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Monday 10 February

11:00 — **Registration**

14:00 — **Opening**

14:20 — **Justin Ye** (Keynote Invited)
Ising superconductivity in transition metal dichalcogenides

Session Mon 1 - Chair: G.Profeta

15:00 — **E. Piatti**
Ultrathin molybdenum disulphide as a gate-tunable multi-valley superconductor

15:20 — **D. Mondal**
Observation of spin polarized bands in $NiTe_2$

15:40 — **L. Tomarchio**
THz Nonlinear Response of the Weyl Semimetal WTe_2

16:00 — **C. Grazianetti**
Optical properties of Xenes epitaxially grown on AlO(000) substrate

16:20 — **Coffe Break**

	Session Mon 2a - Chair: J. Lorenzana	*Session Mon 2b - Chair: R. De Renzi*
16:40	**T. Shiroka** Structure and superconductivity in the binary $Re_{1-x}Mo_x$ alloys	**A. Stroppa** Magneto-optical Kerr switching properties and spin configurations of magnetic 2D heterostructures
17:00	**M. N. Gastiasoro** Superconductivity mediated by ferroelectric fluctuations	**M. Benini** Organic semiconductors modulating cobalt thin films magnetic
17:20	**G. Marini** Superconductivity in Chevrel phases from first principles	**G. Varvaro** Designing new ferrite/manganite nanocomposites
17:40	**D. Romanin** Electric field exfoliation and high-Tc superconductivity in field-effect hole-doped hydrogenated diamond	**M. Slimani** Mesostructured silica/spinel iron Oxides nanoarchitectures: investigation of the magnetic properties
18:00	**G. Venditti** Transport properties, superfluid stiffness and intrinsic inhomogeneity in two-dimensional superconductors	**E. Illes** Impact of shell composition on iron oxide nanomagnets for biomedical use

19:00 — **Welcome**

20:00 — **Poster Session**

Tuesday 11 February

Morning

08:30	**M. V. Ganduglia-Pirovano** (Keynote speaker) CeO-based Materials and Catalytic Function: The Non-Innocent Role of the Ceria Support	
	Session Tue 1a - Chair: A. Filippetti	*Session Tue 1b - Chair: R. Mathieu*
9:10	**C. Autieri** (Invited) Berry phase engineering at oxide interfaces	**E. Gilardi** (Invited) Interface Effects in Doped Ceria – Yttria-stabilized Zirconia Heterostructures
9:40	**P. Gentile** Topological phases driven by Rashba spin-orbit coupling in low-dimensional nanostructures	**C. Aruta** Role of dopant cations on functional properties in cerium oxide thin films for energy applications
10:00	**W. Brzezicki** Topology in non-symmorphic and non-Hermitian chiral chains	**C. Sanna** Structural and electrochemical characterization of $La_{0.4}Sr_{0.6}Co_{0.2}Fe_{0.8}O_{3-\delta}$ electrospun electrode for solid oxide cell applications
10:20	**A. Lanzara** The many faces of spin orbit coupling in quantum materials	**D. Colombara** Giant efficiency boost of Chalcopyrite/Zn(O,S) heterojunctionsupon low-temperature annealing
10:40	**Coffe Break**	
	Session Tue 2a - Chair: S. Lupi	*Session Tue 2b - Chair: C. Senatore*
11:10	**A. Caviglia** (Invited) Ultrafast optical control of quantum materials	**F. Grilli** (Invited) REBCO coated conductors are ready to take off
11:40	**F. Pineider** Magnetic modulation of plasmon resonances in Indium Tin Oxide nanocrystals	**G. Celentano** Development and Perspectives of HTS Cable-In-Conduit Conductor with Al-Slotted Core for Fusion Applications
12:00	**M. Sygletou** Optical properties of Transparent Conductive Oxides (TCOs)-based Systems	**R. Musenich** Superconducting Magnets for Space Applications
12:20	**M. Corasaniti** Fermi surface instability in the Dirac material $Ca_{1-x}Na_xMnBi_2$	**A. Pietropaolo** Superconducting Neutron Detectors: a proof of concept at spallation neutron source
12:40	**C. Bigi** Distinct electronic character and selective control of localised vs. delocalised carriers at (001) surface of anatase TiO_2	**A. Traverso** Bi–wire development for Canted Cosine Theta solenoids
13:00	**Lunch**	

Tuesday 11 February

Afternoon

Session Tue 3 - Chair: S. Sanna

14:40 **G. Ghiringhelli**
Charge density waves and charge density fluctuations in high Tc superconducting cuprates

15:00 **M. Meinero**
Hydrodynamical charge density wave description for transport in the strange metal phase of cuprates

15:20 **G. Profeta**
Superconductivity in Mercury

15:40 **J. Lorenzana**
Silver route to high-Tc superconductivity

16:00 **S. Caprara**
Intrinsic inhomogeneity in low dimensional superconductors

16:20 **Coffe Break**

	Session Tue 4a - Chair: F. Grilli	*Session Tue 4b - Chair: G. Ghiringhelli*
16:50	**C. Senatore** (Invited) Improvment of J_c and further enhancement of B_{c2} in Ta doped Nb_3Sn	**F. Carbone** (Invited) Switching the Verwey transition in magnetite
17:20	**L. Civale** How to improve $REBa_2Cu_3O_y$ films and coated conductors by tailoring pinning centers	**M. Udina** Theory of coherent-oscillations generation in terahertz pump-probe spectroscopy: from phonons to electronic collective modes
17:40	**M. Polichetti** Flux creep and second magnetization peak effect in type-II superconductors: correlation and universality	**A. Marini** Ultrafast nonlinear dynamics of two-dimensional materials
18:00	**M. Capra** Proteins MgB carbon doping through Freeze-drying process	**S. Lupi** Ultrafast manipulation of matter by extreme terahertz fields
18:20	**L. Piperno** Strategies for critical current enhancement in YBCO films obtained via chemical solution deposition	

20:00 **Conference Dinner**

Wednesday 12 February

Morning

Session Wed 1 - Chair: A. Caviglia

08:30 **F. Giazotto** (Invited)
Josephson field-effect transistors go metal: A groundbreaking route towards concrete superconducting electronics

09:00 **C. Barone**
Current-Resistance Effects and Nonlinear Fluctuation Mechanisms in Granular Aluminum Oxide Nanowires for Quantum Computing Applications

09:20 **M. Salluzzo**
Quasi-2D-oxides spintronics and quantum electronics

09:40 **G. Prando**
Influence of hydrostatic pressure and of Eu/Bi substitution on the magnetic properties of $Eu_2Ir_2O_7$

10:00 **S. Sanna**
Physical and structural properties of electron-doped 5d1 double perovskites

10:20 **Coffe Break**

	Session Wed 2a - Chair: C. Autieri	*Session Wed 2b - Chair: E. Gilardi*
16:50	**D. Amoroso**	**L. Pellegrino**
	First-principles approach to novel D ferromagnets	VO_2–based microactuators
17:20	**A. Filippetti**	**V. Bonino**
	Layered Perovskites: a structural framework to implement ferroelectric and electromagnetic metals	New perspectives for X-ray nanopatterning of oxide systems
17:40	**R. Mathieu**	**C. Groppi**
	Magnetic and dielectric properties of Yb-doped PbFe/W/O	Integration of lead-free piezoelectric $(K_xNa_{1-x})NbO$ on silicon for microactuator technology applications
18:00	**F. Forte**	**A. Sambri**
	Spin-Orbital Excitations in Spin-Orbit Coupled Mott Insulator	Self-formed, conducting LaAlO/SrTiO micromembranes
18:20	**A. Avella**	**N. Manca**
	Defects, Disorder, and Strong Electron Correlations in Orbital Degenerate, Doped Mott Insulators: Defect-Induced Orbital Polarization and Collapse of Orbital Order	Reversible strain-tuning of crystalline oxide microstructures via hydrogen gas

12:30 **Lunch**

Wednesday 12 February

Afternoon

14:00 — **Opening joint session with IBS2app**

14:10 — **Yanwei Ma** (Keynote Invited)
Status of high-field iron-based superconducting wires and tapes

Session Wed 3 - Chair: G. Celentano

14:50 — **S. Calatroni**
Study of HTS coatings for beam impedance mitigation in the FCC

15:10 — **E. Silva**
YBCO coated conductors and thin films for high frequency applications in dc magnetic fields

15:30 — **L. Muzzi**
Superconductors for the Italian Divertor Tokamak Test Facility project

15:50 — **A. Morandi**
Research status and direction of HTS Fault Current Limiters

16:10 — **Coffe Break**

Session Wed 4 - Chair: S. Pagano

16:40 — **T. Gorni**
Impact of non-local exchange on Iron Pnictides

17:00 — **F. Caglieris**
Elasto-transport: a probe for nematic fluctuations in iron-based superconductors

17:20 — **R. Hussain**
Magnetic ordering and spin dynamics in $La_2O_3Fe_2Se_2$: a ^{139}La NQR study

17:40 — **F. Bernardini**
Evidence of the isoelectronic character of F doping in $SmFeAsO_{1-x}F_x$

18:00 — **V. Vlasenko**
Planar defects and vortex pinning in EuRbFeAs iron-based superconductor

Poster Session

P01	L. Nessi	Development of free-standing magnetic membranes for spin polarimetry
P02	R. Carcione	Study of the CdS QDs formation in film by thermal and laser treatment
P03	M. W. Rabbani	Nano-XRD mapping of structural modifications induced by high-power density irradiation of Bi-2212 single crystals
P04	N. Manca	Microresonators based on single-crystal $(La, Sr)MnO_3$ thin films
P05	E. Ragucci	Thermal and mechanical properties in single-crystal VO_2 micro-structures
P06	G. Sylva	Fe(Se, Te) Coated conductors on simple RABiTS templates
P07	V. Malginov	Model fault-current limiter with iron-based superconducting wires
P08	A. Napolitano	Multiphysics simulation of YBCO superconducting bolometer with a portable LN_2 cryostat for infrared detection
P09	M. Breschi	Modeling quench in HTS devices: from individual tapes to full-scale magnets
P10	L. Gozzelino	High magnetic mitigation by machinable MgB_2 practical shields
P11	G. A. Ummarino	Theoretical explanation of electric field-induced superconductive critical temperature shifts in Indium thin films
P12	L. Martinelli	Effects of spatial confinement on charge order in $YBa_2Cu_3O_{7-\delta}$
P13	G. Ghigo	Interplay between magnetism and superconductivity in $EuFe(As_{1-x}P_x)$ single crystals investigated by a microwave technique
P14	A. Nigro	Angular dependence of quasiparticle relaxation time in Fe(Se, Te) microbridges
P15	F. Laviano	Visualization of critical state dynamics in superconductors by means of magneto-optical imaging
P16	B. Siri	Impact of Annealing on Titanium Thin Films T_C and Crystalline Structure
P17	G. Bioletti	Pressure dependence of J_c in series of Ni-doped Ba122 single crystals
P18	D. Torsello	Analysis of the London penetration depth in $CaK(Fe, Ni)_4As_4$
P19	A. Vannozzi	Epitaxial $La_2Zr_2O_7$ and Zr-doped CeO_2 films by chemical solution deposition as buffer layers for Fe(Se, Te) film growth
P20	A. Masi	Iron chalcogenide crystals grown in molten chlorides: structure and properties
P21	A. Gallerati	Exploiting weak field gravity-Maxwell symmetry in superconductive fluctuations regime
P22	A. K. Ghosh	Phase stiffness in superconducting states in cuprate superconductors
P23	K. Pervakov	Superconducting properties of the hole-doped bulk $B_{a-x}K_xFe_2As_2$ and $B_{a-x}Na_xFe_2As_2$ materials synthesized by mechanical alloying
P24	F. Gömöry	AC susceptibility study of CC tapes prepared by inclined substrate deposition process
P25	A. Saba	Synthesis and study of Tl–Superconducting Thin Films for the Future Circular Collider (FCC-hh) Beam Screen
P26	N. Pompeo	Microwave studies of the anisotropy in $YBa_2Cu_3O_{7-d}$ thin films
P27	N. Riva	Over-critical current resistivity characterization of ReBCO commercial coated conductors: improved E–J characteristic at high electric fields
P28	P. Pęczkowski	The influence of Fe on $YBa_2Cu_3O_{7-\delta}$ structure, microstructure and superconducting properties
P29	P. Maltoni	Exploring the magnetic properties of Strontium-Hexaferrite Nanoparticles for the development of rare-earth-free Permanent Magnets
P30	S. Massardo	Effect of pressure on the structural properties of rare earth doped ceria
P31	K. V. Kulikov	Ferromagnetic resonance and dynamics of magnet moment in Josephson junction + nanomagnet system
P32	S. K. Chaluvadi	Epitaxial strain and artificial super lattice modulation mediated magnetic properties in $La_{0.67}Sr_{0.33}MnO$ thin films

P33	K. Kuramochi	Synthesis of New Iridium Oxyfluoride Using Topochemical Reaction Method and Their Physical Properties
P34	F. Airaldi	Vervey transition in bi-magnetic multi shell spinel iron oxide nanoparticles
P35	Y. Iwasa	Excitonic luminescence of a series of layered mixed-anion compounds $Sr_3Sc_2M_2Ch_2O_5$
P36	A. Plaza	Influence of free charge carrier density on the magnetic behavior of (Zn, Co)O thin film studied by Field Effect modulation of magnetotransport
P37	A. Omelyanchik	Hard/soft and soft/hard magnetic spinel ferrites nanoparticles
P38	P. Blah	Freestanding Strontium Ruthenate Membranes
P39	I. Pallecchi	Thermoelectric behavior of transition metal dichalcogenides
P40	A. Plaza	Investigation of the effective mass enhancement in ZnO/ZnMgO heterostructures through quantum effects
P41	N. Lorenzini	Non-volatile field-effect modulation of transport properties in crystalline and amorphous $LaAlO_3$/$SrTiO_3$ interfaces
P42	G. Cuono	Nonsymmorphic symmetries in MnP-type crystal structures
P43	P.C. Forino	Effect of the electron doping on Ba_2NaOsO_6 via Na/Ca substitution: a nuclear magnetic resonance study
P44	D. Takagi	$0-\pi$ transition and odd-frequency pairing in Rashba superconducting nanowire junction

VERVEY TRANSTION IN BI-MAGNETIC MULTI SHELL SPINEL IRON OXIDE NANOPARTICLES

F. Airaldi[1], E. H. Sánchez[2], S. Villa[1], A. Omelianchik[3], J. A. De Toro[2], F. Canepa[1], D. Peddis[1,3]

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[2]IRICA and Departamento de Física Aplicada, Universidad de Castilla-La Mancha, 13071 Ciudad Real, Spain
[3]Istituto di Struttura della Materia-CNR, 00015 Monterotondo Scalo (RM), Italy)

Magnetic Mono-domain Nanoparticles (MMNPs) have obtained increasing interest during the last 20 years, due to their wide range of applications (e.g. biomedicine, catalysis). In particular spinel oxides, especially magnetite (Fe_3O_4) and maghemite (γ-Fe_2O_4), have been studied since the beginning of magnetism, because of their scientific and technological importance. Nowadays they are of great interest mainly for biomedical applications (e.g. Hyperthermia, MRI) [1]. Magnetite exhibits a crystallographic phase transition (from monoclinic to cubic) called Verwey transition at 110-120 K (for bulk) [2] accompanied by abrupt changes in resistivity, heat capacity, magnetization, and coercivity. Any deviation from stoichiometry (i.e. ratio Fe^{2+}/Fe^{3+}) in magnetite influences T_v. Recently, a large development has been reported in soft and hard exchange-coupled core shell MNPs [3], such as systems with Fe_3O_4 core. This study focuses on the investigation of Verwey transition in core, core-shell and multi-shell structure of different spinel ferrites MNPs (Fe_3O_4 (~7 nm), $Fe_3O_4/NiFe_2O_4$ (~10nm) and $Fe_3O_4/NiFe_2O_4/Fe_3O_4$ (~13nm)) synthesized using thermal decomposition of organometallic precursors. All samples have been investigated by AC/DC magnetization measurements. Temperature dependence of magnetization by means of zero field cooled field cooled highlights the presence of Verwey transition in core shell (Fe_3O_4/NFO) and multi shell systems (Fe_3O_4/NFO/Fe_3O_4). No evidence of T_v is present in Fe_3O_4 samples, probably due to some conversion of magnetite in maghemite (i.e. oxidation of Fe^{2+} to Fe^{3+}). AC measurements in core shell and multi shell system show a very weak frequency dependence peak (total frequency shift p = $(\Delta T_p \langle T_p \rangle)/\Delta(log\omega) \approx 0.04$ [4] where T_p is the temperature peak and ω is the angular frequency of the applied AC field) in the out of phase component (X'') around 100-120 K that can be identified as the Verwey transition. X'' in multi shell system evidences also a small peak at low temperature (25 K), showing a more strong frequency dependence ($p \approx 0.12$). The origin of this peak is currently under investigation.

References (Times New Roman 10 pt; bold)

[1] Robles, J.; Das, R.; Glassell, M.; Phan, M. H.; Srikanth, H. *AIP Adv.* **8** (2018) 056719
[2] Muscas, G.; Concas, G.; Cannas, C.; Musinu, A.; Ardu, A.; Orru, F.; Fiorani, D.; Laureti, S.; Rinaldi, D.; Piccaluga, G.; Peddis, D.; Rm, M. S.; Chimiche, S.; Cagliari, U.; Universitaria, C. *J. Phys. Chem C* **117** (2013) 23378
[3] Moon, S. H.; Noh, S. H.; Lee, J. H.; Shin, T. H.; Lim, Y.; Cheon, J. *Nano Lett.* **17** (2017) 800
[4] Toro, J. A. De; Lee, S. S.; Salazar, D.; Cheong, J. L.; Normile, P. S. *Appl. Phys. Lett* **102** (2013) 183104

First-principles approach to novel 2D ferromagnets

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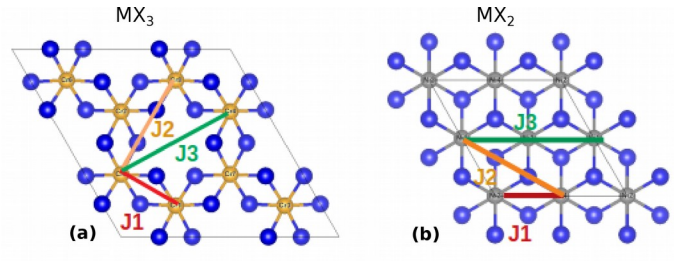
There is currently an increasing enthusiasm towards long-range magnetic order in two-dimensional materials (2D) (such as CrI_3 and $CrGeTe_3$), from the fundamental and from the applicative point of view, from theory and from experiments. As known, functional properties can change when scaling down the dimension of a system. Particularly, this applies to magnetic materials, which must display anisotropic couplings in order to preserve a magnetic ordering in the two-dimensional space, as follow from the Mermin-Wagner theorem [1]. In the aim of finding new appealing 2D-magnetic materials, starting from the database of exfoliable materials reported in [2], in this work we thus carry out an extensive investigation based on density functional theory (DFT) on two classes of such materials. Our analysis focuses on tri- and di- halides (with formula M-(VII)$_3$ and M-(VII)$_2$, where M is a transition metal and VII = Cl, Br, I). Particular attention has been put on monolayer Ni-(VII)$_2$ [3]. Beyond standard analysis of structural and electronic properties, we put special emphasis on the magnetic properties, in terms of magnetic moments, Heisenberg exchange coupling constants and magnetic anisotropy energy. Moreover, starting from the DFT results, our analysis also rely on Monte-Carlo based simulations to investigate the magnetic ordering of the ground-state and trends at finite temperature. Some of the considered materials show exchange coupling constants significantly larger than the prototypical CrI_3 along with strong anisotropic behaviour, leading to exotic spin configurations.



Atomic arrangement in monolayer MX_3 (a) and MX_2 (b). J1, J2 and J3 identify magnetic exchange interactions between first, second and third cationic neighbors

References

[1] N.D. Mermin and H. Wagner, *Phys. Rev. Lett.* 17, 1133 (1996).
[2] N. Mounet et al. *Nature Nano.* 13, 26 (2018).
[3] M. A. McGuire *Crystals* 7, 121 (2017).

Role of dopant cations on functional properties in cerium oxide thin films for energy applications

Carmela Aruta [1]

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Functional properties caused by mobile oxygen ions in solid oxide materials are gaining greater and greater importance for a wide range of applications, such as catalysts, gas sensors, memristors, electrochemical energy storage/conversion systems, including solid oxide photoelectrochemical and fuel cells. New possibilities in thin film fabrication allow the growth of oxide thin films with a more precise control of the structure and chemical stoichiometry, unveiling new perspectives in the study of technologically important properties of oxide materials. While this approach is quite established in the field of nanoelectronics, it has been more recently adopted also to study ion conducting materials, raising the question of whether by using epitaxial thin films the functionalities based on mobile oxygen ions can be properly tuned. In this context, doped ceria is widely investigated for the intricate interrelationship between microstructure and chemical substitution defects affecting the transport and catalytic properties, as well as the photoactive properties exploting the mixed ionic-electronic conductivity and good surface reactivity. We will discuss the results on the epitaxial doped ceria films obtained by complementary state-of-art experimental techniques, both in laboratory and with synchrotron radiation facilities. The amount of doping and the different ion radius size of the rare-earth dopants affect the local structure and defects distribution, which in turn modifies the electronic band structure. We show how such microscopic properties influence ion conductivity, oxygen exchange surface reaction and charge carriers trapped by oxygen vacancies, with particular regard to the doped ceria used in environmental-friendly applications, so as in solid oxide photoelectrochemical cells. [1,2,3]

References

[1] Nan Yang et al. *ACS Appl. Mater. Interfaces* **8** (2016) 14613
[2] Nan Yang et al. *J. Phys. Chem. C* **121** (2017) 8841
[3] Yanuo Shi et al. *to be published* (2019)

Berry phase engineering at oxide interfaces

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Geometric phases in condensed matter play a central role in topological transport phenomena such as the quantum, spin and Anomalous Hall Effect (AHE). In contrast to the quantum Hall effect - which is characterized by a topological invariant and robust against perturbations - the AHE depends on the Berry curvature of occupied bands at the Fermi level and is therefore highly sensitive to subtle changes in the band structure.

A unique platform for its manipulation is provided by transition metal oxide heterostructures, where engineering of emergent electrodynamics becomes possible at atomically sharp interfaces. We demonstrate that the Berry curvature and its corresponding vector potential can be manipulated by interface engineering of the correlated itinerant ferromagnet $SrRuO_3$ (SRO). Measurements of the AHE reveal the presence of two interface-tunable spin-polarized conduction channels. Using theoretical calculations, we show that the tunability of the AHE at SRO interfaces arises from the competition between two topologically non-trivial bands. Our results demonstrate how reconstructions at oxide interfaces can be used to control emergent electrodynamics on a nanometer-scale, opening new routes towards spintronics and topological electronics.[1]

We discuss the evolution of the anomalous Hall conductivity as a function of the orientation of the magnetization encoded in the angle with respect to the z-axis perpendicular to the electron motion plane. We argue that the maximal of the anomalous Hall conductivity is obtained at a finite value of the angle due to the interplay the orbital Rashba field, the anisotropy, the topological bands and the magnetization.[2]

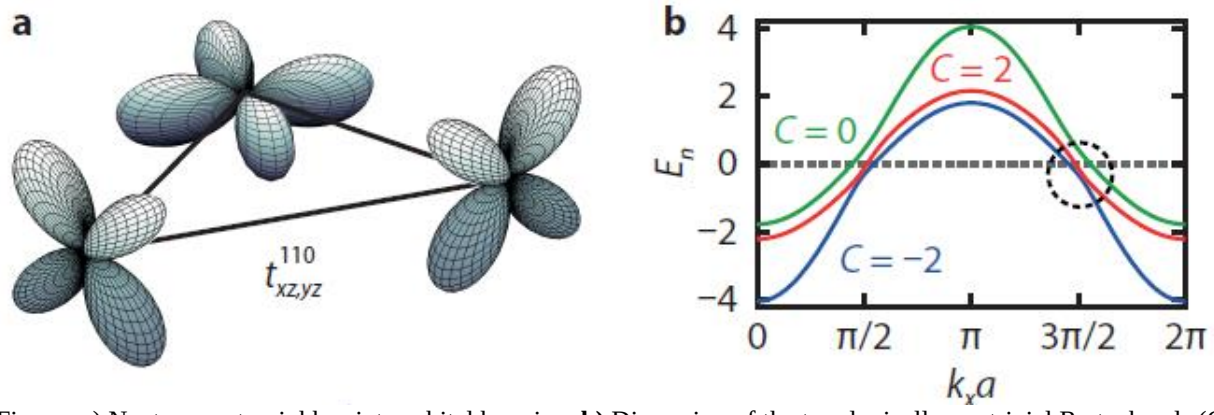

Figure: **a**) Next-nearest-neighbor interorbital hopping. **b)** Dispersion of the topologically nontrivial Ru t_{2g} bands (Chern numbers C =-2, 0, 2) along $k_x = k_y$ for a representative value of the magnetization.

