bulk counterpart, opens opportunities for integrating oxide nanoelectronics with silicon-based architectures.
The results have been published in Nano Letters 2022, doi.org/10.1021/acs.nanolett.2c00992.

26 July 2022

The High-Performance Computing-Europa3 program

HPC Europa3

HPC-Europa3
Certificate of Appreciation
The HPC-Europa3 programme presents this
CERTIFICATE OF APPRECIATION
to: Dr Alessandro Stroppa of CNR-SPIN
This certificate is presented in recognition of the exceptionally high number of visitors Dr Stroppa has supported through the HPC-Europa3 programme, his dedication to supporting junior researchers in particular, and his strong commitment to continuing to support these visits throughout the Covid-19 pandemic.

Signed: HPC-Europa3 Transnational Access Co-ordinator
12th April 2022

The High-Performance Computing-Europa3 program offered access to world-class HPC systems for academic and industrial researchers and provided a great opportunity to computational scientists to expand their scientific network by hosting researchers from different international Institutions. Within the program, a special recognition was given to Alessandro Stroppa who has been selected as scientific host for 20 successful applications, including scientists from China, India, Europe, USA and Third World countries. 7 young researchers conducted the research project by remote, and 13 scientists visited the CNR-SPIN unit in L'Aquila from September 2021 to April 2022, also thanks to the Department of Life, Health and Environmental Sciences (Prof. Guido Macchiarelli, Director MeSVA) of University of L'Aquila.

Life and Events

2022

26 July 2022

Workshop “Challenges in Designing Room Temperature Superconductors”

The international workshop “Challenges in Designing Room Temperature Superconductors” was held in L'Aquila, on July 26th-29th 2022. The aim of this workshop was to bring together international experts in ab-initio superconductivity, crystal structure prediction, material informatics, as well as researchers in high-pressure and low-dimensional physics, to design new strategies for the discovery of better superconductors. This workshop was the first after the LaH10 discovery to actively promote cross-fertilization among different theoretical and experimental fields.

27 July 2022

Best Young Researcher Article Award – 2022

With the paper “Anyons in Quantum Hall Interferometry” published in Nature Review Physics, Matteo Carrega was the winner of the Best Young Research Article Award for the 2022 edition. As for the past years, by this award, SPIN intends to give maximum visibility to the work of young (under 35 years) researchers of its community being first authors of distinguished papers published in international peer-reviewed journals. In 2022, for the first time, all the candidates were also involved in the organization of a workshop, held online on July 14th 2022, where they could introduce their scientific work. The first BYRAA workshop was chaired by G. Campagnano and A. Guarino.

01 August 2022

Three new Research Areas for SPIN

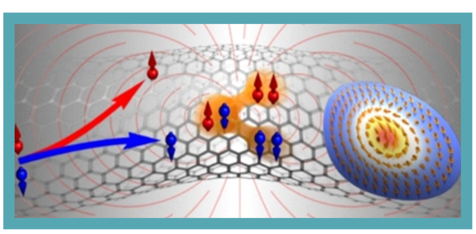
After a long discussion phase supervised by the Director Fabio Miletto Granozio together with the Institute Council and involving the entire community through different initiatives, three new Research Areas have been identified as the main pillars of the SPIN future scientific organization.
The new Research Areas, which will be officially activated later this year, will be named:

- Superconductors and Innovative materials for Energy and Environment
- Functional and Complex Materials for Innovative Electronics and Sensing
- Quantum Science and Technologies

The whole SPIN researcher group will be almost equally spread over these three sectors. Future steps will be aimed to select a Responsible for each Area and a proper number of research sub-areas able to satisfactorily map all the present topics developed by the SPIN community.

15 September 2022

“Electronic materials with nanoscale curved geometries” published in Nature Electronics



The exciting developments in the discovery and exploitation of novel effects induced by curvature at the nanoscale allow to define a completely new field – curved nanoelectronics – as reported in a paper published in the prestigious journal Nature Electronics(Gentile, P. et al., *Electronic materials with nanoscale curved geometries,* Nat Electron (2022)) by an international research group including Paola Gentile and Mario Cuoco of CNR-SPIN Salerno, Carmine Ortix of the Physics Department of the University of Salerno, and researchers from the HZDR of Dresden (Germany), of the University of Manchester (UK) and of the Lanzhou University (China). The article examines in detail the origin of curvature effects at the nanoscale and illustrates their potential applications in innovative electronic, spintronic and superconducting devices, leading to novel coherent effects for quantum technologies.

2022

23 September 2022

The European Researchers' Night 2022

On Friday 30th September and Saturday October 1st the "European Researchers' Night 2022" has been celebrated. Promoted by the European Commission since 2005, the "Night" is now the most established scientific dissemination event in Europe, with the simultaneous participation of 25 countries. SPIN researchers participated in this event, with the following activities:

In Genoa, on September 30th, Luca Pellegrino held a seminar at the Emanuele Luzzati Gardens entitled "Micro and nanomechanics: materials, techniques and devices".

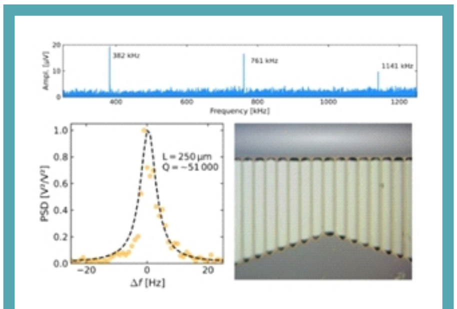
In L'Aquila, Alessandro Stroppa, proposed activities for primary schools: "Having fun with symmetries" (K. Giorgini, A. Stroppa); "From Geometry to Geo-Matter" (G. Dionisi, A. Stroppa); "Colored arithmetic" (S. D'Agostino, A. Stroppa);

In Naples, on September 30th Mario Barra, Fabio Chiarella, Mikkel Ejrnaes, Paolo Scotto Di Vettimo set up the exhibit *"Of materials, technologies and innovation"*. Martina Esposito and Gianluca Passarelli animated the activity *"Quantum technologies in the shadow of Vesuvius"* in a form of interactive quiz. Between October 2nd and 8th, Mario Barra and Loredana Parlato participated in the event "Paths around man from micro to macrocosm" in Torre del Greco (NA).

In Salerno, on October 14th, within the event "Le Strade del Campus" at the University of Salerno, Nadia Martucciello, Gaia Grimaldi, Salvatore Abate, Paola Gentile, Filomena Forte, Anita Guarino, Mariateresa Lettieri and Carla Cirillo participated with the activity entitled *"The neighborhoods of physics and emerging technologies in Salerno - From classical physics to the applications of advanced physics to sustainability and environmental protection"*.

23 September 2022

"Stress Analysis and Q-Factor of Free-Standing (La,Sr)MnO_3 Oxide Resonators" published in SMALL



Researchers from the CNR-SPIN and the University of Genoa showed that micro-mechanical-systems made of (La,Sr)MnO_3, a well-known magnetic oxide, have the potential to be employed as highly sensitive micromechanical resonators for detectors, paving the way toward the development of full-oxide MEMS/NEMS sensors. The results have been published in:

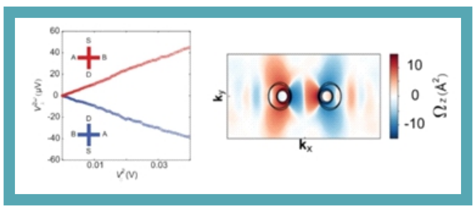
N. Manca, F. Remaggi, A. E. Plaza, L. Varbaro, C. Bernini, L. Pellegrino, and D. Marré, "Stress Analysis and Q-Factor of Free-Standing (La,Sr)MnO_3 Oxide Resonators", Small 18, 2202768 (2022). DOI: 10.1002/smll.202202768

2022

19 October 2022

Science Festival 2022

The 20th edition of the Science Festival, having as keyword "languages" was held in Genoa from October 20 to November 1, 2022.
SPIN participated with (i) the exhibition "Fusione nucleare: ci siamo" , (ii) the conference "E luce fu... LITER della fusione nucleare", meeting with Paola Batistoni (ENEA), Gustavo Granucci (CNR), Piergiorgio Sonato (University of Padua RFX consortium), moderated by Silvia Kuna Ballero;
(iii) the exhibition "Siamo tutti magnetici" – *Come rilevare il magnetismo che è in noi*, at Munizioniere of Palazzo Ducale.