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[1] D. J. Groenendijk, **C. Autieri**, T. C. van Thiel, W. Brzezicki, N. Gauquelin, P. Barone, K. H. W. van den Bos, S. van Aert, J. Verbeeck, A. Filippetti, S. Picozzi, M. Cuoco and A. D. Caviglia "Berry phase engineering at oxide interfaces". Preprint available at https://arxiv.org/abs/1810.05619
[2] W. Brzezicki, **C. Autieri** and M. Cuoco submitted.

Defects, Disorder, and Strong Electron Correlations in Orbital Degenerate, Doped Mott Insulators: Defect-Induced Orbital Polarization and Collapse of Orbital Order

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We elucidate the effects of defect disorder and e-e interaction on the spectral density of the defect states emerging in the Mott-Hubbard gap of doped transition-metal oxides, such as $R_{1-x}(Sr;Ca)_xVO_3$ (R = Pr; Y; La). A soft gap of kinetic origin develops in the defect band and survives defect disorder for e-e interaction strengths comparable to the defect potential and hopping integral values above a doping dependent threshold; otherwise only a pseudogap persists. These two regimes naturally emerge in the statistical distribution of gaps among different defect realizations, which turns out to be of Weibull type. Its shape parameter k determines the exponent of the power-law dependence of the density of states at the chemical potential (k − 1) and hence distinguishes between the soft gap (k ≥ 2) and the pseudogap (k < 2) regimes. Both k and the effective gap scale with the hopping integral and the e-e interaction in a wide doping range. The motion of doped holes is confined by the closest defect potential and the overall spin-orbital structure. Such a generic behavior leads to complex non-hydrogen-like defect states that tend to preserve the underlying C-type spin and G-type orbital order and can be detected and analyzed via scanning tunneling microscopy. We also explore mechanisms of orbital-order decay in these compounds. We show that the rotation of t_{2g} orbitals, induced by the electric field of defects, is a very efficient perturbation that largely controls the suppression of orbital order. We investigate the inverse participation number spectra and find that electron states remain localized on few sites even in the regime where orbital order is collapsed. From the change of kinetic and superexchange energy, we can conclude that the motion of doped holes, which is the dominant effect for the reduction of magnetic order in high-T_c compounds, is of secondary importance here.

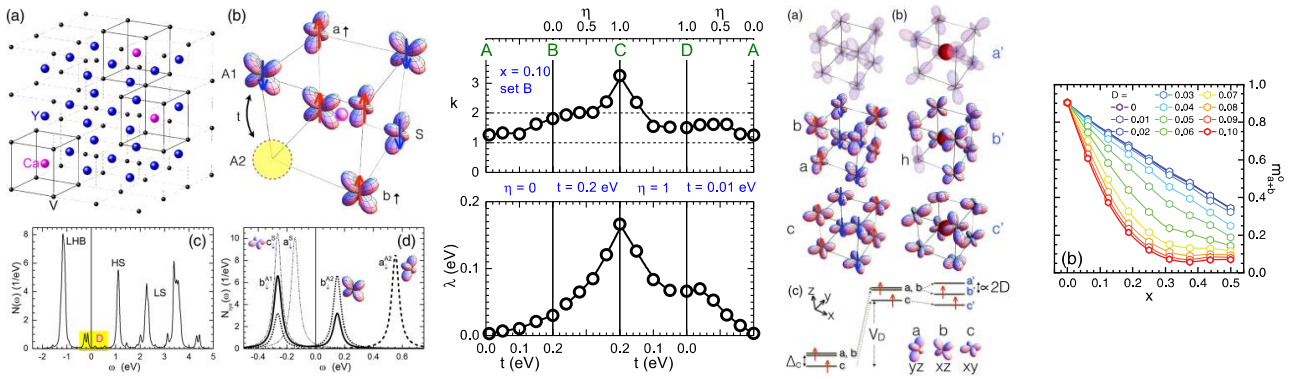

Figure: Defect cube, kinetic gap, Weibull parameters, orbital polarization, and orbital order.

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Current-Resistance Effects and Nonlinear Fluctuation Mechanisms in Granular Aluminum Oxide Nanowires for Quantum Computing Applications

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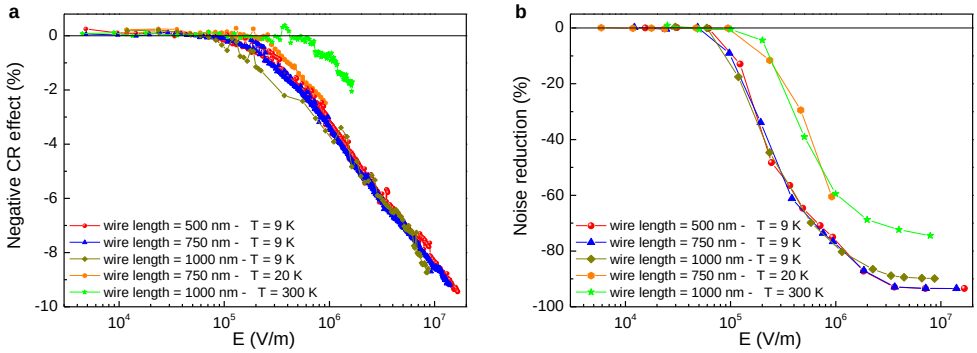
Among granular superconductors, aluminum oxide (AlO_x) may play a prominent role in the design of quantum computing elements, due to its low electric loss and high kinetic inductance [1]. In this system, especially when patterned at the nanoscale level, a good understanding of the effect of disorder is crucial. To this end, electric noise spectroscopy has already revealed its potentials for the sensitive investigation of low-dimensional superconducting films and 2D oxide interfaces, giving more insights on the charge carriers kinetic processes [2,3].

DC electric, magneto-transport, and voltage-noise measurements have been made on AlO_x nanowires, at temperatures between 8 and 300 K. A resistivity reduction with increasing bias has been observed in association with a strong noise level reduction, as shown in the Figure below. The nonlinear electric transport behavior of the nanodevices does not have a magnetic origin, contrarily to what found in thin films [4], but can be explained in terms of a dynamic random resistor network model. This mechanism, usually considered as a variant of the standard percolation process, is also able to explain the behavior of the noise, providing a deeper understanding of the charge carrier fluctuations nature.



The effect of increasing bias is the reduction of the nanowire resistivity (a) and of the overall noise level (b).

The observed transport and noise phenomenology, although related to the normal state, can be reflected also in the superconducting state and at very low temperatures, where quantum circuits operate.

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Organic semiconductors modulating cobalt thin films magnetic anisotropy

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Recent investigations in molecular spintronic devices highlighted the role of the interfacial interactions between the organic molecules and the ferromagnetic metals, defining the electronic and magnetic properties of both components [1-3]. The surface orbitals of a ferromagnetic ultra-thin film rearrange when a molecule chemisorbs over it. This affects the ferromagnetic layer magnetic anisotropy, resulting in magnetization reorientation, magnetic hardening and other effects [1].

In this work we have investigated the in-plane magnetic anisotropy of ultrathin polycrystalline cobalt films (5 nm) by Longitudinal Magneto Optic Kerr Effect (L-MOKE) and the effect of the formation of hybridized layer at their interface with organic molecules. Bare cobalt thin films were obtained by e-beam deposition on single crystal $Al_2O_3(0001)$ substrates. Without breaking the vacuum, in order to preserve interfacial quality, a 25 nm thick continuous organic layer was grown by thermal evaporation. Buckminster-fullerene (C_{60}) [2], tris(8-hydroxyquinolinato)gallium (Gaq_3) [3] and sexithiophene (T_6) are the molecules chosen, all widely used in molecular spintronic devices,

Cobalt ultra-thin films show an atomically flat surface (RMS of 0.4 nm) with a weak uniaxial anisotropy. The molecular layer deposition results in two strong and opposite effects: the coercive field values increase in C_{60}/Co and T_6/Co bilayers, while they decrease for Gaq_3/Co. Moreover, the uniaxial anisotropy is enhanced in C_{60}/Co. The in-plane magnetization process is described by a non-coherent rotation mechanism with anisotropy terms that depends on the specific molecule considered.

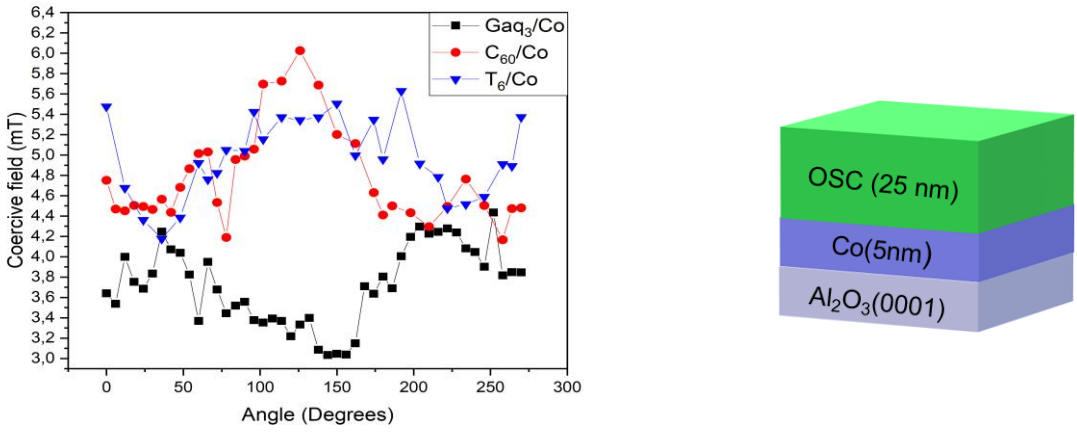

Figure 1. Left: coercive fields as a function of the in-plane angular direction. Right: OSC/Co samples schematics.

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Evidence of the isoelectronic character of F doping in $SmFeAsO_{1-x}F_x$

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The $SmFeAsO_{1-x}F_x$ superconducting alloy has attracted much attention because of its high transition temperature ($T_C = 58$ K) at optimal doping [1]. Recent experiments [2] show that the Shubnikov de-Haas oscillations in the $SmFeAsO_{1-x}F_x$ do not change with F concentration. This behavior is somewhat surprising because it contradicts the common believe that F should behave as a donating impurity. In a semimetal, as the SmFeAsO, electron doping should widen the size of the Fermi surface for the electrons and shrink those related to the holes. Instead, experimental evidence suggests that the size of the Fermi surfaces is independent of F concentration. To shed light on this anomalous behavior, we study the electronic structure of the $SmFeAsO_{1-x}F_x$ alloy by means of first-principle calculations [3]. We find that, contrary to common believe, F-doping does not change the charge balance between electrons and holes free-carriers in $SmFeAsO_{1-x}F_x$. Indeed, within a narrow energy range across the Fermi energy, the effect of F-doping on the band structure dispersion is tiny in both the paramagnetic and stripe antiferromagnetic phase of $SmFeAsO_{1-x}F_x$. Using the concept of Baders charge, we discuss the charge balance between the conducting FeAs-layer and the $SmFeAsO_{1-x}F_x$ charge reservoir layer as a function of F concentration. The results of our calculations show that the charge state of the FeAs-layer is not influenced by the compositional change. Such a surprising behavior can be explained looking at the evolution of the band structure as a function of F concentration. We discover that the additional charge carried by fluorine, with respect to the oxygen, is compensated by a change in the oxidation state of the Sm ion from 3+ to 2+. A comparison with the $SmFe_{1-x}Co_xAsO$ system shows that such a charge compensation by the Sm ion is not shared by donors substituting at the Fe site.

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Distinct electronic character and selective control of localised vs. delocalised carriers at (001) surface of anatase TiO_2

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Titanium dioxide (TiO_2), especially its quasi-metastable anatase form, is one of the most widely investigated systems for energy-related applications. Despite pristine anatase is expected to be a wide (3.2 eV) band gap insulator, a localised electronic state occurring at shallow binding energies (in-gap) and a highly dispersive metallic state have been recently reported [1,2]. However, whereas the in-gap presence is commonly attributed to the n-doping due to the native oxygen defects, the effects produced on the metallic state by oxygen vacancies is still highly debated [3-5], proving to be key parameters to understand and control.

High quality, epitaxial anatase TiO_2(001) thin films were grown by means of Pulsed Laser Deposition. In-situ Angle-Resolved Photoemission Spectroscopy (ARPES) characterisation on the Low-Energy branch of APE beamline [6] clearly show a highly dispersive metallic state (**Fig 1.a**) whose Fermi surface (**Fig 1.b**) follows the periodicity of the well-known (4x1)/(1x4) surface reconstruction of anatase (001) shown by the LEED pattern in **Fig 1.c**. We investigated the spectral changes in ARPES signal upon molecular oxygen dosing at the Soft X-Ray branch of I09 beamline at DIAMOND light source. We observed the strong and instantaneous drop of the intensity for the in-gap states, ascribable to oxygen vacancies recombination and consequent decrease of excess electrons. On the other hand, only minor changes of the dispersive state upon surface oxidation were detectable. Resonant ARPES across the Ti 2p absorption edges revealed Ti3+ character of the in-gap state, clearly demonstrating these localised electrons are strictly linked to the oxygen vacancies. The metallic state, instead, is completely delocalised at the TiO_2 surface having its wave-function stronger overlap with the stoichiometric anatase Ti 4+ sites. These important results demonstrate the different electronic character of the localised and metallic states and refine the understanding on their origin.

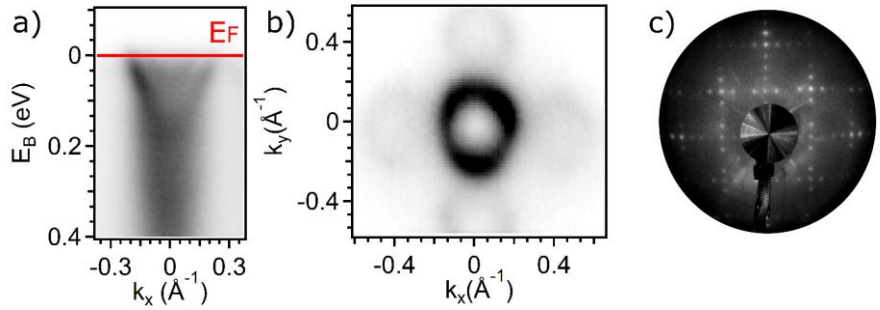

Figure 1 a) ARPES spectra reporting the metallic state E(kx) dispersion **b)** Fermi surface of the metallic state mimicking the structural surface reconstruction shown by the LEED pattern in **c)**

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Pressure dependence of J_c in series of Ni-doped Ba122 single crystals

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Pressure has been consistently shown to have a significant effect on the superconducting properties of high-temperature superconductors (HTS), resulting in observed increases of critical current density (J_c) and/or critical temperature (T_c) [1]. Here, we present a study exploring the effect of hydrostatic pressure on the J_c and T_c of a series of $Ba(Fe_{1-x}Ni_x)_2As_2$ single crystals, performing measurements over a range of pressures to reveal a more detailed picture of the pressure dependencies in HTS materials.

Preliminary results reveal a consistent local maxima around a critical pressure (P_c) of 0.4-0.6 GPa for plots of J_c vs pressure. Many interesting, and potentially useful, effects can be observed such as increases in J_c as high as 300% from 0 to 0.4 GPa as well as a pressure induced shifting of the second magnetization peak in some samples. The series of crystals studied will include doping levels corresponding to underdoped, optimally doped, and overdoped regimes, as well as doping levels associated with a proposed quantum critical point [2]. Interrogation of the how the P_c, percentage increases of J_c, and pinning behaviors evolve for different dopings will shed light on the nature of the mechanism by which pressure successfully augments superconducting properties.

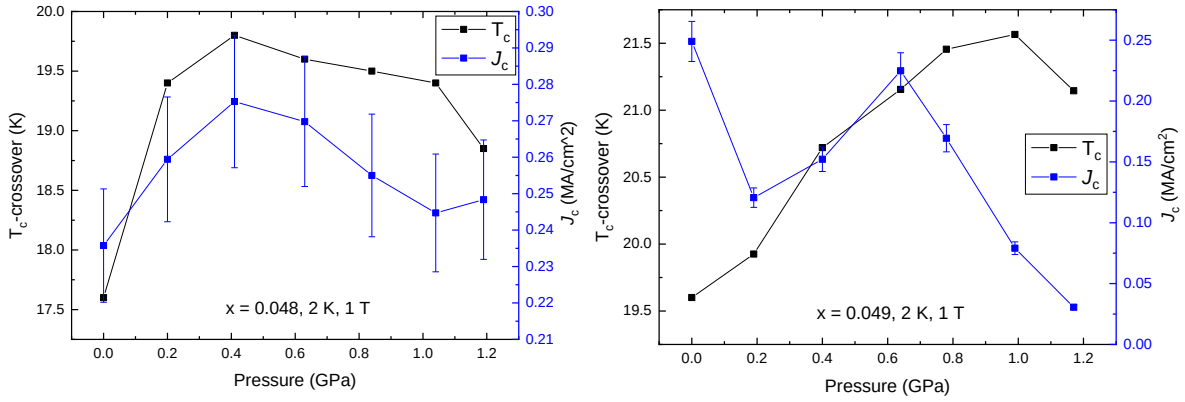

Figure 1: Plots of J_c and T_c vs pressure for two optimally doped $Ba(Fe_{1-x}Ni_x)_2As_2$ single crystals reveal a critical pressure at which we find a local maxima in J_c.

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Freestanding Strontium Ruthenate Membranes

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Freestanding complex oxide membranes are a valuable tool for investigating and tuning a variety of functional properties, including ferromagnetism and superconductivity. Complex oxide thin films are grown via pulsed laser deposition (PLD), with a sacrificial layer deposited underneath the desired film. This sacrificial layer can then be removed via water etching to produce a high quality freestanding membrane [1]. Using a dry-pickup technique this membrane can then be transferred onto a substrate, which then allows electrical contacts to be deposited.

Strontium ruthenate (SrRuO3) is an itinerant ferromagnet that exhibits an anomalous Hall effect that is sensitive to interfacial boundary conditions [2]. Here we discuss the anomalous Hall transport of SrRuO3 membranes transferred on Si substrates and other perovskite single crystals. The samples show robust ferromagnetism with an enhanced Curie temperature when compared to epitaxial thin films. Magneto-optical studies further confirm the ferromagnetic character of the exfoliated films. We will discuss perspectives for transport and out-of-equilibrium dynamics experiments in this new magnetic oxide platform.

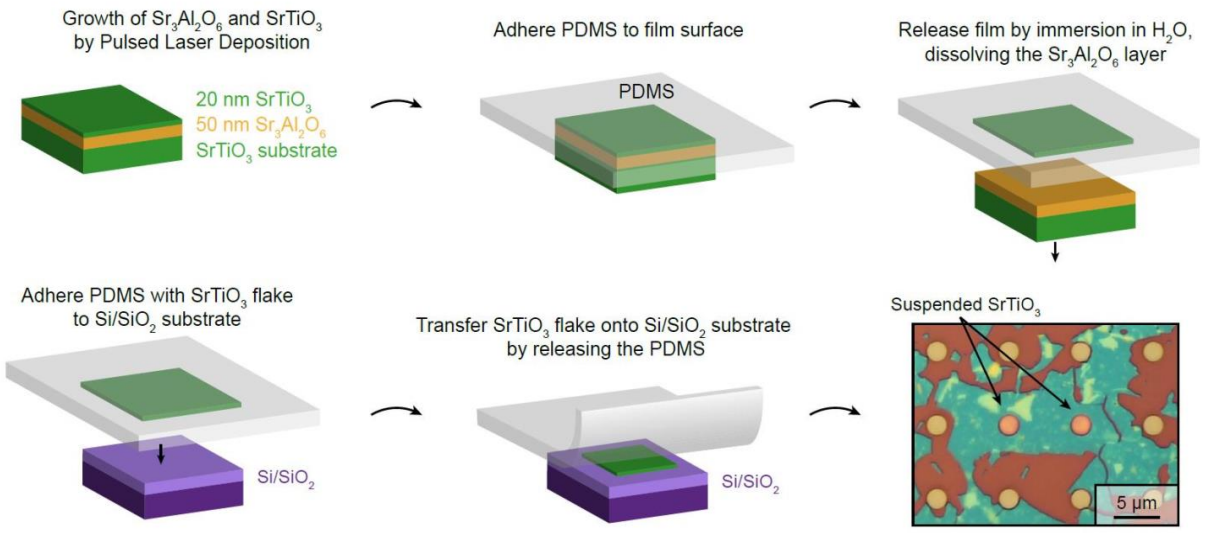

***Figure 2**: Synthesis methodology for exfoliated oxide heterointerfaces. Right: atomic force microscopy of a suspended SrTiO3 membrane on silicon cavities.*

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New perspectives for X-ray nanopatterning of oxide systems

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The advances made in terms of functionalization of new oxide-based devices and patterning techniques constantly innovate the field of electronics. Working on this complex framework, we have recently obtained promising results in the application of X-ray nanobeams from state-of-the-art synchrotron sources to the fabrication of devices based on oxide materials. By qualitatively correlating the irradiation dose with the decrease of the material oxygen content, we have been able to functionalize at the nanometric level different superconducting and semiconducting systems [1-4]. In this contribution, we want to give an overview of the most important results achieved until now and of the future perspectives in the application of X-ray nanopatterning (XNP).

The first results on the irradiation effects of high-power X-ray beams have been collected in devices based on the cuprate superconductor $Bi_2Sr_2CaCu_2O_{8+\delta}$. In this system, a reduction of the crystalline order has been associated to an increase of the electrical resistivity. Recent analyses of the X-ray patterned regions by means of transmission electron microscopy have revealed an amorphous melt-like profile in which small crystalline inclusions are embedded. These observations seem to indicate a synergistic action of both non-thermal and mechanical stresses as the possible origin of the modification mechanism.

On the semiconductor side, we have recently shown that in TiO_2 XNP can induce conductive channels by creating oxygen vacancies in the insulating matrix. Following these results, we have further investigated the resistive switching behavior of these X-ray nanopatterned devices, and preliminary data show that it seems to be possible to induce memristive behavior. Moreover, morphological variations of the irradiated regions (both along the electrical contacts and in the TiO_2 surface) have been observed through atomic force microscopy. These results highlight a complex interplay between the creation of oxygen vacancies by means of X-ray irradiation and the vacancies drift due to the voltage applied to the device.

Overall, these results confirm the capabilities of intense X-ray beams to fabricate new devices based on oxide systems, opening new perspectives for example for THz emitters based on intrinsic Josephson junctions or for the fabrication of memristive devices.

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Modeling quench in HTS devices: from individual tapes to full-scale magnets

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The technical interest in High Temperature Superconductors (HTS) is increasing given their great potential for use in high field magnets and power applications. The occurrence of a quench in devices manufactured from 2nd generation ReBCO tapes is less probable than in Low Temperature Superconducting (LTS) devices, due to the higher enthalpy and temperature margins available in HTS conductors. However, quenches in HTS are characterized by low normal zone propagation velocities, which may result in high hot spot temperatures and consequent damages of the conductor. The proper analysis of quench events is therefore of paramount importance for the development of an adequate quench protection system.

This work describes the electro-thermal models for the analysis of quench in tapes developed at the University of Bologna, based on either distributed non-linear circuits or field models solved with the Finite Element Method (FEM). The tape model is used as the fundamental brick for the construction of more complex analysis tools of HTS cables for fusion and accelerator magnets (with special reference to Roebel cables). The need for treating the tape as a homogenized anisotropic material is pointed out. The model is finally scaled up to study a full-scale high field HTS magnet, namely the 32 T fully superconducting magnet of the National High Magnetic Field Laboratory, USA. In order to account for the magnetic inductive coupling between the HTS insert and the LTS outsert, the FEM code is coupled to an equivalent electric circuit. It is shown that, notwithstanding some simplifying assumptions, the model is able to catch the main aspects of the magnet quench behavior.

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Topology in non-symmorphic and non-Hermitian chiral chains

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We consider a class of one-dimensional (1D) non-Hermitian models with a special type of a chiral symmetry which is related to pseudo-Hermiticity [1]. We show that the topology of a Hamiltonian belonging to this symmetry class is determined by a hidden Chern number described by an effective two-dimensional Hermitian Hamiltonian $H^{eff}(k,\eta)$, where η is the imaginary part of the energy. This Chern number manifests itself as topologically protected in-gap end states at zero real part of the energy. We show that the bulk-boundary correspondence coming from the hidden Chern number is robust and immune to non-Hermitian skin effect. We introduce a minimal model Hamiltonian supporting topologically nontrivial phases in this symmetry class, derive its topological phase diagram and calculate the end states originating from the hidden Chern number.