19 October 2022

A strong non-linear Hall effect in bilayer $MoTe_2$

Kian Ping Loh's group at the National University of Singapore (NUS) successfully synthesized, for the first-time, high-quality, centimeter-scale $MoTe_2$ bilayer and trilayer films. Precise control of thickness enabled the team to investigate thickness-dependent symmetry-related effects showing that the out-of-plane ferroelectricity appears only for the bilayer crystal due to the broken centrosymmetry, while non-linear Hall effect (NLH) occurs for both bilayer and trilayer $MoTe_2$ crystals in the non-centrosymmetric T_d phase. A theoretical study performed by Alessandro Stroppa of CNR-SPIN and Kunihiro Yananose and Jaejun Yu of the Seoul National University (SNU) calculated the Berry curvature dipoles of these phases, providing a theoretical framework for the experimentally confirmed NLH. The results have been published in Nature Communications 13, 5465 (2022).

28 October 2022

New Coordinators for the SPIN Research Areas

The SPIN Institute Council has selected the coordinators for the three SPIN research Areas. The new coordinators are:
Valeria Braccini for "Superconductors and Innovative materials for Energy and Environment"
Nicola Manca for "Functional and Complex Materials for Innovative Electronics and Sensing"
Marco Salluzzo for "Quantum Science and Technologies"
The selection concludes a long process that included, the identification of the new SPIN research Areas, based on the results of a poll that involved the whole SPIN community; the opening of a call to foster the application of candidates for the role of Area coordinator; the selection of the best candidate for each Area, by the SPIN Council, based on a well-defined evaluation grid.

31 October 2022

CNR President Carrozza visits the Territorial Research Area of Genoa

The President of the CNR, Maria Chiara Carrozza, together with the General Director Giuseppe Colpani, visited the Territorial Research Area of Genoa in Corso Perrone. After a meeting in the Sala Azzurra in the presence of a large representation of the Genoese CNR, including many members of the SPIN community, the President was engaged in a short tour inside the structure of Corso Perrone, visiting some of the spaces dedicated to offices and laboratories. With the guidance of the Director Fabio Miletto Granozio and the Head of the Office Andrea Malagoli, President Carrozza visited among others, the SPIN laboratories currently dedicated to the processing of new generation superconducting cables.

2022

09 November 2022

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

Researchers from Stanford University and other academic institutions in the United States have published a list of the top 2% most widely cited scientists. Two main lists have been made available referred both to career-long data (195.605 scientists), updated to end-of-2021, and single recent year (200.409 scientists), dealing with citations received during calendar year 2021. Three SPIN researchers (Filippo Giubileo, Silvia Picozzi, Alessandro Stroppa) have been included in the list for the single recent year impact. The same list contains also the names of Antonio Di Bartolomeo and Giacomo Giacomo Ghiringhelli as University scientists associated to the SPIN activities.

11 November 2022

SPIN4Schools is back with new seminars for High Schools

After the period of greatest difficulty and uncertainty linked to the Sars-Cov-2 pandemic, the SPIN Institute re-proposed the "SPIN4Schools" initiative, making available on the institutional website a renewed list of informative seminars dedicated to secondary school students, offering a broad overview of many of the research topics addressed in the Institute's activities. All seminars can be booked free of charge by schools via SPIN website, and can be held both in person and remotely. Given the role of the CNR as an accredited training body (MIUR Directive no. 170/2016), the seminars can constitute refresher credits for the teachers involved.

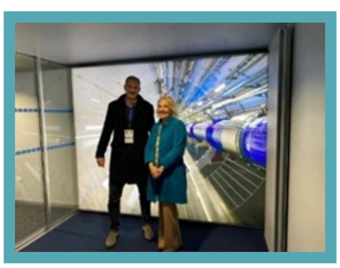
22 November 2022

The 2022 Congress of the SPIN Institute

A new edition of the SPIN Congress took place on November 4th 2022, at Villa Mondragone, in Monte Porzio Catone (Rome). The intense day saw the participation of about 50 researchers, including employees and associates, from all the Institute's Units. After the introductory speech by Director Fabio Miletto Granozio, the PNRR initiatives that involved SPIN were illustrated. Then, the scientific reorganization of the Institute were discussed. In the afternoon the program included 12 talks and a poster section with 20 contributions. The event was organized by C. Aruta, P. Barone, A. Tebano, M. Raimondo, A. Santroni, M. Antonietta Gatti, V. Talamo, S. Scotto and the Deputy Directors of all Research Units.

28 November 2022

SPIN Director, Fabio Miletto Granozio, visiting the CERN labs



On November 15th, CNR-SPIN Director, Fabio Miletto Granozio, visited the CERN labs in Geneva. During his visit, he discussed the ongoing collaborations between SPIN and CERN groups. The topics included the development of superconducting wires for high-field magnets, in view of a future LHC upgrade (HL-LHC: high luminosity large hadron collider) and exploring the potential of low-surface-impedence High-Temperature Superconductors (HTS) coatings for minimizing the impact on the beam of the image currents generated in the tube walls, in view of the future circular collider (FCC).

2022

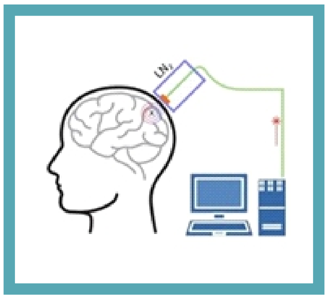
30 November 2022

SPIN on Twitter

The SPIN institutional account on Twitter has been activated. In the initial phase of use, the TWITTER channel reported the publication of new news on the Institute's website, reproposing the title and the relative link.

06 December 2022

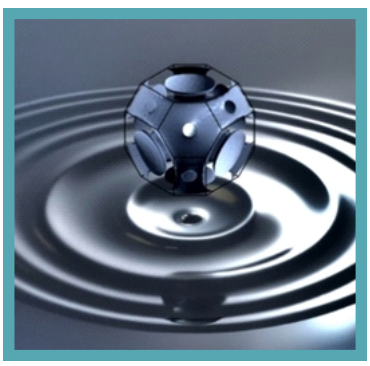
A new granted patent for SPIN



The patent no. US11415642 *"A device for sensing a magnetic field"* owned by the National Research Council (CNR), the University of Chieti-Pescara and Quantified Air B.V. (NL) has been granted by the US Patent & Trademark Office after only 2 years from its filing. The invention is part of the results of the FET-Open project " OXiNEMS2" coordinated by CNR-SPIN and deals with a novel type of mechanical magnetometer based on a superconducting nanostructure and a vibrating magnetic microresonator, whose readout is based on an optical detector. The targeted application concerns the measure and study of very small fields (~1-100 fT) generated by biological processes such as brain or muscle activity, as in magnetoencephalography (MEG) or magnetocardiography (MCG), or by magnetized tissue, as in Ultra Low Field MRI, even in strong (~1T) applied fields as in Transcranial Magnetic Stimulation (TMS).

14 December 2022

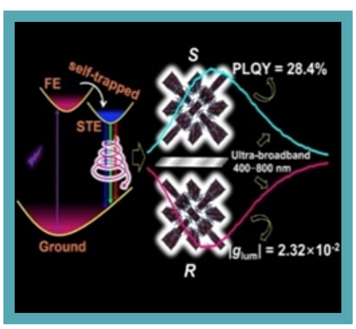
Why is mercury superconducting?



An international collaboration, including CNR-SPIN in the persons of researcher Cesare Tresca and Prof. Gianni Profeta, has explained the microscopic mechanisms underlying the superconducting transition of mercury. The theory used is the SuperConducting Density Functional Theory (SCDFT). It has been shown that peculiar electronic correlations are responsible for the crystalline structure, relativistic effects are crucial to describe the lattice vibrations and finally the repulsive Coulomb interaction between superconducting electrons is strongly reduced by anomalous electronic mechanisms. These results have been published in Phys. Rev. B 106, L180501 (2022), selected as Editor Suggestion, reported in the bulletin of the Italian Physical Society "Il Nuovo Saggiatore", and taken up by Physics Magazine with an interview with Prof. Profeta, and by Physics World which published a commentary article.

22 December 2022

White Circularly Polarized Luminescence in Chiral 1D Double-Chain Perovskites



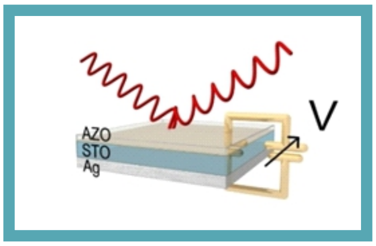
An international collaboration among Southeast University, Nanjing University (China), Donostia International Physics Center (Spain), CNR-SPIN through Alessandro Stroppa and other institutions, focused on Single-Component White Circularly Polarized Luminescence in Chiral 1D Perovskites with a study published in Advanced Optical Materials (Adv. Optical Mater. 2023, 11, 2201996 (2022)). This study provides applicable strategies to explore single-component white CPL emitters.

Life and Events

2023

13 January 2023

Unveiling the Charge-Density Profile in Transparent Semiconductive Oxides under Field-Effect



In an article recently published on ACS Applied Materials & Interfaces, a team of researchers from CNR-SPIN, CNR-NANO and UniGe (OptMatLab@DIFI) have demonstrated the active manipulation of the dielectric properties of aluminium-doped ZnO (AZO) in a field-effect device. The results pave the way to the exploitation of AZO in active photonic devices, replacing the currently-used indium-tin oxide, that is both costly and unsustainable due to the presence of the scarce element In.

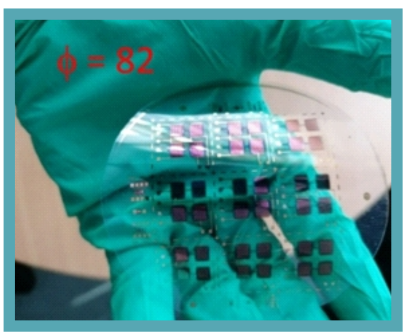
15 February 2023

CNR Missione Fisica

Consolidating the experiences carried out in the recent past, the SPIN Unit of Naples has activated in 2023 Paths for Transversal Skills and Orientation (Percorsi per le Competenze Trasversali e l'Orientamento - PCTO) for high school students, as a part of a broader initiative, shared with the INO and ISASI institutes and entitled CNR Missione Fisica. Two 4th grade classes from the “Rita Levi Montalcini” High School in Quarto (NA) and the “Bernini De Sanctis” High School in Naples have been involved. The inaugural day was held on January 30, 2023, at the Research Area in via Pietro Castellino, with about 160 attending students.

02 March 2023

Flexible fully organic radiation detector

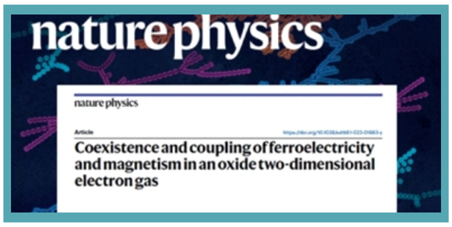


As described in a paper just published in NPJ Flexible Electronics, an innovative fully flexible proton detector, operating at low-voltage (V = −1 V), has been developed within the FIRE project funded by INFN within the activities of the V National Scientific Group, thanks to a national collaboration between the CNR (SPIN-Naples and IMM- Rome), the Universities of Bologna, Trento and Naples (Federico II) and the INFN. The new device was realized on a flexible plastic substrate and is based on the coupling between organic photo-transistors, developed entirely at the CNR laboratories, and scintillators, also flexible and of organic nature, developed at the INFN.

EDU2023

In the year of the celebration of the Centenary of the CNR, the Institutes of the National Research Council (CNR) ofthe Territorial Research Area of Genoa (AreaGe), including SPIN, have designed and created for 2023 the Educational proposal “Edu2023 - Educational activities and laboratories by the CNR structures at the Territorial Research Area of Genoa”. The event in Genoa, held on 8 and 9 March 2023 included the following two contributions by SPIN: the laboratory activity “SUPERconduttività", and the exhibition "Fusione Nucleare: ci siamo?”

2023



21 March 2023

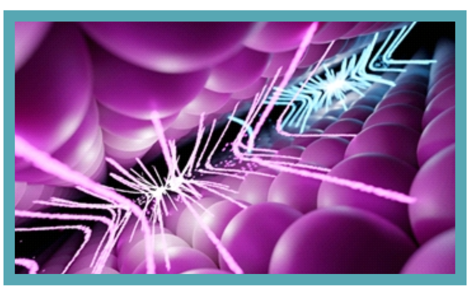
Coexistence and coupling of ferroelectricity and magnetism in an oxide two-dimensional electron gas

As reported in a recent paper published in Nature Physics 19, 823 (2023), a team, composed of researchers from the Unité Mixte de Physique CNRS-THALES, CNR-SPIN, the University Federico II of Naples and the Paul Scherrer Institute in Switzerland, has discovered a new type of 2D-electron gas at the interface between two compounds of the perovskite oxide family, that is both ferroelectric and magnetic while being an excellent electrical conductor. The coexistence of these properties and the possibility to control them easily with an electrical voltage opens the way to new devices for information storage and low energy computing.

21 March 2023

New EU-funded project to advance amplifiers for quantum technologies

Developing the next generation of parametric amplifiers for quantum technologies is the aim of the project TruePA (Truly Resilient Quantum Limited Traveling Wave Parametric Amplifiers) funded by an EU grant of 3 million euros over a period of 3 years. The project's approach integrates novel circuit designs and the use of advanced superconducting materials, combined with new characterization methods based on quantum optics techniques. The outcomes of TruePA will highly advance the field of quantum-limited amplifiers providing novel insights into decoherence mechanisms in superconducting circuits and boosting microwave amplification performance in quantum information with solid state platforms, astronomy and dark matter search.



21 March 2023

Multifunctional quantum properties steer the dynamics of electrons at oxides interface

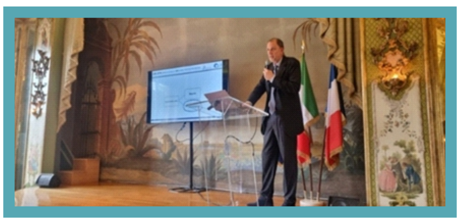
An international team of researchers which includes the CNR-SPIN (Dr. Mario Cuoco), the University of Salerno (Prof. Carmine Ortix, Dr. Maria Teresa Mercaldo, and Prof. Canio Noce), the University of Geneva and the University of Delft has uncovered new quantum effects that can control the dynamics of electrons, predicting the existence of a geometric structure of quantum space characterized by two different geometric curvatures: one related to the spin and the other to the orbital of the electrons. The discovery of the physical laws underlying these particular properties could be used for the development of new magnetic sensors integrated with optoelectronic devices of interest for sixth generation (6G) wireless networks. The research results have been published in Nature Materials 22, 576 (2023).