Motivated by the recent developments in engineering artificial lattices, we also study a Hermitian 1D model, similar to a celebrated Su-Schrieffer-Hegger (SSH) model, where hopping is constant but the onsite energy is dimerized [2] – namely the SSG model. We find that it has a non-symmorphic chiral symmetry and supports topologically distinct phases described by a $\mathbb{Z}_2$ invariant ν. In the case of multimode ribbon we also find topological phases protected by hidden symmetries and we uncover the corresponding $\mathbb{Z}_2$ invariants ν_n. We show that, in contrast to the SSH case, zero-energy states do not necessarily appear at the boundary between topologically distinct phases, but instead these systems support a new kind of bulk-boundary correspondence: The energy of the topological domain wall (DW) states scales to zero as 1/w or $e^{-w/\xi}$, where ξ is an intrinsic length scale and w is the width of the domain wall separating phases with different nu or different ν_n, respectively. We show that the spectral flow of these states and the charge of the domain walls are different than in the case of the SSH model, see Fig. 1.

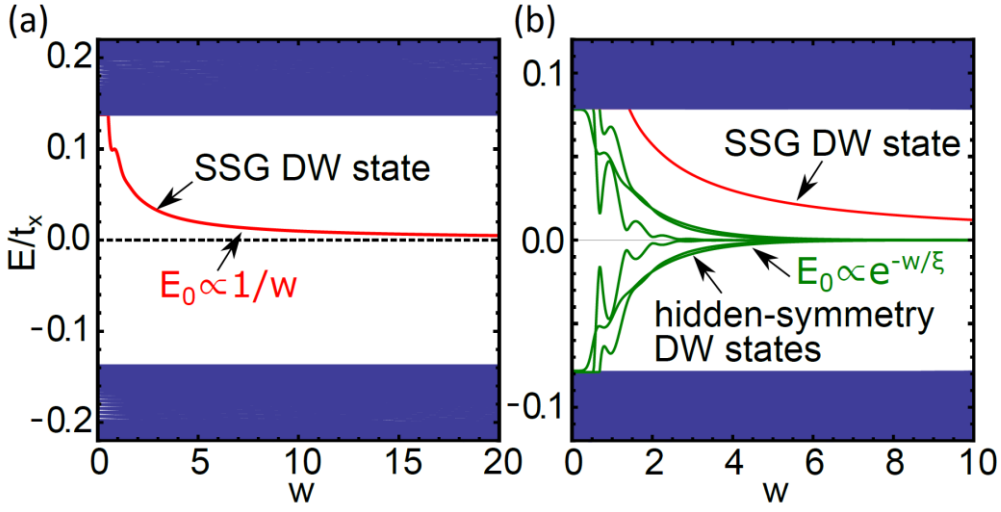

Figure1. Spectral flows or the SSG model versus DW width for DW between two regions (a) with different ν and (b) with different ν_n topological invariants.

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Elasto-transport: a probe for nematic fluctuations in iron-based superconductors

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The investigation of nematic orders in solid state systems has been strongly boosted in recent times by the suggestive hypothesis of their intimate link with the emerging unconventional superconductivity in copper-based and specially in iron-based superconductors (IBS) [1]. In the latter, the nematic order identifies a lowering of the rotational symmetry characterized by a tetragonal-to-orthorhombic structural transition, which typically anticipates the formation of a time-reversal-invariant magnetic order with additional signatures of orbital ordering [1]. Among the several ideas proposed to understand the role of the nematiciy in IBS, a groundbreaking intuition was to use the strain derivative of the resistivity anisotropy as a sensitive quantity mimic of the nematic order parameter [2]. This allowed to reveal an extended region of nematic fluctuations above the structural transition, where the crystalline symmetry is still tetragonal, and to distinguish the electronic origin of the nematic phase from a simple ferroelastic distortion [2].

In this work, we extended the experimental technique by introducing the strain-derivative of the thermoelectric coefficients, namely the Seebeck and the Nernst effects. This was realized by combining a standard thermoelectric measurement configuration, with the highly controlled uniaxial strain offered by a piezoelectric device (Figure 1a). By applying this new technique to the 1111 family of IBS, we discovered that a universal Curie-Weiss-like behavior governs electric and thermoelectric elasto-transport above the structural transition, as a fingerprint of the original trigger of the nematicity (Figures 1b and 1c). Remarkably, our measurements reveal a band-selective character of the nematic phenomenology and show that different transport properties are not equivalently representative of the nematic susceptibility.

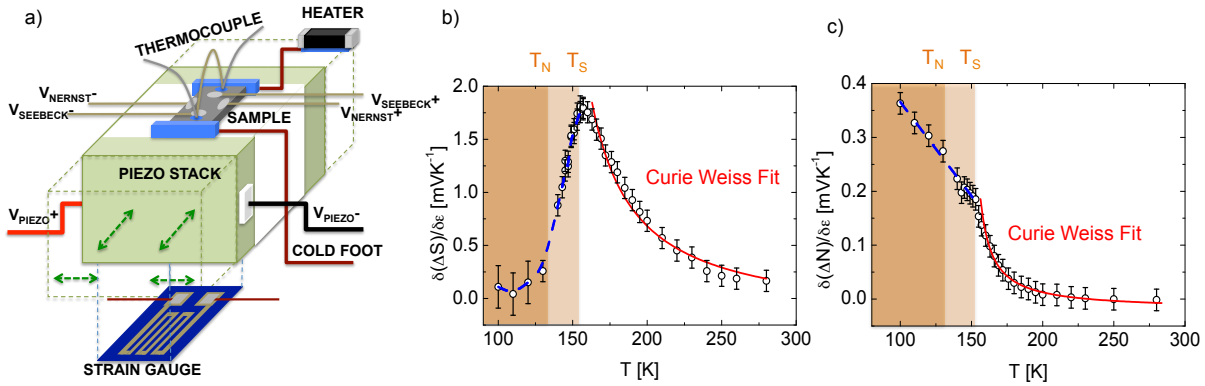

Figure 1: a) Schematic of our experimental setup for elasto-thermoelectric transport. b) Elasto-Seebeck and c) Elasto-Nernst effect of a LaFeAsO compound. Red curves are the Curie-Weiss fit for the nematic fluctuations.

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Study of HTS coatings for beam impedance mitigation in the FCC

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The beam screen of the proposed FCC-hh collider at CERN presents several operating challenges. Its main function is to intercept the synchrotron radiation emitted by the beam, shielding the accelerator magnets, which are cooled at 1.9 K. It should operate at 50 K as a compromise between energetic efficiency and vacuum requirements; however at this temperature a copper coating facing the beam, like in the LHC at present, would have a relatively high electrical resistivity, thus a high beam coupling impedance, resulting in too little margins for beam stability.

Since 2016 a collaboration between CERN and several European institutes has been exploring the possibility of using HTS for the beam screen, in replacement of copper. We will discuss, based on a simple theoretical modelling, the selection criteria for the superconductor, which should guarantee a low surface impedance in a magnetic field up to 16 T. We will then discuss the two routes selected, namely a coating of Tl-based cuprates directly on the beam screen or soldering REBCO coated conductors on its surface. Several key milestones have been achieved during the collaborative work and a great deal of promising results have been demonstrated on test samples, including many different requirements related to the accelerator environment.

Finally, we will discuss the plans for the next phase of the collaboration, aimed at designing and fabricating proof-of-concept prototypes which could be measured in an ad-hoc impedance and field quality test set-up.

"Proteins MgB_2 carbon doping through Freeze-drying process"

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We introduce the exploration of protein doping on MgB_2 as a carbon sources. Dopants are introduced in the boron precursor powder with the use of the patented freeze-drying process [1] for nanometric boron production via B_2O_3 reduction (Moissans process). This procedure allows to prepare doped boron nanoparticles with average grain size of 150 nm with a reproducible process capable of synthesize hundreds of grams of powders per batch.

The process consists in the creation of a water solution containing both boron oxide and the protein (this must be soluble). The solution is sprayed into liquid nitrogen and small droplet of doped boron oxide are formed. The final step is to remove water through freeze-drying process. The obtained powders are reduced into elemental boron at high temperature and organic molecule degrade to raw carbon or borides.

Protein degradation into B_4C phase and consequential carbon diffusion in the reacted MgB_2 powders has been studied with the variation of the most influential parameters (dopant concentration, MgB_2 reaction temperature, protein dimension etc.). Proteins present some advantage over usual carbon sources as polymer, carbohydrates and carbon soot in terms of atomic doping control and dimensions: each protein has the same atomic amount of elements and the same dimensions, so these class of compounds can be very promising for producing an homogeneous and controlled carbon doping source. In particular, tested proteins include haemoglobin and albumin as most promising candidate. These proteins have a spherical shape and each particle have an average diameter of 6 nanometres; this dimension fit with the coherence length of superconductive MgB_2 and it's suitable for producing a lattice of regular and homogeneously distributed normal defects into magnesium diboride. This is possible because a great amount of carbon introduced do not substitute in the MgB_2 structure and tends to form non-superconducting region (carbon cluster usually) that act as pinning centres. The aim is to create an optimized MgB_2 structure where part of the carbon substitute (increasing H_{C2}) and the remaining carbon enhance critical current thanks to the formation of pinning centres.

To compare proteins with other usual dopant, a new parameter has been introduced as the "Doping efficiency" to estimate % of carbon effectively substituting vs nominal carbon introduced in the powders. Data shows that powders doped with proteins present a higher doping efficiency and in respect to carbon-soot source. Doping efficiency influence on superconductive properties is presented and analysed in term of J_C, H_{C2} and T_C.

In this work, we present the characterization of doped boron and MgB_2 powders. Also, wires samples have been produced using different techniques including PIT (Powder in tube) in-situ, ex-situ and IMD (internal magnesium diffusion). Superconducting properties has been evaluated through magnetic and resistive measurements.

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

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Charge density modulations have been observed in all families of high–critical temperature superconducting cuprates. Although they are consistently found in the underdoped region of the phase diagram and at relatively low temperatures, it is still unclear to what extent they influence the unusual properties of these systems. Using resonant x-ray scattering (RIXS) [1], we carefully determined the temperature dependence of charge density modulations in $YBa_2Cu_3O_{7-\delta}$ and $Nd_{1+x}Ba_{2-x}Cu_3O_{7-\delta}$ for several doping levels. We isolated short-range dynamical charge density fluctuations in addition to the previously known quasi-critical charge density waves. They persist up to well above the pseudogap temperature T^*, are characterized by energies of a few meV, and pervade a large area of the phase diagram (see Fig. 1).

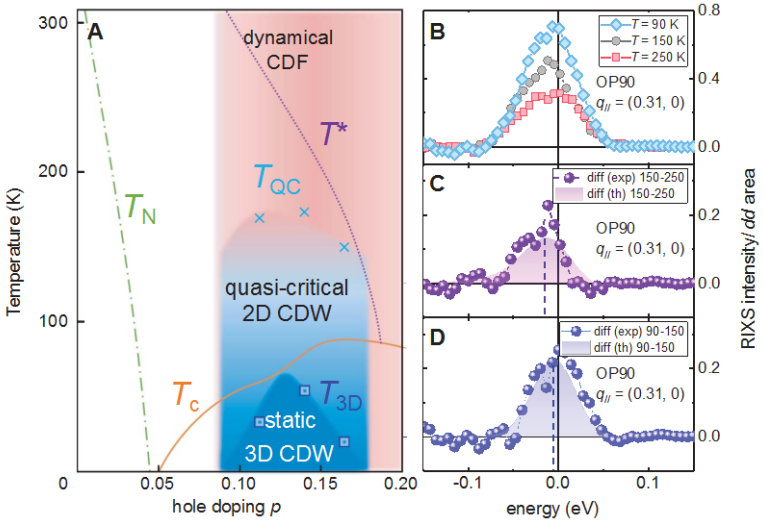

Fig. 1 – (A) The temperature vs. doping phase diagram of cuprates encompasses the antiferromagnetic, pseudogap, and superconducting regions (with onset temperatures T_N, T^*, and T_c). Charge density modulations pervade most of these regions. Two-dimensional (2D) charge density waves (CDWs) are observed in the pale blue region below T_{QC} (X) as a narrow peak (NP). They are quasi-critical and are precursors of static three-dimensional (3D) CDWs (blue region). We cannot access this region without a magnetic field, but the temperatures T_{3D} (□) inferred from the T dependence of the NP full width at half maximum are in agreement with those previously determined by NMR and hard x-ray scattering experiments [2,3]. Short-range charge density fluctuations (CDFs), observed as a broad peak (BP), pervade the phase diagram (red region), coexist with both 2D CDWs and superconductivity, and persist even above T^*. CDFs disappear in undoped/antiferromagnetic samples (white region), whereas their occurrence for $0.05< p <0.08$ has yet to be assessed. The characteristic energies w_0 of the BP was extracted from high-resolution RIXS spectra at various temperatures on the samples OP90 (optimally doped, T_c = 90 K) and UD60 (underdoped, T_c = 60 K). **(B)** Quasi-elastic spectra at T = 90, 150, and 250 K, measured on sample OP90 at an in-plane wavevector $q_{||}$ = (0.31, 0). **(C** and **D)** Experimental 150 K–250 K and 90 K–150 K difference spectra (❍), and theoretical predictions (solid areas). The data are in agreement with the theory, assuming $w_0 \approx 15$ meV at 150 and 250 K and $w_0 \approx 7$ meV at 90 K (dashed lines).

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Switching the Verwey transition in magnetite

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Magnetite undergoes a metal insulator transition (MIT) termed Verwey transition, which is accompanied by a structural rearrangement of the atomic positions. The insulating state of the material is characterized by a complex 3D charge order whose microscopic details could be revealed only recently via X-ray micro-diffraction. The micro-twinning of the sample below the critical temperature impeded previous studies by k-resolved probes. The mechanism of the MIT in magnetite has been debated for decades, as disentangling the lattice and electronic contributions to it proved an experimental challenge. In this talk, we will review a recent study which combined inelastic neutron scattering experiments with ultrafast optical spectroscopy and electron diffraction to elucidate the dynamics of the charges and ions across the Verwey transition. We will provide an explanation for its mechanism and show routes to control it via light pulses.

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Study of the CdS QDs formation in film by thermal and laser treatment

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The synthesis of II-VI quantum dots (QDs) [1] from a single source precursor is one of the emerging strategies to obtain the QDs directly in polymer matrices, thus to form hybrid nanocomposite materials, promising in a wide range of optoelectronic applications.

In the scenario of the single source precursors, the xanthate molecules are particularly suitable for the formation of the CdS QDs in the polymeric matrix, because the decomposition compounds are volatiles. In fact, in the present contribution a xanthate molecule is synthesized and studied as a single source precursor of CdS QDs. The selected xanthate is first tested in solution to verify the formation of the QDs by solvothermal synthesis. Then, the same precursor is mixed with a polymer to produce solid thin films and two different methodologies, such as thermal treatment and laser patterning, were employed to obtain the CdS QDs directly in the polymer matrix. The laser patterning method is indeed one of the most cutting-edge technologies to activate the precursor phase embedded in a polymeric matrix and paves the way to large-scale technology transfer [2].

The CdS QDs obtained both in film and in solution are characterized by UV-Vis, photo-luminescence (PL) spectroscopy the X-ray Photoelectron Spectroscopy (XPS) and Fluorescence Microscopy.

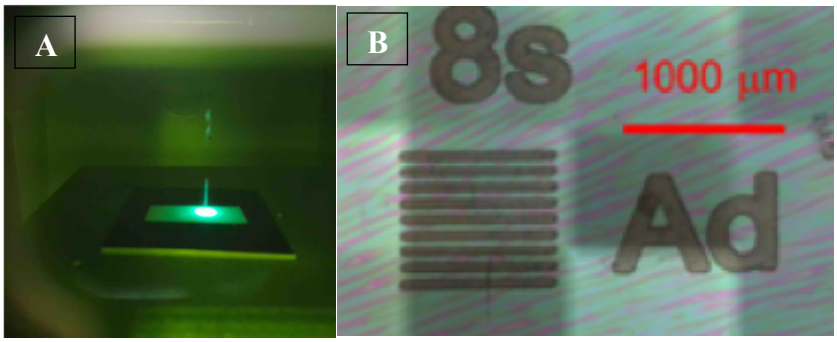

Figure 1 a) the laser under patterning; b) the laser effect of the polymer loaded with the precursor.

This work is supported by a grant of the Regione Lazio (Nanoscrila project 22376 www.nanoscrila.enea.it) and is focused towards the laser patterning formation of quantum dots for display manufacturing.

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Ultrafast optical control of quantum materials

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Selective optical excitation of the crystal lattice can drive phase changes in materials with competing ground states. In this talk we will review the experimental technique of resonant excitation of infrared active phonon modes and its non-linear coupling to low-energy collective modes including magnons, polarons and Raman active phonons. We will discuss several examples of ultrafast control of spin arrangements, metal-insulator transitions and crystal structures made possible by this novel approach.

Firstly, we will consider ultrafast phonon excitation across heterointerfaces. This phenomenon is the non-equilibrium analogue of static strain engineering in heterostructures. Here, we make use of time-resolved non-resonant and resonant x-ray diffraction to clarify the underlying physics, and to separate different microscopic degrees of freedom in space and time. We measure the dynamics of the lattice and that of the charge order in $NdNiO_3$, in which an insulator metal transition is driven by coherent lattice distortions in the $LaAlO_3$ substrate. We find that charge disordering propagates at supersonic speeds from the interface into the $NdNiO_3$ film, followed by a sonic lattice wave. When combined with measurements of magnetic disordering and of the metal-insulator transition, the present results establish a hierarchy of events for ultrafast control at complex oxide hetero-interfaces.

Secondly we will discuss ultrafast lattice control of the magnetic insulating oxide $DyFeO_3$ whose energy landscape hosts competing anti- (AFM) and weak-ferromagnetic (wFM) orders. Resonant pumping of a lattice vibration promotes an ultrafast coherent transition from the AFM to the wFM state. Coherent ballistic switching between competing magnetic phases is demonstrated by resonant phonon pumping and accounted for by ultrafast control of the magnetic energy landscape. Finally we will show that conducting oxide interfaces with strong electron-phonon coupling display phonon-induced ultrafast dynamics consistent with the excitation and relaxation of polarons.

Development and Perspectives of HTS Cable-In-Conduit Conductor with Al-Slotted Core for Fusion Applications

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In recent years, due to the increasing performances of the High Temperature Superconductor (HTS) REBCO-based conductors, i.e. *coated conductors*, the development of HTS based technology for extremely high field generation applications is emerging as one of the most favorable opportunities in either nuclear fusion or particle accelerator sectors. As far as nuclear fusion is concerned, several conceptual designs and R&D studies have been carried out for the implementation of HTS magnetic systems in DEMO and SPARC tokamak reactors, in the FFHR-d1 helical reactor, or in Spherical Tokamaks. More recently, in the framework of the foreseen activities of the newly proposed Italian DTT (Divertor Tokamak Test facility) nuclear reactor, the manufacturing and test of a HTS insert coil for the central solenoid magnetic system has been proposed and planned for the next years.

In view of these application perspectives, new concepts of fusion conductors incorporating HTS coated conductor tapes have been designed and specific activities implemented (fabrication and tests). Among them, a Cable-In-Conduit (CIC) Conductor comprised of an Aluminum-slotted-core has been developed [1].

In this contribution, the state of the art of the CIC conductor development will be presented. In particular, the manufacturing process, the electrical and mechanical behavior of the cable will be discussed based on the experimental results obtained in cable prototypes and numerical simulations performed with FEA codes. Based on the results of the 5-slot configuration, the most advanced concept of the cable with 6 slots and square jacket made of high strength Al – alloy has been developed. The first results on the jacketing process and mechanical behavior will be provided showing how this solution is particularly suitable for fusion magnets. The experimental and simulation activities aimed at the manufacturing of the sample for quench experiments to be performed in the near future at the SULTAN facility will be reported. This experiment carried out in the framework of the EUROfusion work program on HTS magnets will be performed on a sub-size conductor rated for 15 kA at 4.2 K and 12 T. Preliminary experimental results of the electrical behavior and termination concept of the SULTAN sample will be presented and the expected behavior of the cable described. These results supported by new thermal-hydraulic/electric 1D multi-region conductor model allow the prediction of the quench propagation behavior in HTS conductors.

The possible scenario of the additional HTS insert coil for the DTT Central Solenoid aimed at the increase of the CS magnetic flux will be discussed as a future perspective.

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Epitaxial strain and artificial super lattice modulation mediated magnetic properties in $La_{0.67}Sr_{0.33}MnO_3$ thin films

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Epitaxially strained $La_{0.67}Sr_{0.33}MnO_3$ (LSMO) thin films with different thicknesses, t = 12, 25 and 100 nm were grown on (001) oriented $(LaAlO_3)_{0.3}$ $(Sr_2AlTaO_6)_{0.7}$ (LSAT) substrates by pulsed laser deposition technique. As the thickness increases, the initial pseudomorphic growth of the LSMO film tends to relieve its strain partly by the formation of rhombohedral distortions resulting in periodic lattice modulations. A combination of omega and phi scans by using high-resolution X-Ray Diffraction revealed that these lattice modulations are different along different crystal axis directions. In case of t = 100 nm, the modulations are dominant towards [100] direction whereas, for t = 25 nm, the modulations present along [100] and [010] axes as seen in Figure 1.

Angular dependent *in-plane* magnetic properties of LSMO films were studied by Vectorial Magneto-Optical Kerr magnetometry. We found an intriguing competition between uniaxial and biaxial in-plane magnetic anisotropy and the weight of such contributions depends on the film thickness. At t=12 nm, strong uniaxial anisotropy was observed whereas, for t=25 nm, a combination of biaxial and uniaxial anisotropy was observed at 300 K. At 100 nm, combination of weak uniaxial in-plane and out-of-plane anisotropy was observed. The magnetic anisotropy results are interpreted with emphasis on epitaxial strain/shear strain (rhombohedral distortions)/lattice modulations developed in LSMO films. Inspired from the previous reports[1], [2], we are also investigating structural characterization at atomic scale in the interfaces to correlate the magnetic properties with structural properties. These findings will hint us the importance of thickness, strain, lattice modulations driven magnetic anisotropy transitions and its complex nature in functional oxides.

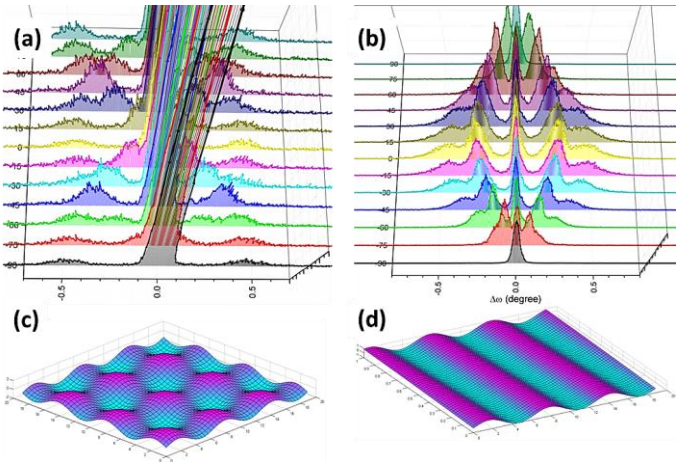

Figure 1: XRD Omega vs Phi scan of (a) 25 nm (b) 100 nm LMSO film showing 90° and 180° periodic lattice modulations. (c, d) Sketch of the lattice modulations observed in the 25 and 100 nm film.

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How to improve REBa$_2$Cu$_3$O$_y$ films and coated conductors by tailoring pinning centers

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Three properties of a superconductor that are obviously desirable for applications are high critical temperature (T_c), large upper critical field (H_{c2}), and strong pinning. The arrival of the oxide high T_c superconductors represented a huge improvement in the first two conditions. However, the large influence of thermal fluctuations in these materials (orders of magnitude stronger than in conventional superconductors) produces new vortex liquid phases where vortex pinning vanishes, reducing the magnetic field range useful for applications, and induces a fast detrimental dynamics in the solid phases (flux creep) that effectively reduces J_c. In this talk I will focus on REBa$_2$Cu$_3$O$_y$ films and coated conductors (where RE=Y, a rare earth, or a combination of them). These systems exhibit the highest J_c in any known superconductor, making the study of their vortex matter relevant both from the fundamental and technological perspectives. Large efforts from many research groups have shown that non-superconducting second phases, incorporated either in the form of self-assembled nanorods or randomly dispersed nanoparticles, can act as strong pinning centers, dramatically increasing the in-field J_c. I will discuss our latest advances in tuning the size and density of randomly distributed nanoparticles (NPs) to optimize high-field pinning conditions. I will show that the NPs extend the vortex solid phase, shrinking the vortex liquid. I will also present results on J_c down to 4K and up to magnetic fields of 65 Tesla obtained at the Pulsed Field Facility of the National High Magnetic Field Laboratory. Finally, I will discuss the effects of the NPs on the vortex dynamics.