2023

April 2023

Italian Quantum Weeks 2023

With its second edition, the Italian Quantum Weeks project has continued its organizational mission of informative events dedicated to the world of quantum mechanics and the development opportunities it offers. The exhibition **"Dire l'indicibile – l'entanglement quantistico"**, held from 15 to 28 April at the Physics Museum of the University Federico II has been inaugurated on the occasion of the second World Quantum Day. CNR-SPIN participated in the Italian Quantum Week (IQWs) together with the University of Naples Federico II, CNR-INO and CNR-ISASI. The SPIN personnel involved in the IQWs includes Salvatore Abate, Mario Barra, Gabriele Campagnano, Carla Cirillo, Mikkel Ejrnaes, Paola Gentile, Anita Guarino, Nadia Martucciello, Marco Salluzzo.



April 2023

SPIN Director presenting the Institute research at the GRIM event in Paris

On April 13rd 2023, on the occasion of the annual edition of the "Italian Research Day in the World" (Giornata della Ricerca Italiana nel Mondo - GRIM), SPIN Director Fabio Miletto Granozio presented the activity of the CNR-SPIN Institute at a scientific meeting held at the Italian Embassy in Paris. The meeting was organised by the Embassy in collaboration with ReCIF (Rete dei Ricercatori Italiani in Francia (ReCIF) and ANRT (Association Nationale de la Recherche et de la Technologie). F. Miletto Granozio gave a perspective on the applications of superconductivity within the context of energetic sustainability in our future society. On April 14th 2023, the CNR president Maria Chiara Carrozza attended a second GRIM event in Paris on the theme "International partnerships: opportunities for competitiveness and recovery in the era of green and digital transformation".

April 2023

Memorandum of Cooperation for the High Field Magnet

A Memorandum of Cooperation (MoC) for the High Field Magnet (HFM) Research and Development Programme has been signed by Dr. Mike Lamont, Director of CERN Accelerator and Technology Sector, Dr. Andrzej Siemko, HFM R&D Programme Leader, and Dr. Fabio Miletto Granozio, Director of Institute CNR-SPIN.

The HFM R&D Programme shall be to demonstrate Nb3Sn high-field magnet technology for large scale deployment, and to show the suitability of HTS high field magnets for accelerator applications. By signing this Memorandum, CNR-SPIN becomes a Participant in the HFM R&D Programm, with the assigned task to initiate the research and development path to demonstrate a baseline concept for HTS materials for magnet technology beyond the reach of Nb3Sn (target 20 T or more).

2023

May 2023

Kick-off meeting of LSMOMEMS project

The kick-off meeting of LSMOMEMS took place in the GREYC lab at ENSICAEN on 15-16 May 2023. This 2-years project of cooperation IEA 2022 between CNRS-GREYC and CNR-SPIN aims developing oxide-based MEMS resonators for infrared detection. The project is coordinated by Dr. Laurence Méchin (CNRS-GREYC, Caen) and Dr. Nicola Manca (CNR-SPIN, Genova).

The objective of LSMOMEMS is to study the principle of operation of infrared bolometers making use of MEMS resonators (i.e. MEMS bolometers) fabricated with epitaxial oxide thin films, like (La,Sr)MnO3 (LSMO). LSMO-based MEMS are currently under development within the OXiNEMS Project, a European project devoted to the development of oxide-based MEMS sensors.

29 May 2023

Italian Quantum Weeks 2023 in Salerno

In 2023, the Italian Quantum Weeks exhibition "Dire l'indicibile", with the theme "Quantum Entanglement" has been also held in Salerno. Following the exhibition organized in April in Naples by the CNR SPIN, INO and ISASI institutes and the Federico II University, a short path has been set up in the spaces of the Department of Physics of the University of Salerno in May 2023. The exhibition has been included in the orientation program of the Physics Department. The SPIN personnel involved includes Salvatore Abate, Mario Barra, Carla Cirillo, Paola Gentile.

NANO LETTERS

Letter

Pattern Formation by Electric-Field Quench in a Mott Crystal

Nicolas Gauquelin,* Filomena Forte, Daen Jannis, Rosalba Fittipaldi, Carmine Autieri, Giuseppe Cuono, Veronica Granata, Mariateresa Lettieri, Canio Noce, Fabio Miletto-Granozio, Antonio Vecchione,* Johan Verbeeck, and Mario Cuoco

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ABSTRACT: The control of the Mott phase is intertwined with the spatial reorganization of the electronic states. Out-of-equilibrium driving forces typically lead to electronic patterns that are absent at equilibrium, whose nature is however often elusive. Here, we unveil a nanoscale pattern formation in the Ca_2RuO_4 Mott insulator. We demonstrate how an applied electric field spatially reconstructs the insulating phase that, uniquely after switching off the electric field, exhibits nanoscale stripe domains. The stripe pattern has regions with inequivalent octahedral distortions that we directly observe through high-resolution scanning transmission electron microscopy. The nanotexture depends on the orientation of the electric field; it is nonvolatile and rewritable. We theoretically simulate the charge and orbital reconstruction induced by a quench dynamics of the applied electric field providing clear-cut mechanisms for the stripe phase formation. Our results open the path for the design of nonvolatile electronics based on voltage-controlled nanometric phases.

KEYWORDS: Electric field, electron microscopy, orbital ordering, metal−insulator transition, electronic ordering, stripe phases

29 May 2023

Unveiled new paths to design nanoscale patterns in Mott insulators

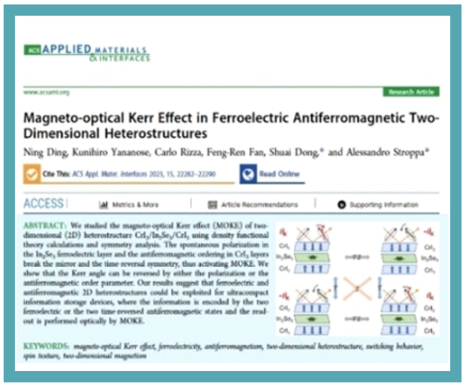
An international team which includes researchers from CNR-SPIN and scientists of MagTop Research Centre in Warsaw, University of Salerno, and University of Antwerp has discovered that a nucleation of a robust nanoscale striped phase can be achieved by switching off the electric field after driving a Mott insulator into a metallic-like uniform configuration. This spectacular phenomenon has been observed for the first time by profiting of the high expertise in the synthesis of Ca2RuO4 single crystals by the group at CNR-SPIN. The research results have been published in the journal Nano Letters https://pubs.acs.org/doi/full/10.1021/acs.nanolett.3c00574

31 May 2023

Join CNR-SPIN: 7 new positions available!

CNR-SPIN has opened 7 new temporary work positions (researchers, technicians etc.) across multiple PNRR (Italian National Recovery and Resilience Plan) projects.

2023



05 June 2023

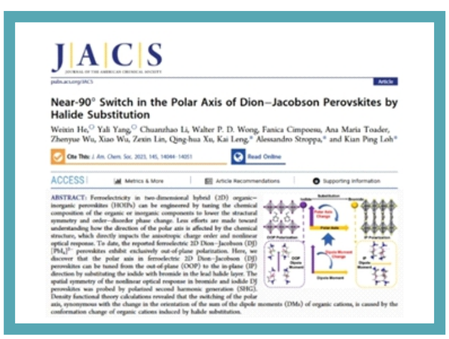
Magneto-Optical Kerr effect in an Anti-ferromagnetic Polar Heterostructure

An international team, including researchers from CNR-SPIN, Seoul National University, The University of Hong Kong, University of L'Aquila, Southeast University studied the magneto-optical properties of multiferroic heterostructure. As reported in ACS Appl. Mater. Interfaces 2023, 15, 18, 22282-22290 https://doi.org/10.1021/acsami.3c02680, this collaboration has shown an unusual magneto-optical Kerr effect in a antiferromagnetic and polar heterostructure, namely $CrI_3/In_2Se_3/CrI_3$. The proposed 2D structure, combining ferroelectricity and anti-ferromagnetism, suggests a novel route toward developing high-performing information storage technology.

27 June 2023

Remarkable results of SPIN researchers in the 2022 Call of the Research Projects of National Interest (PRIN)

The evaluation process of the proposals presented at the first 2022 Call for the Research Project of National Interest (PRIN) ended with six projects funded in the Condensed Matter Physics sector (PE3), having a SPIN researcher as Principal Investigator (PI); other six awarded proposals include a CNR research unit led by a SPIN researcher. Finally, within other Physical Sciences and Engineering (PE) sectors, a SPIN researcher participates in the funded research team for other five endorsed projects. The ratio between the number of the approved projects and that of all presented proposals including at least one SPIN researcher is about 55%, giving the best performance ever achieved by the SPIN community in this type of national program.



06 July 2023

"Near-90° Switch in the Polar Axis of Dion–Jacobson Perovskites by Halide Substitution"

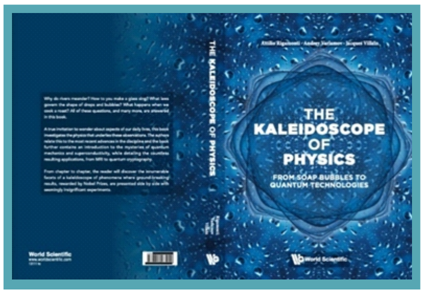
A collaboration between A. Stroppa (CNR-SPIN), K.P. Loh (NUS) and K. Leng (PolyU) showed that the polar axis in ferroelectric 2D Dion-Jacobson (DJ) phase hybrid organic-inorganic perovskites (HOIPs) can be switched by almost 90° using halide substitution. In DJ phase $(4AMP)PbX_4$ ferroelectric system (4AMP = 4-(Aminomethyl)piperidine, X= I and Br), by substituting the iodide with bromide element in perovskite layer, the obtained $[PbBr4]^{2-}$ compound presented In-Plane (IP) polar axis, in contrast to the all previously reported $[PbI4]^{2-}$ counterparts with Out-of-Plane (OOP) polar axis. Such tuning is due to the conformation of organic cations, which is highly sensitive to the electrostatic interaction between the divalent diamine cations and halide anions. Understanding this principle allows the design of other diamine cations whose conformation can be tuned by the structure of the inorganic lattice, thus providing a new approach to tune ferroic, optoelectronic or mechanical properties by conformational changes. https://pubs.acs.org/doi/10.1021/jacs.3c03921?ref=PDF.

Life and Events

2023

25 July 2023

“The Kaleidoscope of Physics” published by World Scientific Publishing



Attilio Rigamonti (University of Pavia), Andrey Varlamov (CNR-SPIN) and Jacques Villain (Academy of Sciences of France) are the authors of the new book "*The Kaleidoscope of Physics: From Soap Bubbles to Quantum Technologies*” just published by World Scientific Publishing. While providing an introduction to the physics which underlies several aspects of our daily lives, the book discusses even some of the most recent advances in modern disciplines like quantum technologies and superconductivity. The book is specially aimed at high school students but, more in general, it is suitable for anyone being interested in the physical laws which rule the world. Commented by Giorgio Benedek (Member of the Lombard Institute Academy of Science and Letters and of the Italian Academy of Science “Dei Lincei”).

07 August 2023

International Conference on Crystal Growth and Epitaxy (ICCGE20)

CNR-SPIN and CNR-IMEM (chairmen: Dr. Antonio Vecchione and Dr. Andrea Zappettini) organized the International Conference on Crystal Growth and Epitaxy ICCGE20, held in the San Giovanni Campus, the new pole of the Naples University “Federico II”, from 30 July to 4 August 2023. The conference, organized under the auspices of the International Organization for Crystal Growth (IOCG), has been attended by almost 600 scientists, from academy, national research centres and industry, coming from 40 different countries. Info at https://www.iccge20.org/

September 2023

Eucas2023 - We have a dream: room-temperature superconductivity

On September 6th 2023, as part of the 16th European Conference on Applied Superconductivity "EUCAS", held in Bologna from 3rd to 7th September 2023, there was a round table titled “We have a dream: room-temperature superconductivity”, open to journalists and media operators (live stream on https://youtube.com/live/wV0t76cc6ts).

The “EUCAS” conference is a world event where top experts in applied superconductivity share the latest advances in their fields, from materials to conductors, large-scale applications for medicine, research and energy transition, as well as in electronics for novel devices and quantum computing. https://www.cnr.it/it/evento/18664 and https://eucas2023.esas.org/

Life and Events

2023

04 September 2023

Italian Quantum Weeks at the 109th SIF National Congress

The exhibition "Dire l'indicibile - L'entanglement quantistico" organized within the Italian Quantum Weeks project continued at the Department of Physics of the University of Salerno, on the occasion of the 109th SIF National Congress. The exhibition has been set up in the space in front of rooms P1 and P2 (Building F3, Ground Floor), which will host most of the general reports of the congress. The exhibition is part of the Italian Quantum Weeks project The SPIN personnel involved includes: Salvatore Abate, Carla Cirillo, Paola Gentile, Nadia Martucciello.

05 September 2023

109° Congress of the Italian Physical Society – SALERNO EDITION

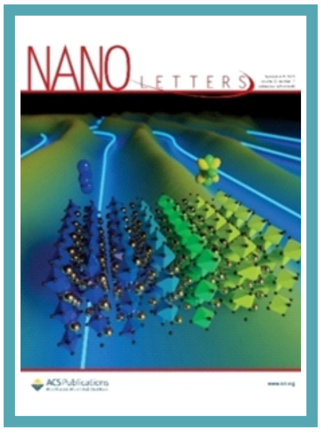
The 109° Congress of the Italian Physical Society has been organized by the Physics Department of the University of Salerno (Prof. Salvatore De Pasquale, president of the Organizing Committee) and CNR-SPIN Salerno (Dr. Nadia Martucciello, vice-president). The event took place at the Fisciano Campus from 11th to 15th September 2023. The Congress gathered about 800 Italian physicists for the whole week. The opening ceremony of the Salerno edition of the Congress, on Sept 11th, guested Prof. Maria Chiara Carrozza, President of CNR, who gave a speech about the "Future of CNR" to celebrate the 100 years of the CNR. She also attended a Round Table about "Quantum Technologies" on the same day.
https://www.primapagina.sif.it/article/1742/salerno-capitale-della-fisica-italiana-per-una-settimana

14 September 2023

New significant achievements of SPIN researchers in the second 2022 Call of the Research Projects of National Interest (PRIN)

As for the 1st Call , the evaluation process of 2nd Call for the 2022 "Research Project of National Interest (PRIN)", being directly related to the National Recovery and Resilience Plan (PNRR), recognized the capability of the SPIN researchers to present innovative proposals. Seven projects having a SPIN researcher as Principal Investigator were approved, and in other two funded proposals, SPIN researchers are involved in a CNR. An outstanding achievement was specifically obtained in the Call section dedicated to the Italian southern regions (Linea SUD) where, for the Condensed Matter Physics sector (PE3), all the submitted proposals were accepted.