Giant efficiency boost of Chalcopyrite/Zn(O,S) heterojunctions upon low-temperature annealing

Marco Zutter[1], Jose Virtuoso[1], Pedro Anacleto[1], Liam Yasin[1], Marina Alves[1], Miguel Madeira[1], Oleksandr Bondarchuk[1], Saibal Mitra[1,2], David Fuster Signes[3], Jorge M. Garcia[3], Fernando Briones[3], Rolf Waechter[4], Oliver Kiowski[5], Dimitrios Hariskos[5], Diego Colombara[1,6*], Sascha Sadewasser[1]

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Besides being at the centre of incessant fundamental debates for more than 30 years [1], chalcopyrite photovoltaics is among the most promising thin film technologies for solar electricity generation. Commercial panels are based on a p-n heterojunction comprising $Cu(In,Ga)Se_2$ as the p-type semiconductor and CdS as the n-type component. However, CdS films contain the toxic element Cd and are generally grown by a material-inefficient chemical bath deposition (CBD).

Here, Zn(O,S) films deposited by magnetron sputtering are investigated as an alternative n-type material on $Cu(In,Ga)Se_2$ absorbers produced by NICE Solar Energy GmbH. The study was performed on samples cut from a module-size glass/Mo/CIGSe stack fabricated in a commercial pilot line. Reference solar cells (0.5 cm^2) with an immediately-deposited CdS buffer layer averaged 16.5% efficiency, while references prepared with a CdS buffer layer deposited later at the same time as the Zn(O,S) averaged 13.0% efficiency.

Devices comprising the Zn(O,S) layer with optimized thickness averaged 4.7% efficiency. Thermal annealing up to just 200 °C is shown to improve the performance to a maximum of 10.5% [2]. The improvement is mostly attributed to a boost of open circuit voltage, indicative of an improved heterointerface between $Cu(In,Ga)Se_2$ and Zn(O,S). Indeed, temperature dependent current density versus voltage (J–V) characteristics show a reduced interface recombination upon annealing. Electrical device simulations explain the observed effects by a modification of the band offset at the interface and defects passivation [3]. Both effects are attributed to elemental interdiffusion during annealing, as revealed by X-ray photoelectron spectroscopy depth profiling.

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Fermi surface instability in the Dirac material $Ca_{1-x}Na_xMnBi_2$

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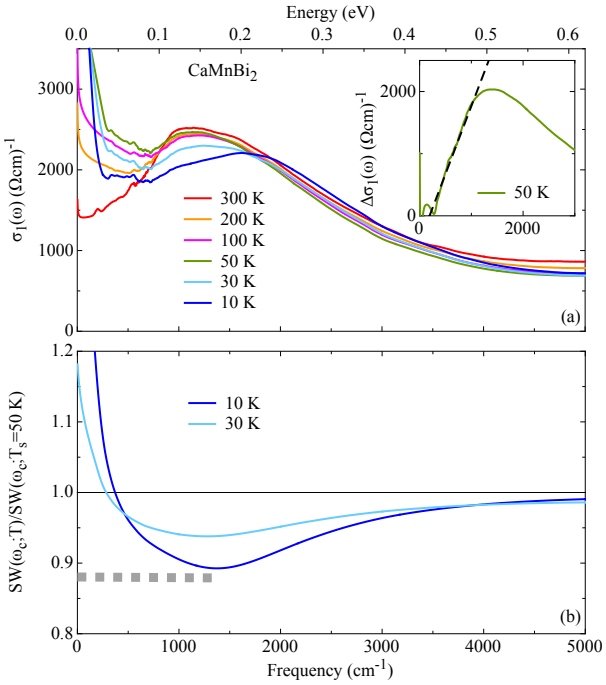
We uncover optical signatures for a partial gapping of the Fermi surface, for energy scales up to 0.2 eV, at the onset of the spin reorientation transition which also manifests as an anomaly in the dc transport data of the title compound [1]. This may reveal the inclination towards a Fermi surface instability in topological materials, possibly related to a density-wave order.

The quasi-two-dimensional bismuth layer-like AMnBi$_2$ (A = alkaline as well as rare earth atom) lately advanced as an arena for the investigation of low-energy quasiparticle excitations in topological materials. The A = Sr or Ca compositions have attracted special attention because anisotropic Dirac cones may be realized. This latter property can be exploited for making new electronic devices with electrons propagating differently from one direction to the other. In a broader context, the title compound also provides an opportunity to study low-dimensional magnetism and its putative relationship to the electronic properties, a central topic in condensed matter.

This work describes novel results of reflectivity measurements from the far-infrared up to the ultraviolet that probe the optical response as a function of temperature. This gives access to the optical conductivity which captures the relevant energy scales shaping the electronic structure. We discover a depletion of spectral weight in the real part of the optical conductivity at mid-infrared energies, which signals the partial gapping of the Fermi surface and seems to directly affect the electronic properties at the Dirac cones.



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Nonsymmorphic symmetries in MnP-type crystal structures

Giuseppe Cuono[1], Filomena Forte[2,1], Mario Cuoco[2,1], Rajibul Islam[3], Jianlin Luo[4,5,6], Canio Noce[1,2] and Carmine Autieri[3,2]

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Recently, superconductivity under pressure has been discovered in CrAs and MnP [1-3], compounds belonging to the family of the transition metal pnictides with formula MX (M=transition metal, X=P, As, Sb) and having orthorhombic MnP-type crystal structure at ambient conditions. More recently, Liu et al. [4] discovered a new superconductor, namely the WP, belonging to the same Pnma space group, with a bulk superconductivity appearing at 0.84 K, at ambient pressure.

We use relativistic *ab-initio* methods combined with model Hamiltonian approaches to analyze the normal-phase electronic and structural properties of the WP [5]. The outcomes of such study can be employed to set fundamental connections among WP and the CrAs and MnP superconductors belonging to the same space group.

The band structure of these systems, other than the time-reversal and inversion symmetries, exhibits nonsymmorphic symmetries that bring to four- or eight-fold degeneracy of the bands along some high-symmetry lines of the Brillouin zone. In particular, we demonstrate that the eight-fold band degeneracy obtained along the SR line of the Brillouin zone due to inversion-time reversal invariance and a pair of nonsymmorphic symmetries, brings to some constraints on the multiplicity and dimensionality of the Fermi surface [5]. The presence of multiple degenerate Fermi points along the SR direction constraints the topology of the Fermi surface, which manifests distinctive marks when considering its evolution upon band filling variation.

When the role of the spin-orbit coupling (SOC) interaction is considered, we show that the interplay between the SOC and the inter-orbital degrees of freedom allows a selective removal of the band degeneracy.

Finally, we comment on the connections between our results and recent experimental and theoretical proposals about the triplet superconductivity [6] in this class of compounds.

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Layered Perovskites: a structural framework to implement ferroelectric and electromagnetic metals

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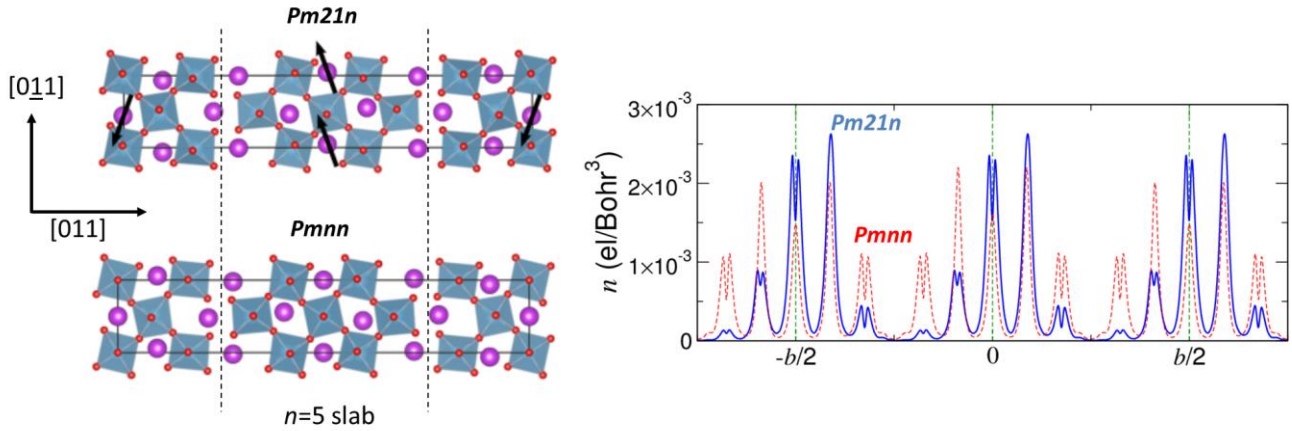
A number of theoretical studies carried out in the last few years [1,2] defies the conventional paradigm according to which metallic materials cannot be electrically polarized. The possibility to have polar distortions in metals where already pointed out over 50 years ago by Anderson and Blount. Nowadays, the capability to perform accurate ab-initio calculations for complex materials has opened to the investigation and design of materials embodied with this fascinating functionality. Yet, the existence of a switchable intrinsic electric polarization in a metal has not been experimentally demonstrated.

Here I will discuss the properties of a layered oxide ($Bi_5Ti_5O_{17}$) purposely designed to support the coexistence of native metallicity and bulk electric polarization [2]; strikingly, this system is found to maintain an electrically switchable polarization in the thin film limit, a possibility denied to most of conventional insulating ferroelectrics. This capability derives from a self-screening mechanism due to the intimate interplay between polar distortions and carriers. Beside an obvious conceptual interest, the search of ferroelectric behavior in metals unveils opportunities of great technological appeal; for example, multiferroic behavior can be more easily at reach, since metals are more likely to be ferromagnetic than insulators. Preliminary results on $Bi_5Mn_5O_{17}$ shows that this is in fact a practical possibility.



Left: Ab-initio calculated *Pmnn* (centrosymmetric) and *Pm21n* (non-centrosymmetric) structures of $Bi_5Ti_5O_{17}$; color code: O (red), Bi (violet), Ti (not visible) are within the polyhedrons. Right: calculated conduction charge, planarly averaged along the b=[011] direction, for the two corresponding structures.

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Effect of the electron doping on Ba_2NaOsO_6 via Na/Ca substitution: a nuclear magnetic resonance study

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Osmium-based double perovskite belongs to a novel class of *quantum materials*, emerging from the combined effects of strong electronic correlation and spin-orbit coupling (SOC). The study of the physical properties of those compounds leads to a better understanding of the quantum mechanical nature of interactions between constituent electrons.
Ba_2NaOsO_6 is a $5d^1$ Mott insulator that displays an exotic canted two-sublattice ferromagnetic state believed to be driven by the staggered quadrupolar order, while Ba_2CaOsO_6 is a $5d^2$ compound which displays an antiferromagnetic phase.
Here, we investigate the evolution of the local magnetic properties as a function of Na/Ca substitution on the magnetic ground state of Ba_2NaOsO_6 by using ^{23}Na nuclear magnetic resonance on powder samples. The NMR techniques are very suitable to study the local static magnetic ordering, that is the magnetic ordering temperature, the evolution of canting angle and staggered magnetization, even in case of small ordered moment such as those observed in osmates. Also structural and charge related phenomena can be measured via the interaction between the crystalline electric field gradient and the nuclear quadrupole moment.
The behavior of the spin-lattice relaxation rate T_1 and the spectra have been measured as a function of temperature from 5 to 300 K for concentrations of $Ba_2Na_{1-x}Ca_xOsO_6$ in the range $0<x<0.75$. The results show an anomalous peak of $1/T_1(T)$ in the high temperature regime (100-200 K) probably related to a thermally activated charge dynamic. In the low temperature regime ($T<50$ K) both the spectra and the T_1 measurements will be considered to investigate the crossover from FM-canted to AFM state as a function of Ca/Na substitution.

Spin-Orbital Excitations in Spin-Orbit Coupled Mott Insulator

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4d or 5d transition metal oxides are recently attracting considerable attention due to novel paths to Mott physics and quantum orderings. A paradigmatic example in this context is provided by the single- and double-layer members of the CaRuO series. Indeed, apart from Mott physics [1], superconductivity can emerge in strained films or upon the application of pressure, as well as non-standard magnetic anisotropy [2], electric driven giant diamagnetism [3], and colossal magnetoresistance effects [4]. In this talk, I will start by discussing the nature of the spin-orbital excitations in the Ca_2RuO_4 and $Ca_3Ru_2O_7$ for the antiferromagnetic and ferromagnetic Mott insulating states, respectively. The theoretical predictions are then compared with recent experimental results of a high resolution oxygen K-edge Resonant Inelastic X-ray Scattering study [5]. I will show that all salient features of the spectra can be well reproduced. We highlight the emergence of low-energy states, which are marked by composite dispersive spin-orbital excitations consistent with a scenario where the antiferromagnetic phase is set out by pseudospin-1 spin-orbital modes. Their nature is a distinctive mark of the interplay of crystal-field splitting and spin-orbit coupling in the band-Mott phase. The high-energy excitations are also identified and correspond to non-dispersive intra-atomic singlet-triplet transitions at an energy scale set by Hund's coupling. Those findings give a unifying picture of the spin and orbital excitations in the band-Mott insulator Ca2RuO4. A comparative study of the nature of the low energy excitations for the antiferromagnetic and ferromagnetic ground state is also presented.

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Exploiting weak field gravity-Maxwell symmetry in superconductive fluctuations regime

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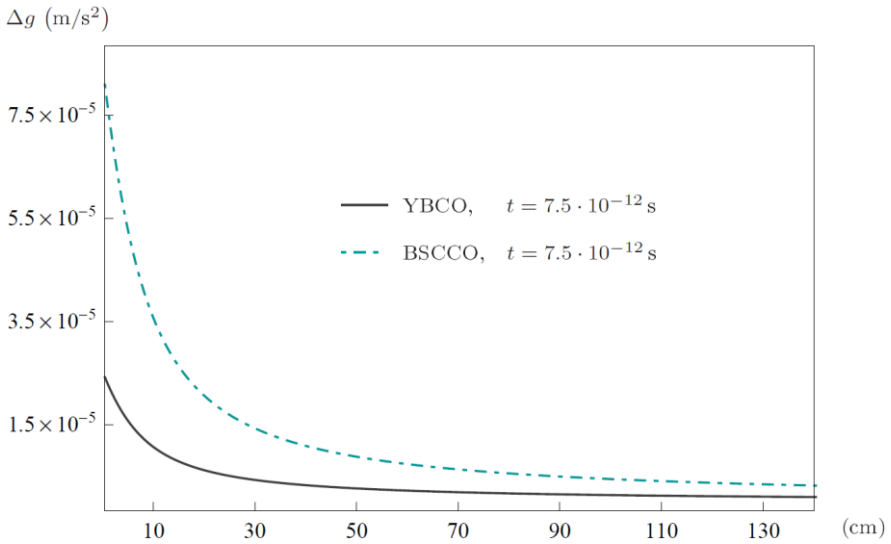
It is since 1966, with the paper of DeWitt [1], that there is great interest in the interplay between the theory of gravitation and superconductivity [2]. In the following years, a lot of theoretical papers about this topic have been produced, until Podkletnov and Nieminem declared to have observed a gravitational shielding in a disk of YBaCuO [3]. Of course, after the publication of this paper, other groups tried to repeat the experiment obtaining controversial results so that the question is still open. Many researchers tried to give a theoretical explanation of the phenomenon [4,5], but the complexity of the formalism makes it difficult to extract quantitative predictions.

Our study provides quantitative calculations in a range of temperatures very close to the critical temperature, in the regime of fluctuations. In particular, we study the behavior of a superconductor in a weak static gravitational field for temperatures slightly greater than its transition temperature (fluctuation regime). Making use of the time-dependent Ginzburg–Landau equations, we find a possible short time alteration of the static gravitational field in the vicinity of the superconductor, providing also a qualitative behavior in the weak field condition. Finally, we compare the behavior of various superconducting materials, investigating which parameters could enhance the gravitational field alteration.



The variation of gravitational field as a function of distance in the vicinity of a superconductive sample of YBCO and BSCCO. The field is measured along the axis of the disk, at the fixed time $t=7.50\cdot10^{-12}$ s that maximizes the variation; the radius of disk is R=10 cm and the thickness is h=1 cm.

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CeO_2-based Materials and Catalytic Function:

The Non-Innocent Role of the Ceria Support

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Ceria (CeO_2) –an easily reducible oxide– is the most significant of the oxides of rare-earth metals in industrial catalysis. Deep understanding of oxygen vacancy defects at ceria surfaces, is central to our understanding of the role of ceria in catalysis. For the CeO_2(111) surface, whether oxygen vacancies prefer the subsurface or the surface, and if surface oxygen vacancies attract or repel, as well as whether oxygen vacancy migration and polaron (Ce^{3+}) hopping are entangled, are still heavily debated. Also, a number of ordered phases have been observed upon reduction but their structures have remained elusive. Here, supported by experimental and theoretical results, the current understanding of the structure of the CeO_{2-x} (111) surface will be discussed [1-8].

Moreover, the function of ceria as support in the catalytic activity of metal-ceria systems is not fully understood, and will be here discussed using ceria-supported metal nanoparticles as model catalysts [9]. The emphasis is here put on theoretical studies in combination with experiments using ambient pressure X-ray photoelectron spectroscopy. The Ni-ceria system will be used as example of catalyst for water (H_2O) dissociation [10], methane (CH_4) activation [11,12], and the direct oxidation of methane to methanol (CH_3OH) –a holy grail in catalysis [13]. The ability of ceria to stabilize oxidized nickel species (Ni^{2+}) on the CeO_2 surface, by re-localizing electrons on localized *f*-states (Ce^{3+}) is a key factor determining the catalytic activity of nickel-ceria catalysts.

The collaboration with the experimental groups led by Michael Reichling (Uni. Osnabrück, Germany), and Jose A. Rodriguez and Sanja Senanayake (BNL, USA) is acknowledged, as well as that with Pablo G. Lustemberg (ICP-CSIC, IFIR-CONICET, Argentina), Gustavo E. Murgida, Valeria Ferrari, and Ana Maria Llois (CAC, INN, CNEA-CONICET, Argentina), Zhong-Kang Han, Dawei Zhang, and Yi Gao (SINAP, CAS, Shanghai, China).

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Topological phases driven by Rashba spin-orbit coupling in low-dimensional nanostructures

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Over the past thirty years, Rashba spin-orbit coupling (RSOC) has been at the basis of the predictions and discoveries of new classes of topological materials and novel phenomena, particularly attractive within the context of spintronics, such as non-standard magnetic textures, spin Hall and topological spin Hall, Edelstein effects, etc [1]. These progresses renewed the interest in the development of new inversion asymmetric structures, like for instance the interfaces between complex oxides, where the presence of Rashba interaction promotes and allows to tune the formation of unusual interfacial electronic phases which are absent in the constituent materials. A new frontier of exploration within the context of spin manipulation has been recently opened by the demonstration of the possibility to create flexible semiconductor nanomaterials bent into curved, deformable objects ranging from semiconductor nanotubes, to nanohelices, etc.

We have thus explored the impact that nanoscale geometry [2] has on electronic, topological and superconducting properties of low-dimensional nanomaterials, showing the possibility to exploit the interplay between geometry, RSOC and superconductivity as a tool for the realization of novel platforms for spin-orbitronics and superconducting spintronics. By considering the paradigmatic example of quantum wires with RSOC, which is periodically modulated at the nanometer scale, we show that inhomogeous RSOC effects in low-dimensional nanomaterials can lead to metal-insulator transition and promote the generation of topological states of matter [3,4] . Relevantly, such a system, under the application of a rotating magnetic field, can realize the Thouless topological pumping protocol in an entirely novel fashion [5]. We also show that geometric curvature effectively acts like a spin-torque, twisting the electron spin, thus driving non-trivial spin textures, which in turn affect the electron spin interference in closed loop configurations [6] and lead to novel paths for an all-geometric manipulation of the superconducting state [7], as well as of the supercurrent in weak links between Rashba coupled superconducting nanowires with geometric misalignment [8].

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Interplay between magnetism and superconductivity in $EuFe_2(As_{1-x}P_x)_2$ single crystals investigated by a microwave technique

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The interplay between superconductivity and magnetism is currently one of the most intriguing topics in condensed matter physics. In this respect, $EuFe_2As_2$-based systems are particularly interesting due to the proximity of superconducting and ferromagnetic transition temperatures, where the latter is connected to the Eu^{2+} local magnetic moments.

We report on a microwave analysis of the interplay between magnetism and superconductivity in single crystals of $EuFe_2(As_{1-x}P_x)_2$, accomplished by means of a coplanar waveguide resonator technique, through a cavity perturbation approach [1]. The bulk complex magnetic susceptibility $\chi_m=\chi'_m+i\chi''_m$ – extracted from the high-frequency characterization – is demonstrated to be highly sensitive to the magnetic structure and dynamics, revealing two distinct magnetic transitions below the superconducting critical temperature [2]. A comparison with the similar but non-magnetic $BaFe_2(As_{1-x}P_x)_2$ [3] and with other quasi-static measurement techniques helps in identifying these transitions and in understanding the underlying mechanisms. In particular, a comparison with magnetic force microscopy maps of $EuFe_2(As_{1-x}P_x)_2$ allows us to ascribe the χ''_m peak observed at about 17 K to the transition from the ferromagnetic domain Meissner phase to the domain vortex-antivortex state, with the subsequent evolution of the domain structure at lower temperatures. The second χ''_m peak observed at 11 K reflects a specific high-frequency feature, connected to vortex/antivortex dynamics and eventual spin reorientation transition of the Eu^{2+} canted ferromagnetic subsystem. The two peaks merge and vanish upon application of an in-plane magnetic field, which is compatible with the presence of a quantum critical point below 1 T.

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Charge density waves and charge density fluctuations in high Tc superconducting cuprates

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It is commonly accepted that charge density waves (CDW) are present in all high Tc superconducting cuprates in the underdoped regime. Their importance is due to their interplay with superconductivity, as competing and/or intertwined phenomena. Resonant soft x-ray scattering is probably the most direct and sensitive experimental method for their observation, and has been providing the core of the systematic information on them, including temperature dependence and onset temperature that are used to delimitate the CDW region in the phase diagram. The picture is nonetheless still fragmented, also because other techniques have been bringing results not easy to reconcile, eg the influence of magnetic fields on c-axis correlation and the role of discommensuration.

We have exploited the superior sensitivity of the ERIXS instrument of the beam line ID32 of the ESRF to take a deeper look at the CDW phenomenon. We could thus observe the existence of Charge Density Fluctuations (CDF) aside the already known CDW in the 123 family [1] Combined with the discovery of charge order in overdoped Bi2201 [2] and with the observation of high temperature CDW in LBCO [3], are going to stimulate a revision of the current understanding of the CDW phenomenon in cuprates. The discovery of CDF can provide a phenomenological explanation of the Marginal Fermi Liquid behavior of cuprates in the normal state [4].

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Phase stiffness in superconducting states in cuprate superconductors

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Critical current density and critical temperatures are affected strongly with the change in the superfluid density. Even though several relations between transition temperature and superfluid density are there for cuprate superconductors it is still an open question how superfluid behavior affects superconducting properties. We have studied exponents of nonlinear current-voltage characteristics of several cuprate superconductors to understand phase stiffness behavior following Kosterlitz-Thouless (KT) transition [1]. We found that onset superconducting critical temperature is greater than the temperature at which the nonlinear exponent becomes greater than 1.0. The width of the separation (T_c and T_{KT}) has been investigated. Superfluid phase stiffness has been extracted in as a function of temperature using Ambegaokar-Halperin-Nelson-Siggia (AHNS) model [2]. Superconducting phase transition region exhibits that there is no minimum value of phase stiffness for which superconducting state can be attained. Experimental results on the variation of the phase stiffness in several anisotropic cuprate superconducting systems will be presented.

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Josephson field-effect transistors go metal: A groundbreaking route towards concrete superconducting electronics

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In their original formulation of superconductivity, the London brothers predicted more than eighty years ago the exponential suppression of an electrostatic field inside a superconductor over the so-called London penetration depth, in analogy to the Meissner-Ochsenfeld effect. Despite a few experiments indicating hints of perturbation induced by electrostatic fields, no clue has been provided so far on the possibility to manipulate conventional superconductors via field-effect. In this talk, I will report the evidence of full field-effect control of the supercurrent in all-metallic transistors made of different BCS superconducting thin films [1]. At low temperature, our field-effect transistors (FETs) show a monotonic decay of the critical current under increasing electrostatic field up to total quenching for gate voltage values as large as ±40V in titanium-based devices. This bipolar field effect persists up to ~ 85% of the critical temperature (~ 0.41K), and in the presence of sizable magnetic fields. A similar behavior, though less pronounced, was observed in aluminum thin film FETs [1]. Moreover, I will show the experimental realization of Ti-based Dayem bridge field-effect transistors (DB − FETs) [2-4] able to control the Josephson critical current (I_C) of the superconducting channel. Our easy fabrication process DB − FETs show symmetric full suppression of I_C for an applied critical gate voltage as low as V_G^C ~ ±8V at temperatures reaching about the 85% of the record critical temperature 550mK for titanium. Our devices show extremely high values of transconductance (up to 15μA/V) and variations of Josephson kinetic inductance with gate voltage of two orders of magnitude. Finally, I will show the behavior of mesoscopic superconductor-normal metal-superconductor (SNS) Josephson field-effect transistors [5] which will reveal as well the impact of intense electrostatic fields even on proximity metals. All this seems to suggest that the field effect is *universal*, i.e., it can affect either genuine or proximity *fully-metallic* superconductors. Besides shedding light on a key issue in physics, these results represent a groundbreaking asset for the realization of an all-metallic superconducting field-effect electronics and leading edge quantum information architectures based on Josephson FETs. Possible electronic and circuital schemes based on this all-metallic technology will be furthermore discussed [3].

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Interface Effects in Doped Ceria – Yttria-stabilized Zirconia Heterostructures

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Interfaces between functional oxides often show different properties compared to the bulk. Various effects can modify the ionic conduction at the interface: Strain, space charge effect, interdiffusion, among others. Many of these systems have important technological applications and it is therefore crucial to characterize possible modification of the defect chemistry at these interfaces. This is the case of 8% mol yttria stabilized zirconia (YSZ) and acceptor doped ceria, usually coupled in high temperature solid oxide fuel cells (HT-SOFC) to improve the stability of the electrolyte at the interface with the cathode.

Thin films and multilayers are useful model systems to study interface effects. Using thin films of CeO_2 on YSZ substrates for instance, it was observed that pure ceria is reduced at the interface with YSZ. [1] The same behavior was confirmed for ceria with different acceptor doping levels. [2] The reduction of cerium ions is expected to affect the conductivity at the interface, both as magnitude and type of conduction, switching from ionic to electronic.

In this work, multilayers of YSZ and samaria doped ceria (SDC) are grown by pulsed laser deposition. [3] Keeping the thickness constant, the number of layers and consequently of interfaces is increased.

Electron energy loss spectroscopy highlights the reduction of cerium ions at each interface with YSZ, in a thickness of about 2 nm. No structural variation instead is observed between bulk and interface. Concurrently, the conductivity measured in plane, decreases increasing the number of interfaces, suggesting the progressive confinement of the ionic conduction to the YSZ layers. The analysis of the conductivity data indicates the formation of an insulating layer of about 2 nm at each interface. At these interlayers both ionic and electronic conduction are very small compared to YSZ and SDC bulk. This is explained in terms of a reduced mobility of the oxygen vacancies in the highly reduced ceria.

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AC susceptibility study of CC tapes prepared by inclined substrate deposition process

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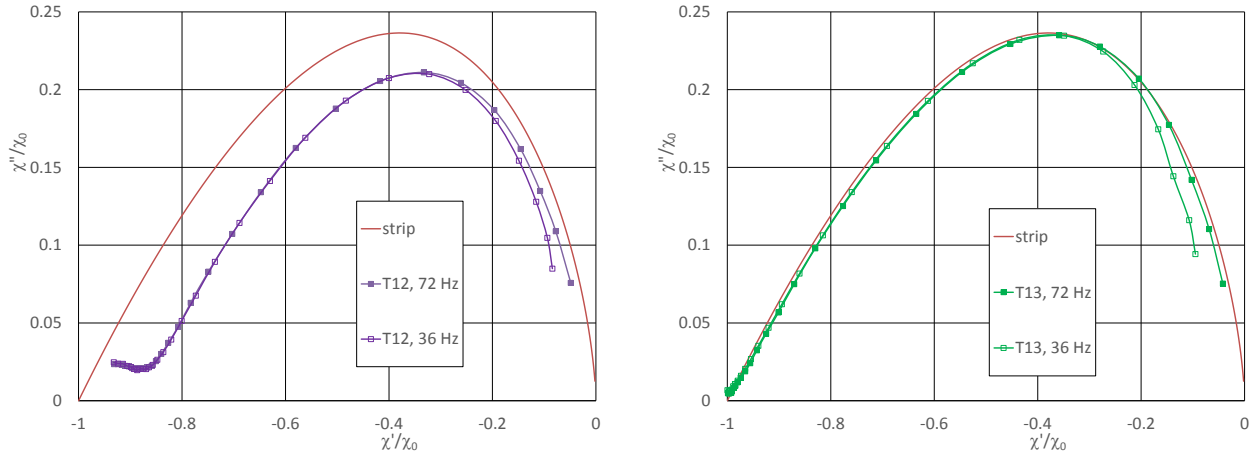
Analyzing the response of a superconducting coated conductor (CC) tape to AC magnetic field allows to determine in indirect way several important characteristics [1]. In particular, the imaginary part of the AC susceptibility provides directly the information about AC loss. Also, comparing the experimental data with theory [2] allows to determine the critical current. Because the theoretical model assumes a uniform superconducting layer exhibiting the same j_c everywhere, any deviation of the experimental data from its prediction indicates some kind of non-uniformity.

We present an example of such an investigation for a series of CC tapes prepared by an all PVD approach. Some of them follow nicely the prediction from the theoretical model utilizing the critical current values obtained by hall scanning (Tapestar) technique. However, for some tapes the observed AC susceptibility behavior indicates a reduced j_c at the tape edge.



Comparison of Cole-Cole plot for the tape with reduced j_c at edges (left panel) with the susceptibility behavior of a tape with uniform properties (right panel).

Particularly powerful tool in analyzing the experimental data is the Cole-Cole plot presenting the imaginary part of (normalized) AC susceptibility as dependent on the (normalized) real part of AC susceptibility. It allows very sensitive comparison with theoretical predictions.

Numerical modeling is a proper tool to predict the behavior of tapes with non-uniform properties. We present the results of finite element computations performed in order to explain the observed AC susceptibility measurement results quantitatively.

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Impact of non-local exchange on Iron Pnictides

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Ten years after their discovery, the physics of iron-based superconductors (IBSC) has yet to be clarified, and a unified understanding of their behaviour is far from being reached. Even though the major role played by local correlations has been widely assessed, low-energy models relying exclusively on them are not able to reproduce some fundamental properties, most notably the size of electron and hole pockets of the Fermi surface [1,2]. In this regard, we study the effect of non-local exchange in the presence of strong local correlations within the IBSC 122-family, by means of Slave-Spin@Density-Functional Theory simulations. Non-local exchange is treated at the Density-Functional Theory level via the screened hybrid functional HSE06, whereas local Hubbard- and Hund-type interactions are accounted for within the Slave-Spin method. Particular attention will be given to the impact of non-local interactions on the Fermi surface, via a thorough comparison with the available experimental data for different electron doping and degree of correlation.

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High magnetic mitigation by machinable MgB_2 practical shields

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Superconductors are key materials for shielding quasi-static magnetic fields. In this field, MgB_2 bulks are a promising solution because the long coherence length of this compound enables the fabrication of polycrystalline samples with almost isotropic properties as well as high and homogeneous critical current density.

In this work, we investigated the shielding properties of MgB_2 cup-shaped shield, produced via an innovative technique that allows the fabrication of fully machinable bulks [1,2]. The shield had a small aspect ratio of height/outer radius. This geometry, though not favorable, is useful to address shielding solutions in situations (e.g. space applications [3,4]) where the space occupied by the shield and its mass must be minimized. Furthermore, the choice of small aspect ratios is necessary when the shield radius is so large that, in practice, its height cannot be much longer than the radius.

The shielding measurements were carried out as a function of temperature (T) and applied magnetic field ($\mu_0 H_{appl}$) using cryogenic Hall probes. Remarkably, in axial field configuration, inside the cup and 1 mm above its close extremity, we measured shielding factors (SFs) higher than 10^4 at T = 20 K up to $\mu_0 H_{appl}$ = 1.8 T [5]. Moreover, at the same temperature and field region, SFs > 10^2 still persisted in the whole inner half of the cup. To our best knowledge, this is one of the greatest SF values found on superconducting shields with comparable shape and size [6]. Since in a real case the direction of the magnetic field to be shielded can be not uniform, the shielding properties were also investigated in transverse field configuration. Although this is the worst case, SFs over 35 were still measured at T = 20 K up to $\mu_0 H_{appl}$ = 1.8 T [5] at a distance of 1 mm from the cup closure.

Finally, by numerical modelling we analysed the effects of the superimposition of a ferromagnetic shield. In axial field configuration, this addition is detrimental at low fields, but leads to significant SF enhancements at high fields, enlarging the range of external fields where efficient shielding occurs.

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Optical properties of Xenes epitaxially grown on Al_2O_3(0001) substrate

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The class of two-dimensional (2D) graphene-like lattices made of atoms out of carbon, so-termed Xenes, today includes elements from the lightest boron to the heaviest tellurium [1]. The Xenes flow started with silicene that first paved the way to the chance of mimicking the graphene's properties in an artificial way [2]. The synthesis by molecular beam epitaxy (MBE) of silicene and silicon nanosheets on a transparent substrate like Al_2O_3(0001) allowed for the survey of the thickness-dependent behavior of the optical conductivity obtained from transmittance measurements via Kramers-Kronig constrained fit. At the 2D limit, the optical conductivity is characterized by two main features at 1.4 and 4.5 eV that closely resemble those arising from π-π* and σ-σ* interband transition in freestanding silicene [3]. Remarkably, the low-energy resonance peak due to bonding-antibonding π interband transition is still visible up to 7 nm thick silicon nanosheet. Two distinct behaviors can be recognized: at the 2D limit, the optical conductivity is consistent with a Dirac-like energy bandstructure, whereas conversely, for thicker silicon layers an anomalous optical behavior shows up which suggest a different energy bandstructure with respect to that of conventional silicon. On the other hand, limited to the IV column of the periodic table, it turns out that increasing the mass of the X element from carbon to tin, the spin-orbit coupling (SOC), a relativistic effect that scales as Z^4 in elements of atomic number Z, converts a honeycomb lattice from an ideal 2D semimetallic state to a quantum spin Hall insulator (as predicted first for graphene) characterized by large bandgap opening and conductive dissipationless edge channels [4]. In this framework, the choice of a heavier element than silicon, like tin, would intriguingly pave the way to access the topological properties of the Xenes giving rise to the emergence of non-trivial topological properties even at room temperature. Interestingly, the Al_2O_3(0001) substrate turns out to be also well-suited even for stanene as predicted by theoretical modeling [5]. In close analogy with silicon [3], we investigated the optical properties of tin deposited by MBE on Al_2O_3(0001). The absorbance from THz to ultraviolet (6 meV - 5 eV) photon range measured on ultra-thin tin nanosheets show two spectral features centered at ~1.25 and 4 eV that can be related to π-π* and σ-σ* interband transition in freestanding stanene albeit broadened and shifted towards lower frequency. Remarkably, as also confirmed by means of optical conductivity, ultra-thin tin nanosheets show hints of a bandgap opening of ~40 (0.5 nm-thick) and ~90 (1.5 nm-thick) meV being consistent with SOC induced predicted values. Moreover in the 0.25-1.10 eV range the optical conductance G_1 are linear following a power-law frequency dependence that universally describes the interband optical response of D-dimensional Dirac electrons.

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REBCO coated conductors are ready to take off

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The European Union-funded ASuMED project started in May 2017 with the purpose of demonstrating the benefits of a new, fully superconducting motor for reaching the targets established by the FLIGHT2050 plan. The project aims at a motor power density of 20 kW/kg using a high-temperature superconducting (HTS) stator. The rotor will use HTS stacks operating like permanent magnets. A highly efficient cryostat for the motor combined with an integrated cryogenic cooling system and associated power converter will be used. This contribution first provides a general overview of the prototype that is currently being built and will be tested soon. Then it gives more details on the role of HTS coated conductor tapes in the motor: in particular, the evaluation of the AC losses in the racetrack coils used in the stator and the issues related to the magnetization of the HTS stacks used in the rotor.

Figure 1. Mock-up of the ASuMED motor presented at the 2019 Hannover Fair.

Integration of lead-free piezoelectric $(K_xNa_{1-x})NbO_3$ on silicon for microactuator technology applications

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Lead-free piezoceramics aiming at replacing the industrial standard $Pb(Zr_xTi_{1-x})O_3$(PZT) have been extensively searched for more than a decade worldwide. This comes in response to environmental and health hazards due to the toxicity of lead [1].

Our research focusses on the development of a scalable process for the deposition of the perovskite-type solid solution $(K_xNa_{1-x})NbO_3$ (KNN) on silicon. This ferroelectric lead-free piezoceramic is featured with a high Curie temperature (around 400°C) and sizeable piezoelectric coefficients, which makes it an eligible alternative candidate to PZT for developing a great variety of MEMS devices [2].

We demonstrate the possibility to integrate (100)-oriented KNN thin films grown by Pulsed Laser Deposition (PLD) on industrial standard $Pt(111)/TiO_2/SiO_2/Si$ stacks as substrates (Figure a). We show how PLD parameters can be finely tuned to adjust composition and morphology of the thin film tailoring for the desired properties. Moreover, a physical vapor deposition technique like PLD allows to consistently reduce film growth times with respect to the currently employed sol-gel sintering techniques for PZT.

Chemical (XPS) spectroscopic and structural (XRD) investigations are conducted to assess the good quality of the grown films. Electrical characterization of fabricated microcapacitors (sketched in Figure b) shows reliable dielectric performance and remanent ferroelectric polarization (Figure c) envisaging possible application in devices.

Preliminary results on microfabrication of MEMS actuator devices such as lead-free piezoelectric cantilevers will be presented as well.

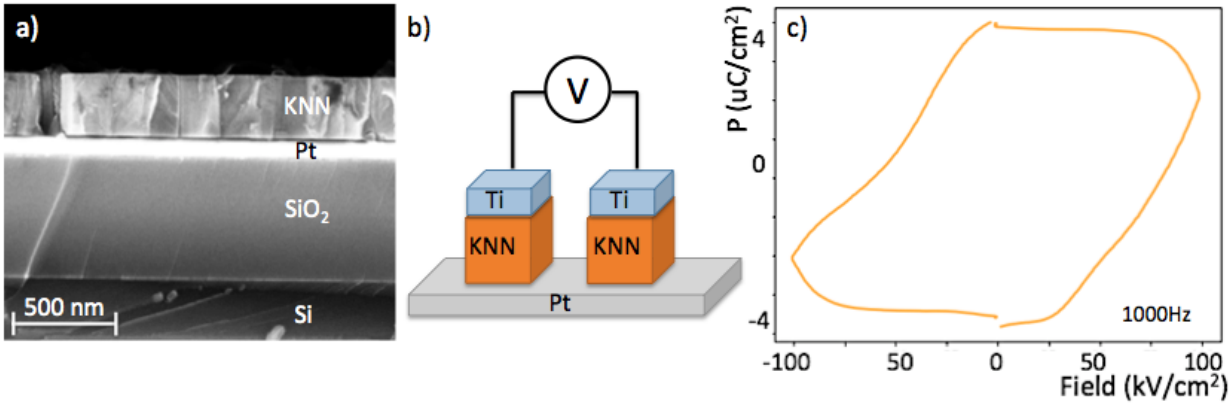

Figure a) Cross-sectional SEM image of the stack. b) Sketch of the measurement configuration. c) Ferroelectric hysteresis loop.

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Magnetic ordering and spin dynamics in $La_2O_3Fe_2Se_2$: a ^{139}La NQR study

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The unique spin and orbital properties of iron-based superconductors (IBSs), including orbitally-selective Mottness and charge ordering, have sparked remarkable interest in the last decade. The parent compounds of IBSs present a test-bed scenario for these properties. In particular, $La_2O_2Fe_2OSe_2$ has recently been a popular choice because of its peculiar antiferromagnetic (AFM) ordering. Its structure consists of alternating stacked layers of La_2O_2 and Fe_2OSe_2 along the c-axis (figure 1). Earlier reports proposed an in-plane FM and AFM magnetic ordering along a- and b-axis respectively [1], while later studies have argued for two perpendicularly-oriented AFM exchange interactions in the two different sub-lattices [2].

Nuclear Quadrupole Resonance (NQR) spectroscopy is a local probe that requires no external perturbations like magnetic field and/or strain; therefore it probes the equilibrium spin and charge ordering. We use both ^{139}La NQR spectra and relaxation measurements for $La_2O_2Fe_2OSe_2$, in order to understand and settle the questions on charge ordering and orbitally-selective behavior. We distinctly identify two magnetically non-equivalent La species (identified as peak#1 and peak#2), in spite of the presence of only one La site per unit cell and in agreement with previous reports [2]. Peak#2 (blue dots in figure 1) appears only below the transition temperature ($T_N \sim 90$K) and strongly shifts to higher frequencies down to about 30K where it saturates. On the other hand, interestingly the peak#1 (red dots), which is the main NQR line, does not broaden or shift, as expected due to the internal magnetic field attributed to an AFM ordering below T_N with a magnetic hyperfine field perpendicular to the c-axis. These two non-equivalent sites can possibly be attributed to orbitally-selective behavior in the ordered phase which has been theoretically predicted for this system [3].

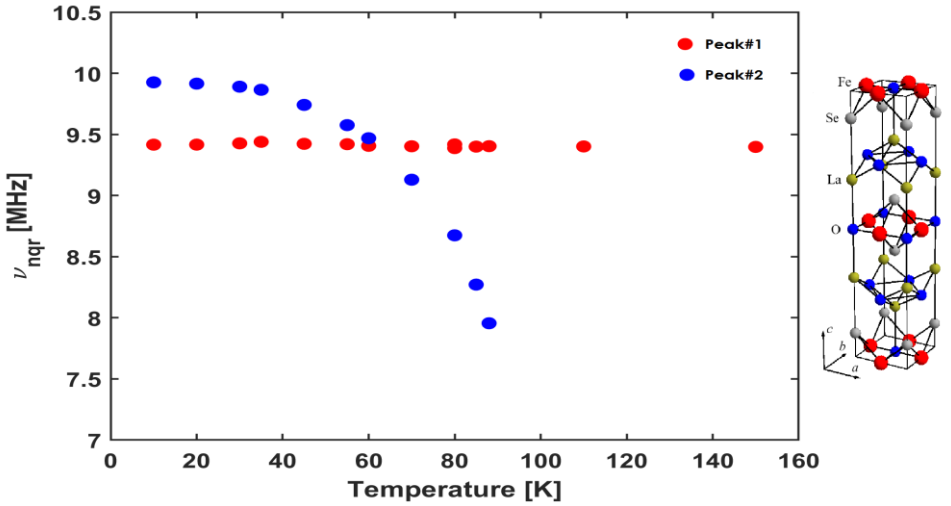

Figure 1 left: ^{139}La NQR frequency positions vs. temperature. Right: Crystal structure of $La_2O_2Fe_2OSe_2$

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Impact of shell composition on iron oxide nanomagnets for biomedical use

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Superparamagnetic iron oxide nanoparticles (SPIONs) serve as multifunctional nanoplatforms for various applications in biomedicine (e.g. magnetic hyperthermia and controlled drug release) and catalysis due to their unique magnetic properties. Magnetically induced heating of SPIONs is influenced by amplitude/frequency of the applied AC field and by the magnetic properties and anisotropy, i.e. size and shape, of nanoparticles. We report here a comparative study on magnetic and structural features of several coated SPIONs with the same magnetic core but with different shell composition designed for biomedical application.

Spherical spinel iron oxide nanoparticles (IONPs, d_{TEM} ~10 nm) were synthesized by chemical coprecipitation as magnetic core and various biocompatible compounds, such as double layer of oleic acid (OA-OA), polyethylene glycol with oleic acid (PEG-OA), polyacrylic acid (PAA), polygallic acid (PGA) and a carboxylated PEG copolymer (P(PEGMA-AA)) were applied as shell. All samples consist of strongly interacting single-domain SPIONs based on Zero Field Cooled (ZFC), Field Cooled (FC) and thermoremanent magnetization (TRM) measurements. Furthermore, it was also shown that the dipolar interparticle interactions were reduced after coating (i.e. the interparticle distance was increased), as T_{max} (proportional to the blocking temperature) decreased from ~250 K to ~230 K, but they are still dominating over the exchange interactions. Although, IONPs are in the superparamagnetic state at room temperature in all samples, the polycarboxylate shell enhance the saturation magnetization (M_S), while the oleate layers induce a clear decrease in M_S. Magnetic hyperthermia studies performed in a wide range of frequency (252-808 kHz) and magnetic field strength (50-250 Gauss) showed that PAA, PGA and P(PEGMA-AA) coated SPIONs produced similar temperature increase as the bare ones, while OA content in the shell led to significant reduction in heat release. Beyond the improved magnetic properties, the preliminary colloid stability, hemocompatibility and MRI results indicated that PAA, PGA and P(PEGMA-AA) coated SPIONs are promising candidates for biomedical use.

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Excitonic luminescence of a series of layered mixed-anion compounds $Sr_3Sc_2M_2Ch_2O_5$

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Luminescent materials which exhibit excitonic emissions can be used for novel applications such as electroluminescent devices or fast scintillators, because of their high oscillator strength while usually it can be observed at low temperature. In order to increase the excitonic binding energy and utilize it at room temperature, low-dimensional materials have been adopted owing to their quantum confinement effects. Some compounds which form low-dimensional structure self-assembly exhibit excitonic luminescence even at room temperature [1–3]. We report the synthesis and excitonic luminescence properties as well as band structure of a series of new layered mixed-anion compounds, $Sr_3Sc_2Cu_2S_2O_5$, $Sr_3Sc_2Cu_2Se_2O_5$, and $Sr_3Sc_2Ag_2Se_2O_5$.

These layered compounds $Sr_3Sc_2M_2Ch_2O_5$ (*M* = Cu, Ag, *Ch*:chalcogen = S, Se) are successfully synthesized by solid-state reaction. The compounds have a common perovskite-like layer of $(Sr_3Sc_2O_5)^{2+}$ and different semiconductor layers of $(Cu_2S_2)^{2-}$, $(Cu_2Se_2)^{2-}$ or $(Ag_2Se_2)^{2-}$. Their band structures are calculated by DFT calculations. Similar band structures are found for the valence band maximum (VBM), while the structure of the conduction band minimum (CBM) is different depending on the chalcogen species, resulting in the different band gap energies of the compounds. The band gap energies are estimated to be 3.3, 2.9, and 2.4 eV for $Sr_3Sc_2Cu_2S_2O_5$, $Sr_3Sc_2Cu_2Se_2O_5$, and $Sr_3Sc_2Ag_2Se_2O_5$, respectively. Excitonic luminescence is observed near the band edge for all three compounds, with different wavelengths according to their band gap. These results are consistent with the DFT calculations. The luminescence properties of the system can be controlled by changing the composition of the semiconductor-layers, thereby offering large flexibility in material design advantageous for various applications.

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Ferromagnetic Resonance and Dynamics of Magnetic Moment in Josephson Junction + Nanomagnet System

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The dynamics of a nanomagnet coupled to a Josephson junction has been studied [1]. Although a magnetic field induced by the superconducting current in the Josephson junction is very weak, an applied voltage can generate the nonlinear dynamics of the nanomagnet, which gives a number of interesting phenomena. It has been shown that a ferromagnetic resonance can occur when the frequency of Josephson oscillations becomes equal to the eigenfrequency of the magnetic system. It has been demonstrated that the easy axis of the nanomagnet is reoriented at an increase in the Josephson-to-magnetic energy ratio, as well as in the coupling parameter between the Josephson current and the magnetic moment and in the frequency of Josephson oscillations. It has been shown that a current pulse can turn the magnetic moment of the nanomagnet, which opens new prospects for the application of this system in superconducting spintronics.

Acknowledgments

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Synthesis of New Iridium Oxyfluoride Using Topochemical Reaction Method and Their Physical Properties

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Layered iridates Ae_2IrO_4 (*Ae* = Sr, Ba) has received considerable attention due to the interesting physical properties such as J_{eff} = 1/2 Mott insulating state and the possibilities of unconventional superconductivity in carrier-doped Ae_2IrO_4[1,2]. Carrier doping by conventional solid-state reaction has been already attempted, but highly doped ones have not yet been obtained. Meanwhile, layered oxyfluroides such as $Sr_2TiO_3F_2$, having TiO_2 plane with more anisotropic structure, have been synthesized using topochemical reaction method with fluorination reagents. Thus, we utilized topochemical reaction method for Ae_2IrO_4 in order to synthesize a novel iridium oxyfluorides.