2023



20 September 2023

"Unveiled new paths to design nanoscale patterns in Mott insulators" selected as cover of the journal Nano Letters

The scientific journal Nano Letters chooses for its September cover a research by the CNR SPIN Institute published in the article Nano Lett. 2023, 23, 17, 7782–7789. The was conducted by researchers from the SPIN Institute of the CNR, in collaboration with the EMAT group of the University of Antwerp, the MagTop Research Center in Warsaw and the Department of Physics of the University of Salerno, and deals with new electrically guided nanometric quantum phases (see also our news on 29 MAY 2023). The discovery of these states of matter and the mechanisms underlying their physical properties could be used for the development of non-volatile electronics at room temperature and, in perspective, for the realization of new optoelectronic devices.

20 September 2023

President Maria Chiara Carrozza met SPIN researchers at the SIF congress

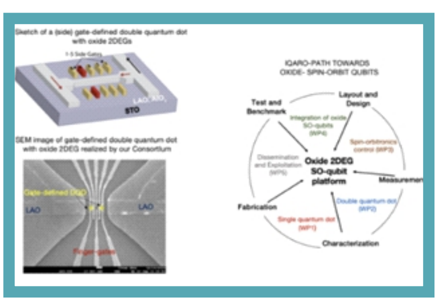
The President of the CNR, Maria Chiara Carrozza, spoke at the inaugural ceremony of the 109th National Congress of the Italian Physical Society (SIF), held at the University of Salerno. On this occasion, the President met the Director of the SPIN Institute and researchers from the Secondary branch of Salerno. The President of the CNR presented a report entitled "The future of science at the CNR".

22 September 2023

Geometry Week for Kids (GWK)

On the occasion of the Centenary of the CNR, Alessandro Stroppa from CNR-SPIN, proposed a week of daily specific educational laboratory, dedicated to primary school students. The initiative started as an extension of the previous educational workshops developed in collaboration with the Department of Human Sciences of the University of L'Aquila. In this first edition (GWK-2023) and on the occasion of the Centenary of the CNR (1923-2023), it represented a satellite event of Street Science held in the city of L'Aquila from 25 to 29 September 2023.

https://centenario.cnr.it/evento/geo-week-for-kids/



26 September 2023

A novel multi-qubit platform: IQARO

CNR-SPIN has been awarded a prestigious project in the framework of the HORIZON-EIC-2022-PATHFINDERCHALLENGES call. The "SpIn-orbitronic QuAntum bits in Reconfigurable 2D-Oxides (IQARO)" project, under the responsibility of Prof. Roberta Citro from the Salerno SPIN unit, involves 7 European partners, including CNR SPIN (Italy), CNRS (France), DTU (Denmark), AHS (Poland) and Chalmers (Sweden), and 2 industrial stakeholders: THALES (France) and RIBER (France). The project, started on October 1st with a duration of 48 months, and a total founding of 3.7M€, aims at realizing spin-orbitronics qubits in single and double quantum dots based on 2D electron gases formed at $SrTiO_3$-based interfaces.

2023

28 September 2023

“Good Vibrations” an educational project selected for the final phase of Science on Stage Europe in Finland

The Project “Good Vibrations" - Sustainable energy for education, born from the collaboration between the Comprehensive Institute "Cornigliano" of Genoa and CNR SPIN, under the coordination of Emilio Bellingeri (SPIN), has been selected for the final phase of *Science on Stage Europe* to be held in Finland in summer 2024. The “Good Vibrations” project led to the creation of two innovative prototypes of “energy harvesting” systems based on piezoelectricity: i) a step of a staircase, which uses the vibrations produced by the passage of people to generate and accumulate electrical energy; ii) a speed bump for urban traffic, which signals pedestrian crossings. This project was also selected for “Science on Stage Festival Italia”, held at the Città della Scienza in Naples, from 22 to 24 September 2023. https://www.science-on-stage.it/it/; https://www.science-on-stage.it/it/festival-europeo/festival-eu-2024

09 October 2023

Macaroni, spaghetti, and physics

The National Festival “Primi d'Italia” was held on September 28-October 1, 2023, in Foligno. In its frameworks, Andrey Varlamov (CNR-SPIN) delivered the talk “*Macaroni, spaghetti, and physics*”, which represents a part of his long-standing popular science activity “Culinary Universe”. https://www.iprimiditalia.it/

12 October 2023

Nanotechnology Materials and Devices Conference (NMDC23)

The Department of Physics of the University of Salerno (Prof. Antonio Di Bartolomeo, General Chair) and the Institute SPIN-CNR (Dr Filippo Giubileo and Dr Nadia Martucciello, Co-Chairs) were the organizers of the IEEE Nanotechnology Materials and Devices Conference (NMDC) 2023. IEEE NMDC is a flagship conference series of the IEEE Nanotechnology Council (NTC), focusing on research advances in the fields of nanoscience and nanotechnology. The IEEE NMDC 2023 was held in Paestum (SA), on October, 22-25, 2023 at the Ariston Congress Center, with the participation of about 400 scientists. https://ieeenmdc.org/nmdc-2023/

16 October 2023

SPIN at the 2023 Researchers’ Night

The 2023 edition of the European Researchers' Night, held in parallel in 26 countries, saw a vast participation of the CNR community:

In **L’Aquila**, at "Street Science", Carino Ferrante, Alessandro Stroppa and Cesare Tresca, carried out dissemination activities. Those dedicated to primary school students was also at the center of the Geometry Week for Kids (GWK) event, curated by A. Stroppa. In Chieti, CNR-SPIN researchers organized the laboratory *"Let's measure the magnetic field of living matter"*, illustrating the concepts and instrumental devices developed within the OXiNEMS project.

2023

In **Salerno**, SPIN took part in the event *Le strade del Campus 2023* on September 15th within the S.T.R.E.E.T.S. project held in Fisciano at University of Salerno. Francesco Avitabile, Carla Cirillo and Paola Gentile led visitors on a journey through the physics of innovative materials, illustrating their potential and possible applications in emerging quantum technologies. The exhibition "Dire l'indicibile", focused on "Quantum Entanglement", part of the "Italian Quantum Weeks" project, was re-set up.

In Naples, on September 29th, at the Monte Sant'Angelo University Campus, as part of the S.T.R.E.E.T.S. project, SPIN contributed to the organization of a station dedicated to the Quantum Creativity Competition, finalized during the 2024 edition of the "Italian Quantum Weeks". In Piazza della Gesù, Mario Barra, Fabio Chiarella, Mikkel Ejrnaes and Paolo Scotto Di Vettimo curated one of the stations of "A scienz int'o street" conceived by the CREO Network for the S.T.R.E.E.T.S. Project.

23 October 2023

Genoa Science Festival 2023

CNR-SPIN took part to the twenty-first edition of the Genoa Science Festival. On October 29th, "Brain and Quantum Sensors" conference took place, moderated by Luca Pellegrino (CNR-SPIN), where Stefania Della Penna (University "G. d'Annunzio" of Chieti-Pescara) and Carmine Granata (Cnr-Isasi) talked about magnetoencephalography, SQUIDs and emerging magnetic field sensors. On November 3rd, "The superconducting technology between research and green deal" round table was held, moderated by Gabriele Beccaria, with the participation of Valeria Braccini for CNR-SPIN.

26 October 2023

SPIN at MAKER FAIRE 2023

An educational project by Alessandro Stroppa (CNR SPIN) and Karin Giorgini, who graduated with A. Stroppa and is now teacher at Primary School, was selected for participation at Maker Faire Rome 2023, an European event that talks about technological innovation in a simple and accessible way, connecting businesses, Academia, people and ideas. In the project presented, *Making fun with Symmetries*, the activities were designed to introduce primary school students into geometrical concepts by exploiting simple arguments and specific games dealing with symmetries.