Precursor Ae_2IrO_4 was synthesized by a conventional solid-state reaction method. Thereafter, they were mixed with various fluorination reagents such as ZnF_2, CuF_2 and PTFE, and the mixture was heated at 250-550 °C for 12 hours in air. Phase identification was performed by powder X-ray diffraction method. Magnetic properties was investigated using a SQUID magnetometer and μSR measurement. Resistivity and the valence state of Ir ion in fluorinated compounds was evaluated using a four-prob method and XAFS measurement, respectively.

The figure shows powder XRD pattern of the Sr compounds and a schematic of topochemical fluorination. New layered iridium oxyfluoride $Sr_2Ir(O,F)_{6-\delta}$ was successfully synthesized by topochemical fluorination with ZnF_2, CuF_2 and PTFE. Consequently, *c*-axis length is elongated because of insertion of fluorine layer into the rock salt layer of Sr_2IrO_4. Temperature dependence of magnetic susceptibility and resistivity shows paramagnetism and semiconducting behavior, respectively. The results of Ba_2IrO_4 will be also given in the presentation.

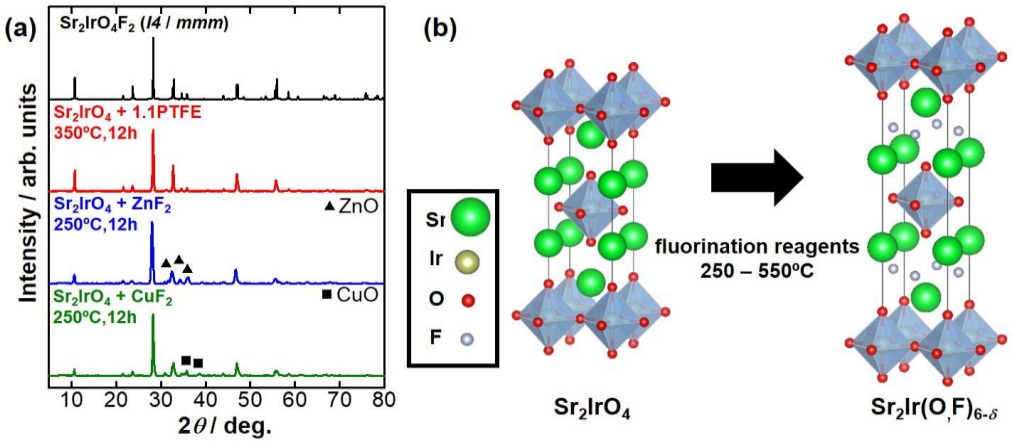

Fig. (a)powder XRD pattern of the Sr compounds and (b) Schematic of topochemical fluorination reaction of Sr_2IrO_4.

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The many faces of spin orbit coupling in quantum materials

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Just when we thought the spin-orbit interaction in solids was finally explained, a plethora of new discoveries have appeared, challenging our understanding and imagination of what the implications and manifestation of this relativistic effect might be. New topology, new particles, broken symmetries, and exotic phases of matter have all been recently revealed and explained as the results of such interactions. Today the field of spin-orbit coupling is a vibrant one, ranging from the construction of revolutionary experimental tools for imaging the spins of electrons to the development of new theories and models aimed at predicting and explaining unexpected behaviors. In this talk I will present an overview on the state of the art in measuring spin-orbit coupling in condensed matter physics, and I will discuss a couple of examples in topological insulators [1-3] and unconventional superconductors where such interaction is driving novel behavior [4,5].

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Visualization of critical state dynamics in superconductors by means of magneto-optical imaging

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Critical state in superconductors is established due to pinning of vortices by structural defects. However, this state is actually metastable because finite temperature causes vortex creep that is the dominant dissipative mechanism both in transport and magnetization properties. Moreover, the vortex matter behavior, determined by the characteristic strong nonlinearity between the current density and the electric field, along with nonlocal interactions, also includes "catastrophic" phenomena like vortex avalanches [1]. Here we present an experimental study of the stability of the vortex patterns, in particular, the analysis of vortex diffusion and the behavior of trapped vortices (remnant state), during temperature/field changes. In order to acquire both local and global quantitative information on the vortex patterns, the magneto-optical imaging (MOI) technique with an indicator film was used (an example is shown in Figure 1) [2]. The real time observation of magnetic field and current density distribution was achieved in dependence on temperature (down to 4 K) and external magnetic field (up to 0.2 T). Statistical analysis of the local vortex density fluctuations and of the roughness of the flux penetration front were performed in order to check if these quantities can be described by known diffusion models. In summary, the stability of the critical state was found to be influenced both by the thermal properties of the system (local heat capacity and thermal conductivity) and by the microscopic disorder, which can finely be tuned in the superconducting system by means of ion irradiation [3].

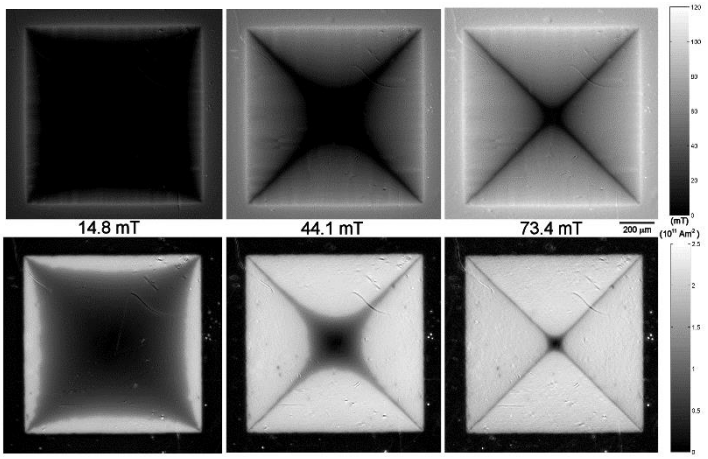

Figure 1: Quantitative MOI measurements of magnetic field (top row) and of current density (bottom row) distribution in a superconducting YBCO film at T= 4.33 K. The applied magnetic field is specified in between the rows.

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Silver route to high-Tc superconductivity

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Analogs of cuprates without copper can pave the way to new quantum materials exhibiting exotic magnetic states and perhaps new high-T_c superconductors. A natural choice is to replace Cu d^9 by Ag d^9. As will be discussed, this requires replacing O by F to retain a positive charge transfer energy. AgF_2 results to be an excellent analog of parent cuprates. Density functional theory show remarkably similar electronic parameters in both materials. Furthermore, Raman scattering shows that the superexchange interaction reaches 70% of cuprates[1]. NMR and model computations show that an important difference is that AgF_2 has a quite large Dzyaloshinskii–Moriya interaction due to the much larger buckling in the + and – direction (Fig. 1) respect to CuO planes, introducing an interesting new ingredient to the problem. On the other hand, we argue that structures that reduce or eliminate the buckling could have an antiferromagnetic coupling that matches or surpasses the cuprates potentially leading to high-T_c superconductivity.

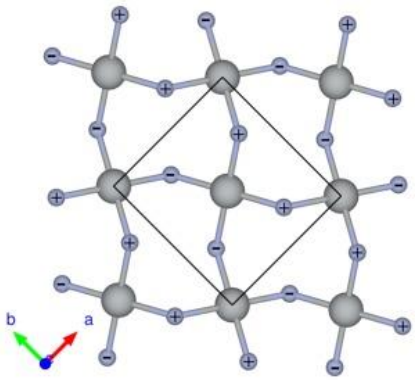

Figure 1. Schematic view of an AgF_2 plane. + and – indicate direction of displacement of fluorine ions.

References

Non-volatile field-effect modulation of transport properties in crystalline and amorphous $LaAlO_3/SrTiO_3$ interfaces

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The field-effect modulation of magnetotransport properties of two-dimensional electron gases at the $LaAlO_3/SrTiO_3$ interfaces with crystalline and amorphous overlayers is investigated in back-gate configuration. In both types of samples, a dramatic and non-volatile resistance divergence is found after the first low-temperature application of a positive gate voltage up to 200V and the pristine state is only recovered after week long storage at room-temperature. We analyze quantitatively magnetotransport data within a two band framework. The role of possible charge exchange between the interface quantum well and localized traps in $SrTiO_3$ in proximity to the interface in determining the metastable state is considered.

Ultrafast manipulation of matter by extreme terahertz fields

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Non linear optical phenomena are related to the dependence of the electric susceptibility on the applied electric field giving rise to fundamental effects like optical rectification and harmonic generation. These effects are amplified in the Terahertz (THz) region of the electromagnetic spectrum (1 THz=33 cm^{-1}=300 um=8 meV), where many excitations in condensed matter show their characteristic excitation energy. Here, by using high-intensity sub-picosecond THz radiation with an associated electric field of tens of MV/cm we will discuss non linear and ultrafast THz effects in V_2O_3 strongly correlated oxide and Bi_2Se_3 Topological Insulator Dirac system.

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Status of high-field iron-based superconducting wires and tapes

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Iron-based superconductors (IBS), especially 122 type, are very promising candidates for high-field applications because of its ultrahigh Hc2 > 70 T at 20 K, low anisotropy (< 2 for 122) , and ease of fabrication. Recently, the highest transport Jc values have achieved 0.15 MA/cm^2 (Ic = 437 A) at 4.2 K and 10 T in densified and textured 122 tapes. Secondly, in order to reduce costs and improve the mechanical strength, high strength stainless steel/Ag and Cu/Ag 122 composite conductors have been fabricated, with transport Jc above 50 kA/cm^2 in 10 T. For round wires, the highest Jc value reached 31 kA/cm^2 in Cu/Ag composite sheathed wires at 4.2 K and 10 T. High-Jc multifilament 122 wires were successfully fabricated by the PIT method. More importantly, transport Jc of 100-m-class 122-type IBS wires has been tripled, compared to the first one, confirming the great potential for large-scale manufacture. Finally, as China is proposing the next generation high-energy particle accelerators for funadamental physics study, I will introduce the SPPC project and the role of IBS technology within it.

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Model fault-current limiter with iron-based superconducting wires

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Iron-based superconductors have a very high critical current density more than 1 MA/cm^2 and low anisotropy at liquid helium temperature. To date, there are a number of long-length wires based on 122 superconducting family material with J_c up to 10^4 A/cm2 [1,2]. Therefore it can be used for the superconducting electrical devices development such as fault current limiters.

A typical fault current limiter for an industrial power grid operates at voltage of U=400V, and to estimate the minimum length of the iron-based superconducting wire we used the data for the already obtained superconducting wires in our laboratory: engineering current density is 13 KA/cm^2, which corresponds to I_{c0} about 100A, resistance in the normal state does not exceed 0.6 Ohm/m for the wire of 1mm in diameter with filling factor of 0.39. Assuming a nominal current of I_n=1000A (usually it is 0.5 of total I_c) and a degree of limitation of N=6, one can estimate the minimum required resistance to provide a limitation according to the Ohm law $R_0=U/(I_n*N)=0.07$ Ohm and the number of parallel superconductors is $n=I_n/2*I_{c0}=20$, where I_{c0} is critical current of a single wire. Limiting the current at the first stage by five times allows connecting conventional limiting blocks. The length of one wire is about $R*n/R_0=2.2$ m, and the total required length of this type of superconducting wire is about 45 meters. Thus, the length of the wire for developing a current limiter based on iron-based superconductors is within reasonable limits.

Using the parameters of the industrial grid, we proposed a prototype of the fault current limiter and showed the possibility of developing this type of device using the iron-based superconductors.

The work was performed with financial support of the Russian Foundation for Basic Research (project no. 17-29-10003) using equipment of the Lebedev Physical Institute's Shared Facility Center.

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Exploring the magnetic properties of Strontium-Hexaferrite Nanoparticles for the development of rare-earth-free Permanent Magnets

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Permanent magnets have gained an increasing degree of interest due to their use in a multitude of energy-related technological applications [1]. In a world of fast-diminishing resources, and ever-increasing cost of rare-earth elements, exploring new avenues for realizing cheap and energy efficient permanent magnets has become extremely important. While a major achievement would be to find new hard magnetic materials, much can be done to improve the performance of known materials. In this context, hexagonal ferrite is one of the most promising materials to be investigated [2], in order to develop novel permanent magnets based on nanoparticles (NPs) with a maximum energy product bringing the gap between conventional bulk hexaferrites and rare-earth-based permanent magnets [3].

In this work, we present an investigation of the magnetic properties of nanostructured Strontium hexaferrites ($SrFe_{12}O_{19}$) synthesized by a sol-gel auto-combustion method [4]. The structural and morphological features of the obtained NPs have been characterized by means of XRD (X-Ray Powder Diffraction), XRF (X-Ray Fluorescence) and TEM (Transmission Electron Microscopy). $SrFe_{12}O_{19}$ has been obtained as a pure phase after thermal treatment at 800 °C, with mean particles size extracted by XRD around 40 nm. The success of the reaction, as well as the dependence of both the size and size distribution of the nanosystems on various annealing treatments is investigated. Furthermore, the effect of the addition of cationic surfactants (CTAB) on the properties of nanocrystallites is discussed. In order to evaluate the magnetic performance of the as prepared NPs, an analysis of their static magnetic properties was performed by SQUID (Superconducting Quantum Interference Device) and VSM (Vibrating Sample Magnetometer): a saturation magnetization of above 60 emu/g was achieved. Finally, we discuss, on the basis of the $(BH)_{max}$ product, the potentiality of nanostructured strontium-hexaferrite NPs in permanent magnet technology.

We thank the Swedish Energy Agency and the Swedish Research Council (VR) for financially supporting this work.

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Reversible strain-tuning of crystalline oxide microstructures via hydrogen gas

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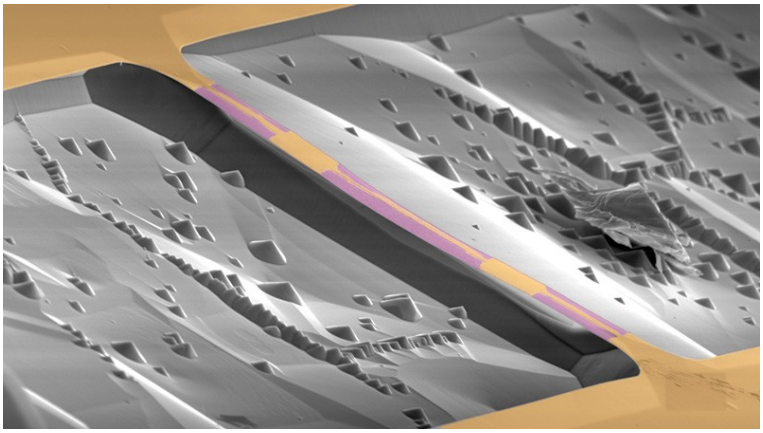
The strain is a crucial parameter to tailor the ground state of strongly correlated materials. In thin films of complex oxides a typical route to control strain is by performing heteroepitaxial growth on substrates having different lattice parameters or by using piezoelectric elements. However, these approaches have intrinsic limitations, such as the difficulty of tuning the material strain-state after growth or the challenge to obtain high-quality crystals on different substrates. Chemical doping by hydrogen is a promising alternative route to induce large modification in the ground state of complex oxides [1,2], but it was never used to dynamically control the strain state of materials.

Here, we report the manipulation of the mechanical properties of single-crystal WO_3 microstructures by reversible incorporation of H_2 gas at room temperature. In WO3 thin films we find that hydrogen doping determines uniaxial lattice expansion up to 1.3%. We exploit this effect in free-standing microbridges, where we observe a progressive transition from tensile-strained to buckled regime during the hydrogen (de)intercalation process, indicating that the stress state of the structure can be controlled over a wide range. Our results demonstrate a robust and general approach towards the reversible manipulation of the mechanical properties of oxide-based micromechanical devices.



Scanning electron micrograph of a 110×5 μm² WO3 microbridge (purple). The Au overlayer (orange) provides laser mirrors to detect mechanical motion and a low-impedance microwire employed for electromotive actuation.

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Microresonators based on single-crystal (La,Sr)MnO_3 thin films

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We perform mechanical characterization of (La,Sr)MnO_3 microbridges and cantilevers fabricated from thin films (<250 nm) deposited on $SrTiO_3$ (001) substrates by Pulsed Laser Deposition. Microbridges mechanical properties are dominated by stress-stiffening effects coming from to the larger lattice constant of the substrate, resulting in high quality factors and large shifts of the resonance frequency. On the contrary, (La,Sr)MnO_3 cantilevers relax the axial strain and show lower resonance frequencies and quality factors. Temperature dependence (300K—400K range) of the mechanical modes and their quality factors are investigated by a custom setup based on optical lever method that works in a controlled environment. The contribution of the magnetic phase transition to the measured mechanical resonance spectra of the freestanding structures is discussed.

Scanning electron microscope micrograph and optical picture of a strained 150×15 μm² microbridge fabricated from a 100 nm thick LSMO single crystalline film

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Superconductivity in Chevrel phases from first principles

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Chevrel phases [1] are a large class of materials with numerous and appealing physical properties, including magnetic properties, metal - insulator transitions, remarkable superconducting properties (critical temperatures as high as 15 K and high critical magnetic fields up to 50 Tesla) and coexistence between superconductivity and magnetic ordering. Here we present a first principles study on the prototypical Chevrel compound $PbMo_6S_8$. We analyze its structural properties and pressure phase diagram, sheding light on the intricated experimental scenario. We then investigate its superconducting properties by means of SuperConducting Density Functional Theory (SCDFT), a first-principles theory which does not rely on any empirical parameter. We succesfully predict the critical temperature of $PbMo_6S_8$ at ambient conditions, highlighting the role of phase instability, electron-phonon coupling with different intra-molecular and inter-molecular phonon modes and the fundamental role of repulsive electron-electron interaction, treated from first principles. In addition, we predict the evolution of the superconducting critical temperature as a function of the external pressure, showing an excellent agreement with available experimental data. The present results provide a comprehensive view of the superconducting transition in Chevrel phases for the first time, open to a systematic theoretical investigation of this class of compounds and confirm the predictive power of SCDFT.

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Ultrafast nonlinear dynamics of two-dimensional materials

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Optical nonlinearity in photonic materials enables a large number of applications such as frequency conversion, all-optical signal processing, and non-classical sources of light. The speed of solid-state electronic devices, determined by the temporal dynamics of charge carriers, could potentially reach unprecedented petahertz frequencies through direct manipulation by optical fields, consisting in a million-fold increase from state-of-the-art technology. In graphene, charge carrier manipulation is facilitated by exceptionally strong coupling to optical fields, from which stems an important back-action of photoexcited carriers. Here we report the instantaneous response of graphene to ultrafast optical fields, elucidating the role of hot carriers on sub-100 fs timescales [1]. The observed nonlinear response and its dependence on interaction time and field polarization reveal the back-action of hot carriers over timescales commensurate with the optical field. An intuitive picture is given for the carrier trajectories in response to the optical-field polarization state. We note that the peculiar interplay between optical fields and charge carriers in graphene may also apply to surface states in topological insulators with similar Dirac cone dispersion relations. Furthermore, we report harmonic generation and saturable absorption in graphene, discussing free-carrier generation and their ultrafast temporal dynamics in the atomically thin material [2,3]. We further discuss the nonlinear optical properties of transition metal dichalcogenides [4,5], illustrating cavity-enhanced second-harmonic generation and parametric down-conversion and demonstrating that phase-matching free operation can be achieved in photonic micro-cavities embedding two-dimensional semiconductors as nonlinear optical media. Our results are promising for the development of integrated optical parametric oscillators and micro-sources of entangled photons.

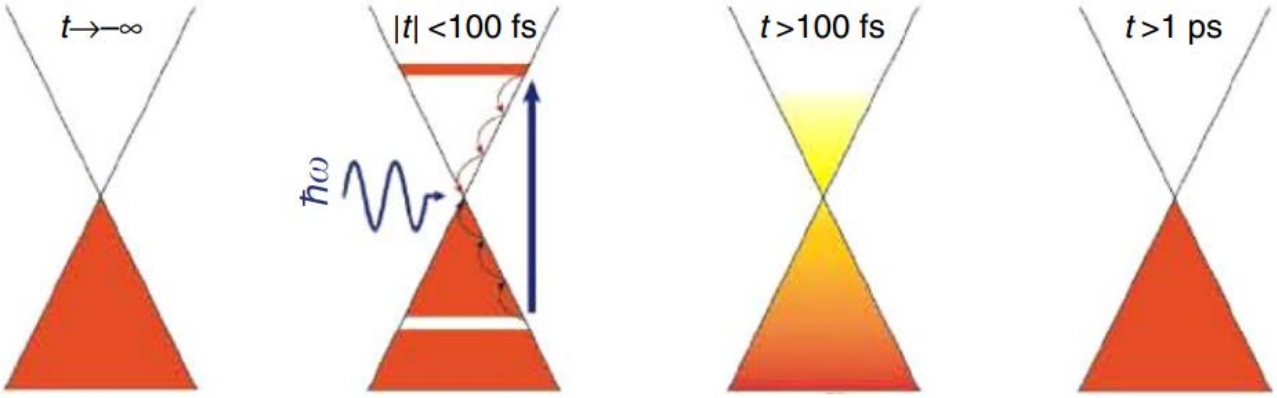

Figure: Schematic representation of the ultrafast temporal dynamics of photoexcited electrons in extended graphene.

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Effects of spatial confinement on charge order in $YBa_2Cu_3O_{7-\delta}$

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Superconductivity, magnetism and charge density waves (CDW) are strictly-entangled orders in cuprate high critical temperature superconductors (HTSs) [1]. They mainly involve the atoms belonging to the CuO_2 plaquettes laying in the weakly-interacting *a-b* planes. In particular CDW are a rather robust order, ubiquitous among all families of cuprates [2,3,4]; at the same time, they are also a local order, with a correlation length ξ_{CDW} in the order of several nanometers, which is very sensitive to small changes in the CO_2 planes. Indeed, recent studies have shown that the strain, either applied mechanically on single crystals or by a substrate on thin films, can be used as an additional degree of freedom to reveal new characteristics [5,6]. To clarify the physics at play for the charge density wave order, we have used Resonant Inelastic X-ray Scattering (RIXS) and Energy-Integrated Resonant X-ray Scattering (EI-RXS), two techniques having a major role for the study of the charge order, on systems where the a-b planes are spatially confined. This has been achieved with the use of untwinned a-axis oriented $YBa_2Cu_3O_{7-\delta}$ films [7]. In these structures, grown at Chalmers University, the 2D CuO_2 planes are parallel to the direction which is normal to the film surface: the a-axis direction is therefore confined by the film thickness, and by changing the thickness it is possible to squeeze the CDW down to dimensions in the same order of ξ_{CDW}. These measurements reveal that the order is stable even in 50 nm thick films, with a temperature dependence similar to the one observed in bulk systems. More interestingly, preliminary analysis shows that, unlike in crystals, it exhibits a larger coherence along the out-of-plane direction. Additional analysis regarding changes in lattice and magnetic excitations due to confinement is currently in progress.

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Iron chalcogenide crystals grown in molten chlorides: structure and properties

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Iron Based Superconductors (IBSCs) have been subject in the last decade of extensive studies thanks to the large critical current densities achieved at high fields. Among IBSCs, iron chalcogenides are appealing with respect to iron pnictides due to the low toxicity. However, the role of the chemical composition and of the synthesis route on the micro-structural and physical properties of iron chalcogenides has yet to be clearly assessed, in order to unveil the applicative potential of this class of materials. Their applicative development has been in fact hindered with respect to iron pnictides, also as a result of the large variability of functional properties reported for compounds characterized by similar chemical compositions. This is observed in particular for the commonly adopted routes of single crystals synthesis, carried out via self-flux method, where chemical inhomogeneity and solidification of multiple phases are often reported.

In this work, we describe a molten chlorides synthesis method to produce Fe(Se,Te) iron chalcogenides single crystals. NaCl/KCl mixtures have been used as a flux, in order to allow the crystallization of the solid in a quasi equilibrium static thermal condition in the 700 °C temperature range. The adoption of this synthesis technique allows to avoid chemical inhomogeneities and phase segregation in the obtained crystals. The obtained materials have been characterised in their morphology, microstructure and chemical composition, evaluating superconducting properties by means of electrical and magnetic measurements.

SEM image of an aggregate of iron chalcogenides crystals grown in a molten chloride flux.

Effect of pressure on the structural properties of rare earth doped ceria

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RE-doped ceria (RE= Rare Earth) represent a family of widely investigated oxides, suitable as solid electrolytes in Solid Oxides Fuel Cells (SOFCs). In fact, at low RE content, these systems retain a fluorite-based structure (F), where Ce^{4+} ions are randomly substituted by RE^{3+}, causing the occurrence of oxygen vacancies, which are free to move trough the lattice. The latter phenomenon is responsible for the excellent ionic conductivity observed for doped ceria systems, within the fluoritic region.

In $Ce_{1-x}RE_xO_{2-x/2}$ systems, the F structure is retained up to a certain x_{max} value, which is determined by the dopant ion. It was observed that the highest ionic conductivity is always reached at x_{RE} lower than x_{max}, due to the presence of C phase nanoclusters (where C stands for the typical RE_2O_3 cubic structure) coherently grown within the fluoritic matrix. The latter aggregates tend to trap oxygen vacancies, hence reducing ionic conductivity. For x_{RE} higher than x_{max}, either a hybrid region F/C (i.e. for RE = Gd^{3+} [1,2] Sm^{3+}[3]) or a biphasic region F + C (i.e. for RE = Lu^{3+}[4]) may occur, mainly depending on the difference in size between Ce^{4+} and RE^{3+} ions.

To date, the present research group is performing high pressure structural studies on different $Ce_{1-x}RE_xO_{2-x/2}$ systems, in order to determine the possible contribution of the oxide compressibility to the ionic conductivity. In fact, since the movements of oxygen vacancies cause a local distortion of the lattice, a low oxide bulk modulus should allow the RE^{3+} ions to better tolerate significant variations in the interatomic distances, thus increasing ionic conductivity. In particular, high pressure synchrotron X-ray diffraction analysis were performed on Lu- [5], Sm- and doubly doped ceria systems, which were obtained using simultaneously two different dopant ions, Nd^{3+} combined with Tm^{3+} or Dy^{3+} [6]. The Nd/Tm and Nd/Dy ratios were chosen to reproduce an average ionic size equal to that of Sm^{3+}, since Sm-doped ceria resulted to be the system showing the highest ionic conductivity [7, 8]. A high pressure micro-Raman spectroscopy study on the same systems is on the way. Comparative results from x-ray diffraction and micro-Raman spectroscopy will be discussed.

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Magnetic and dielectric properties of Yb-doped $PbFe_{2/3}W_{1/3}O_3$

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Multiferroic materials have gained enormous attention due to their potential applications in novel multifunctional devices such as sensors, transducers, memories, and spintronics [1]. In this context, Pb-based ABO_3 perovskites containing magnetic cations provide a great playground to observe and understand new physics related to spin and dipole order and multiferroicity. In the present study, we have investigated a model system of an antiferromagnetic relaxor ferroelectric, the $PbFe_{2/3}W_{1/3}O_3$ perovskite [2], in which the magnetic Fe cations are gradually replaced by Yb ones. We demonstrate that the doping of a few percents of Yb yields inequivalent *B* sites in the structure, and in turn a ferrimagnetic order in the system [3].
By combining experimental results and first-principle calculations, we describe the influence of Yb on the structural, magnetic and (magneto)dielectric properties of the system and compare it to that of other dopants [4,5]. Our results suggest that the correct balance of cation and spin order may bring forth materials with attractive "multiferroic" properties such as ferrimagnetic order and ferroelectricity near room temperature.

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Hydrodynamical charge density wave description for transport in the strange metal phase of cuprates

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The mechanism controlling the exotic behavior of the transport properties in the "strange" metallic phase of high temperature superconductors is one of the main unresolved problems in condensed matter physics. In particular, this phase is characterized by the unusual temperature dependence of the transport coefficients and it has been proposed to emerge from a quantum critical point around the optimally doped region [1]. In addition, charge density wave (CDW) order has proven an ubiquitous feature of the phase diagram of all cuprate superconductors [2] and could play a dominant role in determining the behavior of the transport properties of cuprates.

From the theoretical point of view, the strong correlations which characterize the strange metals prevent from describing these materials within the Fermi liquid scenario. New ideas come from high energy physics and, in particular, hydrodynamics is a tool which gives an accurate description for strongly correlated systems and could therefore be the ideal framework to describe the strange metal phase. Recently, studies that try to explain the electric transport properties of these materials by means of the hydrodynamic theory, have appeared [3]. The theory of quantum critical CDW hydrodynamics allows us to express five transport coefficients (namely electric resistivity, magnetoresistance, transverse thermal conductivity, Hall angle and Nernst effect) as a function of only four hydrodynamic parameters. Eventually, by measuring four of the aforementioned transport properties, one can predict the temperature dependence of the fifth one. In particular, we have measured the five DC transport coefficients in Bi-2201 and by fixing the temperature dependence of the four hydrodynamic parameters using the low temperature behavior of the electric resistivity, the magnetoresistance, the Hall angle and the transverse thermal conductivity, we have been able to uniquely determine the low temperature dependence of the Nernst coefficient. The obtained result is in strong agreement with our experimental observations. This study provides a consistency check, based on the hydrodynamical analysis, that quantum critical two-dimensional CDW order might be the relevant mechanism governing the transport properties of the strange metal phase of cuprates.

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Observation of spin polarized bands in $NiTe_2$

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Recently, materials exhibiting type-II Dirac fermions are attracting great interest because of their high potential for new technological applications. However, the so far reported Dirac points remain often located deeply below the Fermi energy. In such situation the physical properties remain dominated by the non-relativistic carriers.

Recently it was predicted that $NiTe_2$ hosts type-II Dirac fermions in the close proximity of the Fermi level [1]. By means ARPES and Spin-ARPES, we measured experimentally the electronic band structure of $NiTe_2$ at the APE-NFFA beamline (Elettra). We find that, as expected for the group X dichalcogenides [2,3,4], $NiTe_2$ hosts a number of spin polarized surface states as well as the bulk states with strong spin polarization and we confirm that indeed the theoretically predicted Dirac cone is located in proximity, but slightly above the Fermi energy. This suggests that with adequate electron doping the Dirac point can be brought to the Fermi energy, thus paving the way for the exploitation of the topological states in $NiTe_2$.

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Research status and direction of HTS Fault Current Limiters

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High temperature superconductors (HTS) own negligible electrical resistance and very high current density (ten to hundreds times the one of the copper). Not merely a scientific curiosity, their exceptional properties allows the development of power electrical devices with unachieved performance as well as new functionalities. Further advantages are the drastic increase of the efficiency, the compact size and the longer life. Several manufactures exist now around the world which are able to supply HTS materials for real scale application at decreasing costs. Furthermore, substantial progress, both in terms of performance and cost reduction, has also been achieved for cooling technology which is essential for the reliable operation of HTS.

The intrinsic non linearity of HTS material (transition to the normal state due to overcurrent) can be exploited for the development of superconducting fault current limiting (SFCL) devices, able to improve the performance (power quality and stability) of the grid in normal condition and to reduce the risk of disturbance, damage or black out due to fault. Long term field test of real scale HTS fault current limiter prototypes has been performed during the last years and first commercial installations of have also been introduced. In this presentation, the concepts of Superconducting Fault Current Limiters are presented and their state of development is investigated. The benefits that they can bring to the power grid are discussed with reference to practical application cases. Near future research directions, with particular reference to DC SFCL, are pointed out. The research activity on SFCL carried out at the University of Bologna is also resumed.

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$(Au)_z$/CuTl-1223 Nanoparticles-Superconductor Composites: Excess Conductivity Analysis and Activation Energy

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Abstract

Gold (Au) nanoparticles (NPs) extracted from the colloidal solution were added into $(Cu_{0.5}Tl_{0.5})Ba_2Ca_2Cu_3O_{10-\delta}$ (CuTl-1223) superconducting matrix prepared by solid-state reaction to get $(Au)_z$/CuTl-1223, z = 0 ~ 1.5 wt.%, nanoparticles-superconductor composites. The zero resistivity critical temperature $\{T_c(0)\}$ and activation energy {U (eV)} were both increased while normal state resistivity $\{\rho_{300K}$ (Ω-cm)} was decreased with increasing Au NPs contents in CuTl-1223 matrix up to z = 1.0 wt.%. The improvement of superconducting volume fraction can be witnessed from the enhanced value of T_c (0) and suppression of ρ_{300K} (Ω-cm) with the addition of Au NPs. The increase in U (eV) can be attributed to the interaction of carriers with Au NPs settled at inter-grannular spaces. There are two competing processes linked with the addition of Au NPs i.e. non-superconducting regions contributing to U (eV) and improved superconducting volume fraction enhancing T_c (0). The excess conductivity analysis was carried out to estimate the superconducting microscopic parameters, which could be used to explain the outcomes of this experimental work.

Key Words: CuTl-1223 superconducting phase, Au nanoparticles, $(Au)_z$/CuTl-1223 composites, Activation energy, Fluctuation induced conductivity.

PACS codes: 74.76.-w, 74.76.Bz, 74.72.-h, 74.72.-Jt

Superconducting Magnets for Space Applications

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There is little experience about superconducting magnets designed to operate in space. In the 80's, a superconducting magnet for the antimatter detector ASTROMAG was designed but never constructed. The SXS X-ray telescope, launched on February 2016 into a low-Earth orbit and lost soon after, was equipped with an adiabatic demagnetization refrigerator based on an NbTi magnet. The most remarkable example of space magnet is the one for the AMS02 spectrometer: it was designed [1], built, integrated in the detector and successfully tested [2] but, before the launch, it was replaced with a permanent magnet because of the lifetime limitation related to cryogenics.

The main requirements of superconducting magnets for space applications are: (i) low mass budget, i.e. high stored energy to mass ratio; (ii) low power consumption, i.e. efficient cryogenics; (iii) very high stability. Besides, the presence of liquid helium tanks is regarded as a drawback. Stability and helium cryogenics have been the major problems hindering superconducting magnet technology in space, so far. Magnets wound with high temperature superconductors are operable up to 40 K, solving the problems related to stability and avoiding the use of liquid helium. Recent developments of ReBCO tapes (particularly suitable for space magnets) indicate that overall current density can exceed 1 kA/mm^2 at 30 K, 3 T, in the next years. MgB_2 wires, despite their poorer current transport properties, are also a possible option, due to their low average mass density [3-4].

Space applications of superconducting magnets include particle detectors, shields to protect astronauts and devices against charged particles, propulsion and attitude control, magnetic refrigeration, energy storage.

Between 2010 and 2015, for the first time, technological investigations were accomplished to verify the feasibility of superconducting magnets for space radiation shielding. Three studies were carried out: the ARSSEM project (ESA-INFN), the NIAC-MAARS project, and the EU-SR2S project [5].

In response to Call for the VOYAGE 2050 long-term plan, in August 2019, an international group led by INFN submitted to ESA a proposal of a large acceptance space spectrometer. The spectrometer (called ALADINO) will be equipped with a large ReBCO toroidal magnet [6].

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Superconductors for the Italian Divertor Tokamak Test facility project

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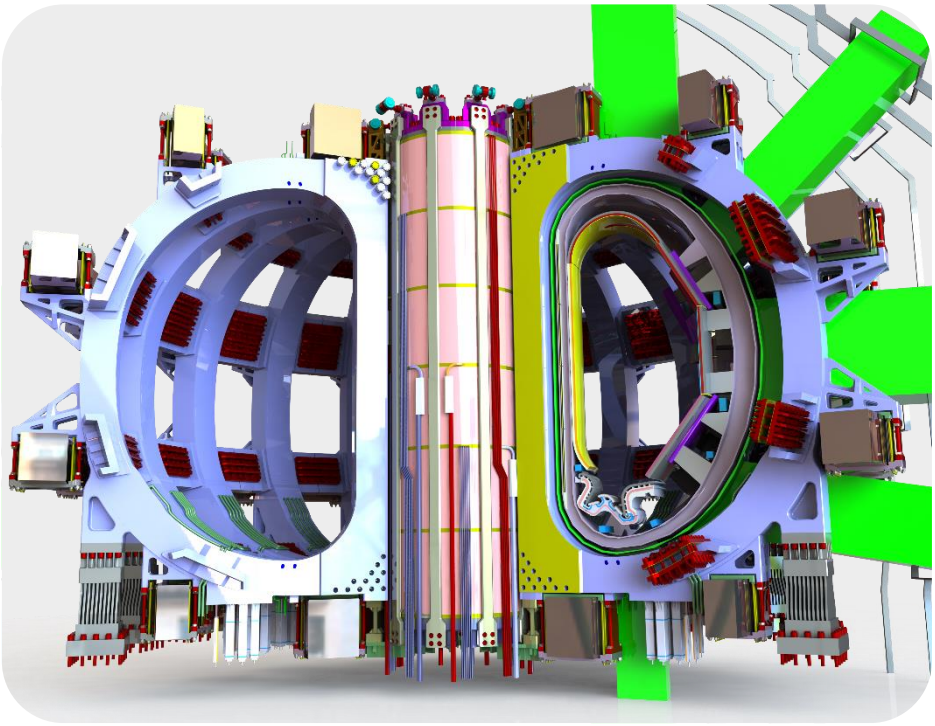
The "Divertor Tokamak Test" (DTT) facility is an experimental tokamak currently under construction in Italy, at the Frascati research center of ENEA. The main goal of this nuclear fusion project is to build a facility able to test various divertor solutions and magnetic configurations. The definition of the most appropriate approach to manage power and particles exhaust for the EU-DEMO machine is in fact still an open issue, and DTT should heavily contribute to the elaboration of a feasible solution. The DTT fully superconducting magnet system consists of 18 Toroidal Field (TF) coils, 6 Poloidal Field (PF) and 6 Central Solenoid (CS) stacked module coils, all independently fed. It is based on Cable-in-Conduit Conductors, and it employs about 25 tons of NbTi and about 75 tons of Nb_3Sn multi-filamentary wires. It has been designed to accommodate stringent requirements of performance and flexibility. In this paper, the main design drivers and up-to-date solutions for the magnet system are presented, from the superconducting strands up to the main structural components, and the outcome of their main analyses discussed in detail. An overview of the technical needs leading to the present design is provided, with a discussion on the aspects that mostly impact on the procurement and construction phases, which are already on-going.



Overview of the Divertor Tokamak Test facility (DTT) magnet system and structures.

Multiphysics simulation of YBCO superconducting bolometer with a portable LN_2 cryostat for infrared detection

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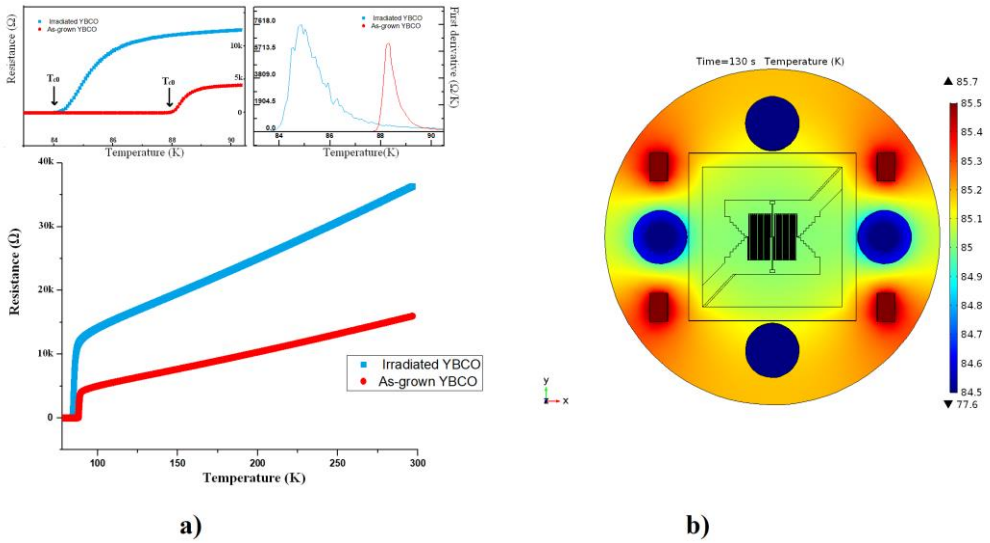
We present the study of an high-temperature superconducting bolometer based on $YBa_2Cu_3O_{7-x}$ (YBCO) films. The superconducting detector is constituted by a double meander structure and partially irradiated by means of micro-collimated high energy heavy ion irradiation. This operation allowed reducing the critical temperature and the critical current density preserving the slope of the resistance versus temperature curve (Fig. 1a) [1]. The detector can work above the liquid nitrogen temperature, hence a portable LN_2 cryostat, which is equipped with an optical window in order to suitably filter the spectrum of the incoming electromagnetic radiation, is used.

The system (detector and cryostat) was optimized by means of simulations with finite element method (COMSOL Multiphysics®) [2]. This study was focused both on the thermal stabilization of the cold finger, in particular for what concerns temperature profiles across the superconducting detector, and on the bolometer response to µs electromagnetic pulses. The temperature was found to be rather homogeneous along the whole central part of the sensor (Fig. 1b) and the response to the infrared radiation well reproduces theoretical calculations and preliminary experimental results.



a) b)

Fig.1 a) Resistance versus temperature curves of the as-grown and irradiated meanders. b) Temperature distribution of the cold finger with the detector and the resistors (heaters).

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Superconductivity mediated by ferroelectric fluctuations

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It was recently proposed [1] that bosonic fluctuations close to the ferroelectric quantum critical point are responsible for superconductivity in lightly doped $SrTiO_3$, a low-carrier density material. Indeed, several experiments indicate there might be an interplay between ferroelectricity and superconductivity in these systems [2-6], including the existence of a strong anomalous isotope effect. Motivated by these reports we study superconductivity mediated by the odd-parity ferroelectric modes. We consider a Rashba-like coupling to the electronic spin, which is possible due to the presence of spin-orbit coupling [7]. We derive the effective pairing interaction and solve the resulting linearized gap equation. We find that the effective coupling, which is attractive in the pseudospin singlet channel, is dominated by the soft transverse optical mode. Moreover, the superconducting gap function is shown to develop an anisotropy which grows as the system approaches the ferroelectric phase. Finally, we discuss the competition with other even-parity superconducting channels.

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Development of free-standing magnetic membranes for spin polarimetry

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The spin-filtering properties of free-standing magnetic membranes make them an effective candidate for spin polarimetry of electron beams generated by an electron gun or photoemitted by a sample in photoemission spectroscopy experiments [1]. The angular and energy resolution of the electron beam can be achieved simultaneously, e.g. at the exit slit of a hemispherical analyzer, by integrating the magnetic membranes into two-dimensional matrices [2]. The underlying physical principle is the selective transmission of the electrons with spin parallel or anti-parallel to a quantization axis defined by the direction of the magnetization vector present in the ferromagnetic layer. The objective is the realization of a device with efficient transmission (larger than $3x10^{-2}$) and spin asymmetry (S≈0.5) and a tunable filtering process according to the magnetization direction.

A proper fabrication process is needed to obtain free-standing magnetic membranes which are self-sustained and integrated in a hexagonal (honeycomb) pattern which maximises the effective area. To achieve a three-dimensional control of the magnetization two types of magnetic heterostructures were employed. Co or CoFeB were used as active materials for the in-plane (IP) configuration, while the stack Ta/CoFeB/MgO was exploited for the out-of-plane (OOP) one. The complete membrane stack, that cannot exceed the thickness of ten nanometres to guarantee a sufficiently high transmission, also includes a capping layer (Au) and a mechanical support layer (e.g. graphene, …).

The magnetic properties were characterised by Vibrating Sample Magnetometer, Faraday Effect and Kerr microscopy on micrometric structures suitable to be integrated on free-standing membranes (Figure 1(a)). The thickness and the annealing temperature were optimised to obtain IP and OOP magnetization. Figure 1(b) shows an example of a magnetic imaging by Kerr microscopy, giving information about the dynamics of domains during reversal, the remanence and saturated states and the coercive fields. A mechanical characterisation of the support layer was finally performed by Atomic Force Microscopy.

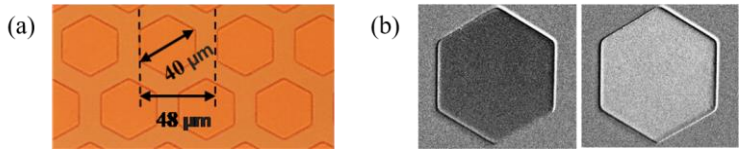

Figure 1. (a) Micrometric geometry of magnetic heterostructures. (b) Kerr microscope measurement. Black and white colours indicate the two opposite directions of the magnetization, while grey part is the non-magnetic region.

The next step of this work will be the study of the spin-filtering properties of the membranes through a low energy spin-polarized electron beam [3] in order to determine the transmitted beam polarization and the figure-of-merit of the device.

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Angular dependence of quasiparticle relaxation time in Fe(Se,Te) microbridges

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The study of the phenomenon known as flux flow instability (FFI) has been proved to be a valuable tool for investigating quasiparticle scattering processes, especially when the quasiparticle distribution is far from equilibrium [1]. The FFI is related to the loss of stability in the electric current transport into the superconductor due to a dramatic change in the moving vortex structure, and its signature is a sudden jump from the flux flow regime to the normal conduction state of the material. There are different mechanisms which can lead to FFI, in particular the microscopic intrinsic processes are related to the nature of the gap. In this work, we take advantage of this powerful tool to analyze the quasiparticle energy relaxation in iron based superconductors in order to enlarge our understanding of superconducting properties of these materials such as the gap anisotropy. Thus, we acquired current-voltage characteristics on thin Fe(Se,Te) microbridges at different magnetic field up to 16 T and as a function of the relative orientation between the field and the sample c-axis. The presence of FFI has been recognized [2] and the quasiparticle energy relaxation time has been estimated as the field orientation goes from c-axis perpendicular to c-axis parallel orientation.

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Hard/soft and soft/hard magnetic spinel ferrites nanoparticles

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Core/shell nanoparticles (NPs) consisted of magnetically hard and soft materials demonstrate enhanced magnetic properties with respect to single-phase systems [1]. In the frame of this work, the magnetic characterization of two NPs systems with core/shell structures are presented where one system is hard/soft with a core consisting of hard magnetic cobalt ferrite ($CoFe_2O_4$) covered by a soft magnetic nickel ferrite ($NiFe_2O_4$), while the second system is the inverted soft/hard NPs with almost the same size and shape. The single-phase cores were synthesized following a modified procedure reported elsewhere [2]. A seed-mediated growth of shell at high-temperature was used to achieve core/shell nanoparticles. The structure and surface morphology of synthesized $CoFe_2O_4$ and $NiFe_2O_4$ seeds and core/shell NPs were revealed by scanning transmission electron microscopy (STEM) images. Concerning the average size obtained from the STEM images, all core/shell samples are characterized by higher diameter than the seeds, confirming the build-up of ~2 nm shell. According to the magnetic characterization of samples performed with SQUID magnetometer, the prepared NPs exhibit a high saturation magnetization (~65 A×m^2/kg for core/shell systems) and a superparamagnetic behavior at room temperature (Figure 1). The growth of the soft nickel ferrite shell affects the hard properties of the cobalt ferrite seeds leading to the decrease of coercivity from 1.3 T to 0.8 T at 5 K; on the contrary, a more hard shell increases the coercive field of the soft seeds of more than one order of magnitude from 0.025 T to 0.3 T. Further studies are now in progress to evaluate the effect of a multi-shell structure on magnetic properties of such systems.

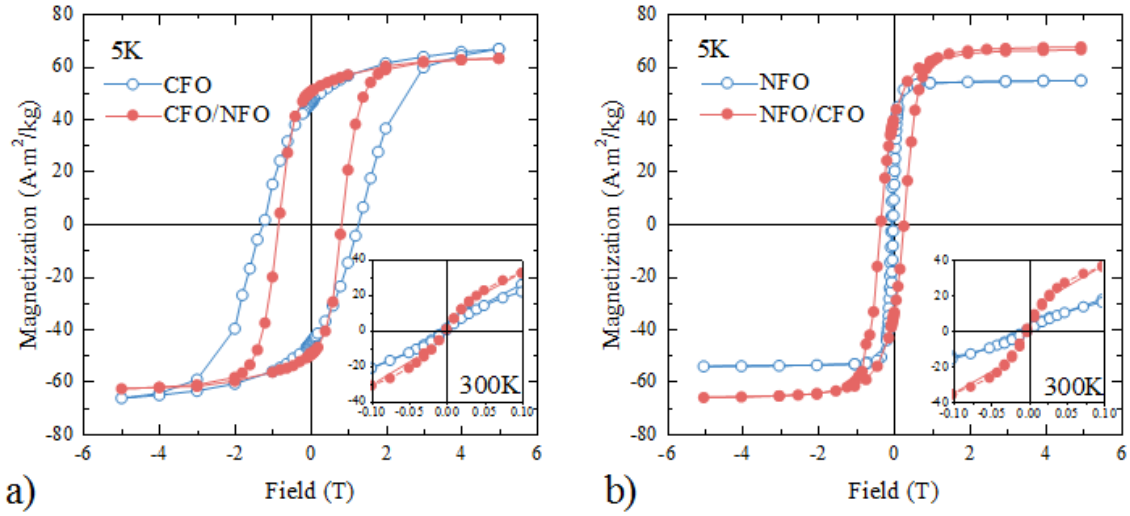

Figure 1. M-H cycles recorded at 5 K and inset is the low-field region of M-H cycles at 300 K for a) CoFe2O4 and $CoFe_2O_4$/$NiFe_2O_4$ NPs; b) $NiFe_2O_4$ and $NiFe_2O_4$/$CoFe_2O_4$ NPs.