06 November 2023

School on Oxide M/NEMS and membranes

CNR-SPIN organized the Online School on Oxide M/NEMS and membranes (November 8th) on the Gather Town platform. Scope of this school, organized in the framework of the OXiNEMS project by CNR-SPIN researchers and associates (Luca Pellegrino, Nicola Manca, Daniele Marré), was to merge together students and young researchers interested in the field of freestanding oxide thin films and micro/nanomechanical systems made with functional (epi)oxide materials towards new applications in sensing and actuating technologies. Online lessons covered the different aspects of this emerging field, including fundamental modeling, fabrication protocols, and characterization techniques. https://www.oxinems.eu/news/school-oxide.html

Life and Events

2023

13 November 2023

CERN-SPIN collaboration on IBS superconductors for future accelerator magnets

On November 9th, a collaboration agreement between CERN and SPIN was signed. Such agreement is an addendum to the Memorandum of Cooperation for the High Field Magnet (HFM) Research and Development Programme and establishes a collaboration between CERN and SPIN in carrying out preliminary R&D activities related to the development of Iron Based Superconducting (IBS) wires through the Powder In Tube (PIT) technology. The Technical Coordinators is Dr. Amalia Ballarino for CERN and Dr. Andrea Malagoli for SPIN. Furthermore, Dr. Andrea Malagoli is now member of the HFM programme Collaboration Board.

23 November 2023

SPIN and the centenary of the CNR

SPIN participated in the celebrations for the Centenary of the foundation of the CNR (1923-2023) with various events. **In Genoa**, on March 8th and 9th, SPIN was involved in the event "Racconti di economia circolare - EDU 2023", with the participation of students from primary and secondary schools in seminar and laboratory activities, dedicated to nuclear fusion and related technologies, the impact of plastic on the seas, virtual reality, and nutrition.
In Naples, SPIN animated two of the PCTO *"CNR Missione Fisica"* courses, with a final event held on May 5th at the CNR Area in via Pietro Castellino, where the young participants shared the knowledge acquired in the related course.
In L'Aquila, the *"Geo Week for Kids"* was organized from September 25th to 29th, with educational workshops exploiting a playful and interactive approach to explain mathematical and physical concepts. On October 30th and 31st, SPIN took part in the event *"Creation of shared value in the territories: research, innovation and sustainability"* with meetings where researches shared the scientific network of the Institution with other entities, both public and private, in the Abruzzo region.
In Salerno, on October 18th, SPIN researchers attended the conference *"Researchers of today and tomorrow"*, introducing their scientific activity and dialoguing with young students, who shared their laboratory experiences carried out in the context of extra-curricular projects and courses.
Finally, SPIN contributed to the initiative "**100xCNR100: 100 questions for the 100 years of the CNR**" of the CREO Network (Campania REte Outreach), with the creation of a web platform where users will find information on the CNR, its history, its organization and its activities.

20 December 2023

Room temperature superconductors in Nature's 10: Rai Radio3 Scienza interviewed Gaia Grimaldi

Rai Radio3 Scienza interviewed the SPIN researcher Gaia Grimaldi during a scientific dissemination event dedicated to Superconductivity, that she was carring out at Liceo Scientifico Genovesi-Da Vinci in Salerno, together with Nadia Martucciello and Salvatore Abate (CNR-SPIN Salerno). In the interview, the story of "James Hamlin, Superconductivity sleuth" was retraced, dealing with the man who investigated in depth the reliability of the sensational discovery of superconductivity at room temperature, originally published in Nature in March 2023 and then retracted a few months later. The interview is available at https://bit.ly/NaturesEleven (starting at minute 16:55).

2023

December 2023

Best Young Researcher Article Award 2023

On December 20th, the 2023 edition of the Workshop “Best Young Research Article Award (BYRA)” was held online and chaired by the SPIN researcher Carino Ferrante. The workshop included the seminars: *"Symmetry, Ferromagnetic and Warping effects on (111) LaAlO3/EuTiO3/SrTiO3 interface"*, by Dr. Yu Chen, and *"Anomalous Josephson coupling and high-harmonics in noncentrosymmetric superconductors with S-wave spin-triplet pairing"* by Dr. Yuri Fukaya. The evaluation committee (Carmine Attanasio, Vittorio Cautadella, Daniele Marrè, Gianni Profeta) selected Dr. Yu Chen as the BYRA winner for the paper Appl. Electron Mater 4, 3226 (2022).

SPIN Seminar Series 2022 - 2023

Starting from January 2022 a regular seminar activity of the SPIN Institute was established.
Its purpose is:

- consolidation of the institution as a single entity;
- making familiar the SPIN community with the state of the art in the v ariousfields;
- development of the ability of young researchers to present publicly the results of their research;
- set up the bridges between facilities and sample production;
- broaden the general knowledge of the Institute staff towards various fields of physics.

Seminars covers the following fields:

- superconductivity;
- magnetism;
- oxides;
- thermal transport and thermoelectricity;
- quantum materials and technologies;
- tutorial lectures on general topics.

SPIN Institute proposes:

- to hold as regular practice seminars devoted to the large-scale projects executed in the Institute,
- to devote special seminars to the discussion of advanced experimental techniques, involving those performed at large-scale facilities,
- to ask young researchers to present not only their specific works but also the state of art in the field of their scientific interests.

SPIN young researchers, experienced researchers as well as Institute associates, and scientists of international recognition are invited to take part in this seminar activity. The frequency of seminars in 2022 and 2023 was one per month, at **3pm, on the last Thursday of each month**. The seminars were held in the hybrid or purely on-line form.

Working group

Andrey Varlamov, Silvia Picozzi, Rosalba Fittipaldi, Fabio Chiarella, Emilio Bellingeri.
Technical support was provided by Marco Raimondo.

SPIN Seminar Series

2022 - 2023

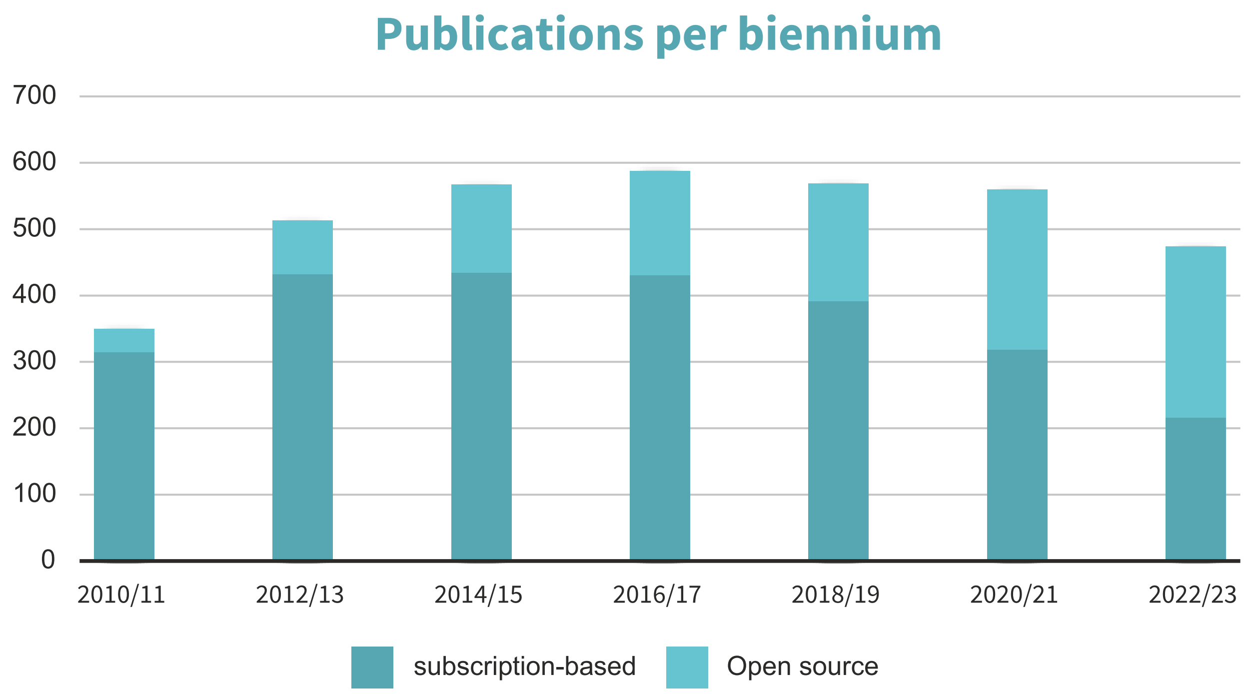
Seminar list

SPEAKER	TITLE	DATE
Martina Esposito	**Superconducting Travelling Wave Parametric Amplifiers: from near quantum-noise-limited amplification to microwave photonics**	27/01/2022
Andrey V. Chubukov	**Superconductivity from repulsion**	24/02/2022
Cesare Tresca	**High temperature superconductors, the interesting case of PdCuHx ternary hydride**	31/03/2022
Giacomo Ghiringhelli	**Exploring the physics of quantum matter with high resolution RIXS**	28/04/2022
Yuriy Yerin	**Topological phase transition between the gap and the gapless superconductors**	26/05/2022
Christian Rinaldi	**From *ab-initio calculations* to nanoelectronics: path and challenges for ferroelectric Rashba semiconductors**	30/06/2022
Geetha Balakrishnan	**Magnetic skyrmion materials**	29/09/2022
Ruggero Vaglio	**High Tc superconductors for the future hadron collider at CERN**	01/12/2022
Andrey Varlamov	**Termoelettricità: dall'arco di ferro dell'epoca di Alessandro Volta ai termogeneratori ferrofluidi di oggi**	22/12/2022
Carino Ferrante	**Coherent and spontaneous Raman with pulsed lasers for investigation of material properties**	26/01/2023
Carmine Ortix	**Designing spin and orbital sources of Berry curvature at oxide interfaces**	23/02/2023
Alexander Buzdin	**Optical methods of flux manipulation in superconductors**	30/03/2023
Ilaria Maccari	**Vestigial Phases in Multicomponent Superconductors: Firsyt Experimental Signature of a Fermion Quadrupling Comndensate that Break Time-Reversal Symmetry**	27/04/2023
Federico Caglieris	**Anomalous transport properties in antiferromagnetic Mn3Ge**	25/05/2023
Gianni Profeta	**A dream comes true: room-temperature superconductivity (?)**	22/06/2023
Jijil JJ Nivas	**Laser-induced surface structuring: an effective approach for surface functionalization**	13/07/2023
Andrea Gauzzi	**Tuning topological Dirac states using correlated d-electrons**	26/10/2023
Nini Pryds	**Symmetry breaking – A peek into the field of oxide heterostructures**	23/11/2023
Yu Chen, Yuri Fukaya	**Presentation for the "Best Young Researcher Article" Award**	20/12/2023

Publications

Publications

SPIN published **474 articles** in the two-years period.
The complete list can be found at **https://www.spin.cnr.it/research/publications**



BYRA

Best Young Researcher Article Award

BYRA Best Young Researcher Article Award

SPIN rewards the best article of a young employee or associate researcher every year, since 2016.
The Researchers eligible for the BYRA Prize should fulfill the following criteria:

- the applicant should hold a non-permanent position within the Institute (as internal or associated staff) at the deadline;
- younger than 35 years (at the date of publication);
- first Author, with SPIN affiliation, of articles published in international journals in the reference year of the award call;
- each young researcher is eligible for only one selected paper.

Admitted candidates give a 20 minutes seminar during the "Best Young Researcher Article Award" workshop, where they illustrate their work to the SPIN community in a wider relevant scientific context, and highlight their contribution.
The winner selection is delegated to a commission appointed by the Director. The commission uses as criteria the scientific impact of the article, the candidate's contribution and the quality of the presentation.
The prize consists in an amount of money which is made available to the winner preferably for the dissemination of the results of their research activities.

BYRA 2022

Selected candidates for BYRA workshop 2022

Yu Chen (PostDoc@SPIN NA)
Talk: "Symmetry, Ferromagnetic and Warping effects on (111) LaAlO3/EuTiO3/SrTiO3 interface" [ACS Appl Electron Mater 4, 3226 (2022)]

Yuri Fukaya(PostDoc@ SPIN SA)
Talk: "Anomalous Josephson coupling and high-harmonics in noncentrosymmetric superconductors with S-wave spin-triplet pairing" [npj Quantum Mater. 7, 99 (2022)]

2022

BYRA 2022 assigned to

"Ferromagnetic Quasi-Two-Dimensional Electron Gas with Trigonal Crystal Field Splitting"

Coauthors: M. M. D'Antuono, N. B. Brookes, G. M. De Luca,R. Di Capua, E. Di Gennaro, G. Ghiringhelli, C. Piamonteze, D. Preziosi, B. Jouault, M. Cabero, J. M. González-Calbet, C. León, J. Santamaria, A. Sambri, D. Stornaiuolo, M. Salluzzo
ACS Appl Electron Mater 4, 3226 (2022).

Motivation

The paper originates from an international collaboration led by CNR-SPIN, involving several prestigious European research institutes. It reports on the realization and characterization of an artificial ferromagnetic quasi-two-dimensional electron gas at the (111) interfaces between LaAlO3, EuTiO3, and SrTiO3. The LaAlO3/SrTiO3 interface has been one of the hottest topics in condensed matter physics over the last two decades, and this work contributes to the investigation of the interplay between ferromagnetism, spin–orbit coupling, and crystal field splitting in such a quasi 2DEG. In this article, the candidate played a relevant role in both the fabrication and characterization of the interfaces and in the realization of models for the analysis of the experimental results. During the seminar, the candidate presented the arguments in a clear and comprehensive way and demonstrated an understanding of the overall logic of the paper, even of the experiments in which he was not directly involved.

BYRA

Best Young Researcher Article Award

BYRA 2023

Selected candidates for BYRA workshop 2023

Michele Ceccardi (PhD student, UniGe)
Talk :"Anomalous Nernst effect in the topological and magnetic material $MnBi_4Te_7$" [npj Quantum Mater. 8, 76 (2023).]

Kimberly Intonti (PhD student, UniSa)
Talk: "Temperature-Dependent Conduction and Photoresponse in Few-Layer ReS_2"
[ACS Applied Materials & Interfaces 2023 15 (43), 50302-50311]

2023

Michele Ceccardi

BYRA 2023 assigned to

"Anomalous Nernst effect in the topological and magnetic material $MnBi_4Te_7$"

Coauthors: A. Zeugner, L. C. Folkers, C. Hess, B. Büchner, D. Marré, A. Isaeva, and F. Caglieris

ACS Appl Electron Mater 4, 3226 (2022).

Motivation

The candidate resented the results of the research activity on the topological effects on the transport properties of ferromagnetic Weyl semimetals. The presentation was clear, linear and complete, showing the results obtained, the experimental techniques used and the possible theoretical interpretations. The excellent mastery of the subject shown by the candidate also allowed him to propose new lines of research that could further clarify various aspects of the physics of the problem and have a significant impact.

In ricordo di Marco Punginelli

Marco Punginelli non era solo un collega, ma un amico prezioso.
La sua è stata un'amicizia fatta di entusiasmo generoso, di grande e disinteressata disponibilità, di appassionata condivisione, di serietà, di un affetto sincero e profondo.
Lavorare insieme a lui è stato un privilegio perché era un collega non solo molto professionale, ma anche disponibile, gentile e sempre pronto ad aiutare il prossimo.
La sua figura sarà ricordata per sempre e non potrà mai morire e rimarrà sempre nei nostri cuori.

Last modified: April 22, 2025

www.spin.cnr.it

Consiglio Nazionale delle Ricerche

SPIN