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Thermoelectric behavior of transition metal dichalcogenides

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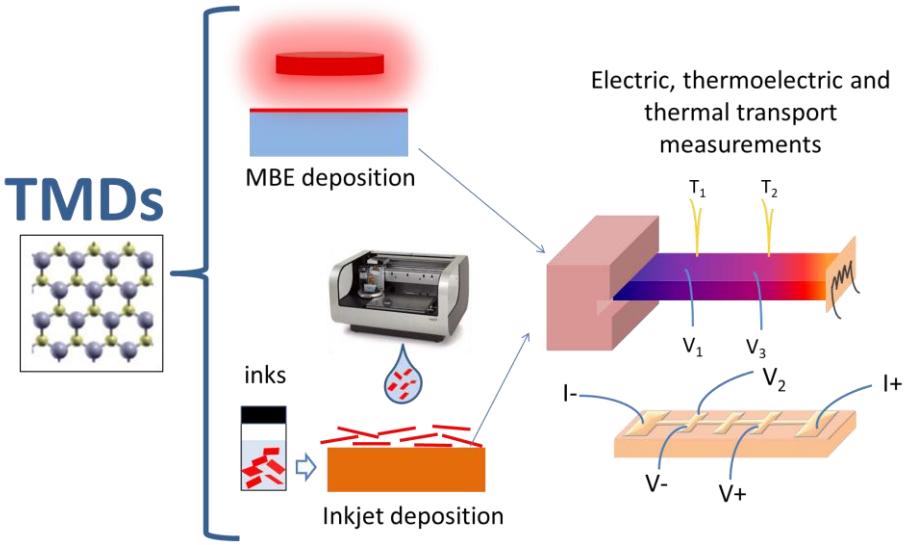
Transition metal dichalcogenides (TMDs) offer a huge flexibility in tuning electronic properties, by changing chemical composition, stoichiometry, but also by field effect and by varying the thickness. Indeed, their electronic structure is found to change dramatically from bulk to few monolayer samples [1]. Moreover, some TMDs exhibit remarkable bulk thermoelectric behavior, which could be may be further improved from the bulk to few monolayer thick nanostructures, according to theoretical predictions [2]. In this work we explore the electric and thermoelectric transport in TMDs, fabricated in the form of thin films deposited by MBE, and nanoflake assemblies, obtained by liquid phase exfoliation and subsequent ink-jet printing or drop-casting. We present preliminary results about magnetotransport and thermoelectric characterization of semimetallic TMD films and semiconducting ($SnSe_2$ and WSe_2) nanoflake assemblies, both electrically connected over macroscopic distances.

Financial support from the FLAG-ERA JTC 2017 MELoDICA project is acknowledged.



Schematic representation of the general approach and research methods of this work.

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The influence of Fe on $YBa_2Cu_3O_{7-\delta}$ structure, microstructure and superconducting properties

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Research on the high-temperature superconductors is still being developed. The current development concerns among others the novel iron-based superconductors or superconductive composites. The present work reports the $YBa_2Cu_3O_7$ (YBCO) material doped by Fe. The Fe doped YBCO crystals are considered to form secondary phases which may aid in superconductivity. The polycrystalline YBCO and with different amounts of Fe doping (1 wt.% - 3 wt.%) were synthesized by a solid-state reaction method. Structural investigations by X-ray diffraction and RAMAN measurements indicated change in the orthorhombic structure in the case of Fe doping changes. The addition of Fe to YBCO caused shifts in the RAMAN peak above 500 cm^{-1} and characterize the non-superconducting tetragonal crystal phase. The microstructural and composition investigations via scanning electron microscope indicated a homogeneous distribution of Fe throughout the YBCO crystallites. As the concentration of Fe is increasing the onset of superconducting transition temperature was decreased (Figure 1). The field dependence of critical current density was investigated at 77 K reveals the development of ferromagnetic behavior in YBCO-Fe samples. As the Fe doping increased, the effective oxygen vacancies increased resulting in carrier density transportation on the CuO_2 planes which caused inferior superconductivity.

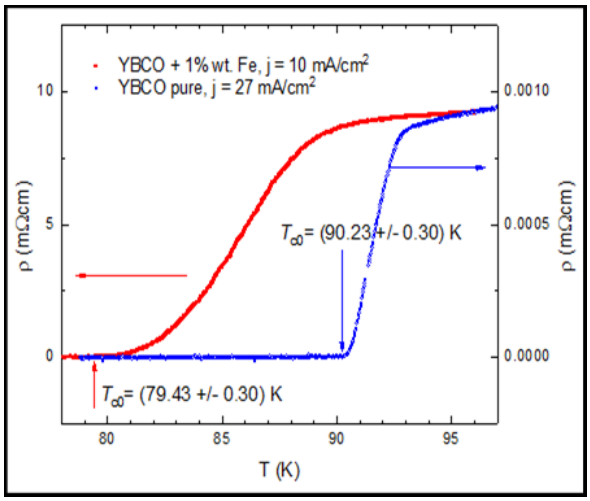

Figure 1. The temperature dependence of electrical resistivity studies which depicts the occurrence of superconductivity in YBCO and YBCO+1 wt.% Fe samples.

VO_2-based microactuators

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We discuss the development of microactuators based on Vanadium Dioxide (VO_2) thin film structures. VO_2 is a promising active material for micro/nanoactuators due to its sharp and reversible Solid State Phase Transition (SSPT) at 68°C from a monoclinic to a tetragonal phase that in single crystal shows strain values up to 1%, large applied forces and high work energy density [1, 2]. Remarkably, this phase transition is intrinsically fast (ps) and occurs in a sharp temperature window of 5-10 °C, with hysteresis between the heating and cooling branches. VO_2 films are grown on MgO(001) and MgO(110) substrates by Pulsed Laser Deposition. Freestanding microstructures are realized by optical and e-beam lithography, followed by selective wet etchings. During the SSPT, VO_2 shows phase separation in domains whose size can vary from nanometric to micrometric dimensions, depending on the substrate of growth. The controlled formation of domains of the two crystallographic phases within the hysteresis window allows tuning the stress and the resonance frequency of the structures [3], but can also be employed to do mechanical work. The mechanical efficiency and the strain direction also depend on the crystallographic properties of the VO_2 films that might be epitaxial, textured or polycrystalline, depending on the growing conditions [4]. The presented structures are the starting elements for developing more complex all-oxides microactuating devices for large force applications at the micro and nanoscale. The advantages and the drawbacks of our devices with respect to the existing technologies will be also discussed.

This research was supported by the Executive programme of cooperation between Italy and Japan by the Directorate General for Cultural and Economic Promotion and Innovation of the Ministry of Foreign Affairs and International Cooperation, of the Italian Republic. Details of the ongoing project "*solid state actuators for micro/nanorobotics*" can be found at http://www.vo2actuators.spin.cnr.it. We also acknowledge the CNR -JSPS joint research project 2018-2019 "*Domain Manipulation in VO_2 Freestanding Nanomechanical Structures*", bilateral agreements of scientific and technological cooperation.

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Superconducting properties of the hole-doped bulk $Ba_{1-x}K_xFe_2As_2$ and $Ba_{1-x}Na_xFe_2As_2$ materials synthesized by mechanical alloying

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Here we report successful synthesis of the hole-doped iron-based superconductors $Ba_{1-x}K_xFe_2As_2$ (BKFA) and $Ba_{1-x}Na_xFe_2As_2$ (BNFA) by mechanical alloying at room temperature and superconducting properties measurements in magnetic fields up to 9T. Synthesized samples exhibit bulk superconductivity with the sharp superconducting transition by magnetic susceptibility measurements.

The initial phase forms from metallic Ba (99.9%), K (99.95%) or Na (99.95%) and precursor FeAs (Fe, 99.98% + As, 6N) taken in a stoichiometric ratio of 0.6:0.4:2 after 2 hours of mechanical treatment in tungsten carbide milling jar using Fritsch Pulverisette 7 Premium Line planetary ball mill. XRD measurements showed the phase formation beginning after two cycles of 5 minutes of treatment and complete formation after approximately 2 hours of milling. Synthesized phase Ba0.6K0.4Fe2As2 has superconducting critical temperature onset of about 37K with a broad transition down to 2K before the heat-treatment.

The effect of ball-milling time on structural and superconducting behaviour of $Ba_{1-x}K_xFe_2As_2$ and $Ba_{1-x}Na_xFe_2As_2$ was studied. We show the formation of the amorphous non-superconducting phase in the BKFA and BNFA compounds during the mechanical alloying and found optimum milling time to be about 1- 1.5h. The compounds obtained exhibit superconductivity after the annealing for both samples. The SEM investigations revealed the apparent formation of crystallites about 3-5μm and magnetic susceptibility measurements show the sharp superconducting transition. We carried out a number of short-term heat treatment experiments. According to the magnetic measurements, the best superconducting transition was obtained after 850°C heat treatment for 1 hour. Mechanical alloying appears to be a very promising technique for large scale producing high-quality ceramic material of BKFA and BNFA superconductors.

The work was performed with financial support of the Russian Foundation for Basic Research (project no. 17-29-10036) using equipment of the Lebedev Physical Institute's Shared Facility Center.

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Ultrathin molybdenum disulphide as a gate-tunable multi-valley superconductor

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Gate-induced superconductivity (SC) at the surface of semiconducting transition metal dichalcogenides (TMDs) has attracted a lot of attention in recent years, thanks to the sizeable transition temperature, robustness against in-plane magnetic fields beyond the Pauli limit, and hints to a non-conventional nature of the pairing. A key information necessary to unveil its microscopic origin is the geometry of the Fermi surface hosting the Cooper pairs as a function of field-effect doping, which is dictated by the filling of the inequivalent valleys at the K/K' and Q/Q' points of the Brillouin zone. While it is often assumed that Cooper pairs reside only in the two electron pockets at K/K′, experimental and theoretical results suggest that a multi-valley Fermi surface (FS) is instead associated with the SC state, involving the six electron pockets at Q/Q'. Here, I will present a work combining low-temperature electric transport and Raman spectroscopy measurements in ion-gated MoS_2 thin flakes [1] with ab-initio DFT calculations of the bandstructure [2] to show that a fully multi-valley FS is associated with the onset of the SC state, and that a sizeable SC transition temperature does not appear until the Fermi level crosses both spin-orbit split sub-bands in the Q/Q' valleys. This combined approach can be employed to map the dependence of the Fermi surface of gated MoS_2 on field-effect doping and demonstrates that the SC state is associated with the FS connectivity and promoted by multiple Lifshitz transitions due to the simultaneous population of multiple electron pockets. I will also discuss some preliminary results on the possible implications that this peculiar FS geometry may have on the structure of the SC gap probed by tunnelling spectroscopy measurements and the temperature-dependence of the out-of-plane critical magnetic field.

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Superconducting Neutron Detectors: a proof of concept at spallation neutron source

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A neutron detection concept is presented that is based on superconductive niobium (Nb) strips coated by a boron (B) layer. The working principle of the detector relies on the nuclear reaction $^{10}B + n \rightarrow \alpha + ^{7}Li$, with α and Li ions generating a hot-spot on the current-biased Nb strip which in turn induces a superconducting-normal state transition.

The latter is recognized as a voltage signal which is the evidence of the incident neutron. The above described detection principle has been experimentally assessed and verified by irradiating the samples with a pulsed neutron beam at the ISIS spallation neutron source (UK).

It is found that the boron coated superconducting strips, kept at a temperature T = 8 K and current-biased below the critical current I_C, are driven into the normal state upon thermal neutron irradiation. As a result of the transition, voltage pulses in excess of 40 mV are measured while the bias current can be properly modulated to bring the strip back to the superconducting state, thus resetting the detector.

Measurements on the counting rate of the device are presented and the basic physical features of the detector are discussed.

A thermodynamic model is presented for the description of the main properties of the device, together with a COMSOL-based analysis used to benchmark the analytical calculations.

Magnetic modulation of plasmon resonances in Indium Tin Oxide nanocrystals

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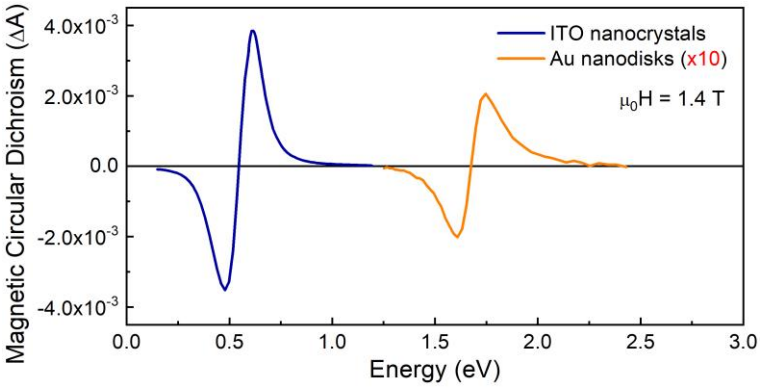
Active plasmonics is an engaging new tool to control light-matter interaction through external stimuli. Among the most appealing prospective applications of this approach are the dynamic control of waveguiding for telecommunications and lock-in detection of frequency-encoded optical signals for enhanced sensing. Tuning or modulating localized plasmon resonance using a static magnetic field -magnetoplasmonics- has been pioneered and proposed for applications in recent years: from simple, non-magnetic noble metal nanostructures [1], to ferromagnetic plasmonic systems [2] and complex dual-component architectures [3], the key concepts of the field have been well understood.

A hard limit to increasing magnetoplasmonic performance is the fact that in general the addition of magnetic materials decreases the figure of merit of plasmon resonance. Overcoming this constraint requires smart design or paradigm shifting choice of materials. Here we show that non-magnetic tin-doped indium oxide (ITO) nanocrystals supporting localized plasmon resonance in the infrared [4] give rise to giant magnetic field modulation, while keeping high quality optical resonances. The figure below shows a 20-fold increase in the magnetic modulation amplitude of ITO nanoparticles over gold nanodisks, as observed by magnetic circular dichroism spectroscopy. In the spectra, plasmon resonances give derivative-like signals with peak to peak amplitude proportional to the field-induced energy shift.



Room temperature magnetic circular dichroism spectra of ITO nanocrystals and gold nanodisks.

This behavior can be traced back to the reduced electron effective mass in ITO compared to most metals, which in turn boosts magnetic modulation (given in first approximation by the cyclotron frequency $\omega_c = eB/2m_e$, where B is the magnetic induction, and e, m_e indicate electron charge and effective mass, respectively [1,5]). We believe that by including the appropriate magnetic ions as co-dopants, ITO nanosystems can be designed into high performance magnetoplasmonic platforms.

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Strategies for critical current enhancement in YBCO films obtained via chemical solution deposition

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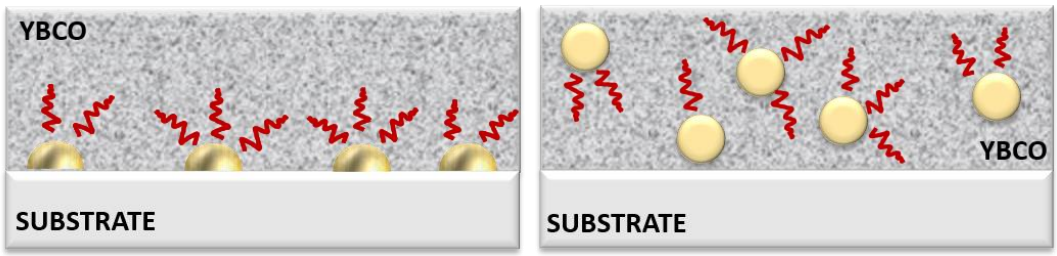
$YBa_2Cu_3O_{7-x}$ (YBCO) films grown by metal organic decomposition (MOD) are promising candidates for the production of high performance HTS tapes [1]. For this reason much effort was spent in developing new techniques for the enhancement of YBCO films performances using a preparation procedure suitable for industrial scale up. In this work, we explore two pinning landscapes that approach this issue in different ways: the preparation of interfacial substrates decorated with oxide nanostructures and the introduction of $BaZrO_3$ nanoparticles. The first method makes use of a procedure known as polymer-assisted-deposition [2] to create a nanostructured surface that will be employed, in a second step, as a substrate for the growth of YBCO via chemical methods. The nanostructures are supposed to produce in the superconducting matrix a specific amount of strain which is generally known to cause an increase in the transport capacity of the samples [3]. The same effect should be caused by the $BaZrO_3$ nanoparticles embedded in the YBCO matrix, in addition to the pinning effect caused by their presence. In this case the $BaZrO_3$ precursors are introduced in the YBCO MOD precursor solution with an in-situ approach. These two methodologies are compared and their effect on YBCO properties is thoroughly analyzed. The produced samples are characterized via a variety of techniques such as atomic force microscopy, scanning electron microscopy and X-Ray diffraction for structural and morphological characterization and magnetic and/or direct current resistivity measurements for the evaluation of transport properties. $J_c(B, T, \theta)$ behaviors are analyzed in terms of improved flux pinning properties and their possible microstructural origins are identified and discussed.



Comparison between surface decoration and the in-situ/ex-situ techniques. The hypothetical strain caused by the presence of the secondary phases is graphically represented by the red doodle.

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

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The origin of (ferro)magnetic ordering in transition metal (TM) doped ZnO is still an open question. For applications, particularly in spintronics, it is fundamental to establish whether it arises from magnetically ordered impurity clusters embedded into the semiconducting matrix or it originates from ordering of magnetic ions diluted into the host lattice.

Our study is focused on the relationship between magnetic properties and free charge density in zinc oxide based field effect transistors. The magnetotransport properties are employed to probe the magnetic status of the system in both pure and cobalt doped zinc oxide transistors.

In our work we have deposited epitaxial cobalt doped ZnO films by pulsed laser ablation. Field effect devices were made using the substrate as dielectric, creating a back gate with silver paste, and patterning by photolithography. Standard XRD, AFM and SEM were performed to control overall quality of the devices. Magnetic and transport properties were measured in a Quantum Design magnetometer SQUID and PPMS respectively.

We find that it is possible to control the magnetic scattering rates by field effect. We believe this is a consequence of the modulation of magnetization and carrier spin polarization by the electric field. Our study strengthen the hypothesis that TM doped ZnO is not a true Diluted Magnetic Semiconductor with ferromagnetic interaction among the TM ions but should rather be considered as an ensemble of superparamagnetic bound polarons that get ferromagnetically ordered above its percolation threshold [1, 2, 3].

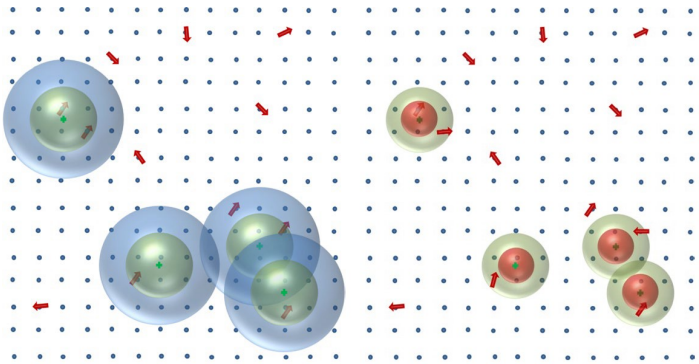

Figure: Schema of bound polaron change with carrier concentration and mutual distance for interaction..

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Investigation of the effective mass enhancement in ZnO/ZnMgO heterostructures through quantum effects

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Shubnikov-de Haas oscillations in the electric charge transport at high magnetic field is one the hallmarks of a two dimensional electron gas (2DEG). The specific features of this behavior can yield wealth of information about the 2DEG physics behind.

Our study is focused on the identification of the relationship between the effective mass and the applied magnetic field in the 2DEG hosted in Mg doped ZnO heterostructures. In our work we have optimized the fabrication of $ZnO/Zn_{1-x}Mg_xO$ epitaxial heterostructures by pulsed laser ablation. High quality heterostructures were obtained, hosting a 2DEG. Magnetotransport measurements were carried out in magnetic fields up to 31T.

We find that quantum effects are visible up to 20K. The quantitative analysis of the magnetotransport curves confirms a dramatic magnetic field dependence of the electron effective mass [1]. Different scenarios are considered, including electron correlation. This result indicates that quantum effects in correlated oxides generate novel mechanisms that need a suitable theoretical framework to be explained.

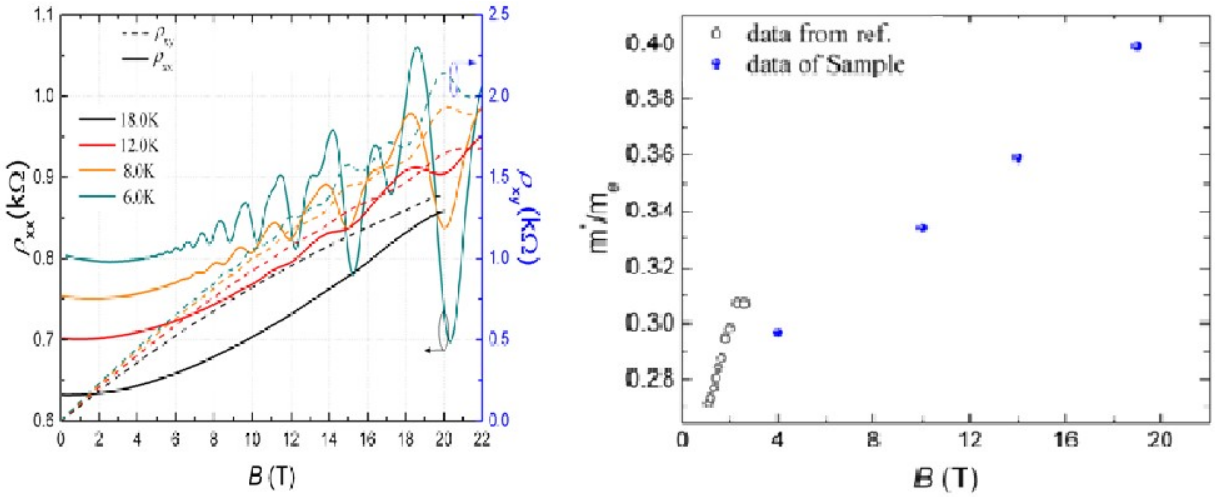

Figure: magnetotransport curves and effective mass vs. magnetic field.

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Flux creep and second magnetization peak effect in type-II superconductors: correlation and universality

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The correlation in type-II superconductors between the creep rate S and the peak effect in J_c, as a function of the field (H), has been investigated at different temperatures by starting from the minimum in S(H) and the onset of the peak effect detected on a $FeSe_{0.5}Te_{0.5}$ sample. In particular, by analysing the entire S(H) curves and comparing our results with other data from the published literature, we find evidence that the flux dynamic mechanisms behind the appearance of the peak effect in $J_c(H)$ are activated at fields well below those where the critical current starts effectively to increase. Moreover, the discovered universal relation between the minimum in the S(H) and the peak effect in $J_c(H)$ shows that both can be attributed to a sequential crossover between a less effective pinning (at low fields) to a more effective pinning (at high fields), regardless of the type-II superconductor taken into consideration.

Microwave studies of the anisotropy in $YBa_2Cu_3O_{7-\delta}$ thin films

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Anisotropy is a fundamental trait of layered superconductors like the copper-oxide $YBa_2Cu_3O_{7-\delta}$ (YBCO). It impacts many material properties ranging from the fundamental ones, like the coherence length, the London penetration depth and the critical fields, to the more technologically oriented quantities like the electrical transport ones, such as the critical current density J_c. The first source of the anistropic behaviour is due to the electron effective mass anisotropy, herein referred to as *intrinsic* anisotropy. On the other hand, electrical transport properties are determined by an interplay between pinning by material defects, hindering vortex motion and thus preventing dissipation, and the underlying intrinsic anisotropy. Material defects add in general directional pinning, so that an effective, *extrinsic* anisotropy comes out. Through time many efforts have been made in tailoring the pinning landscape of YBCO through artificially-added pinning centers (APC), to reduce dissipation and the extrinsic anisotropy. With this goal, it is important to ascertain the effect of pins in determining the extrinsic anisotropy, disentangling it from the intrinsic one.

Measurements in the microwave regime are a valuable tool in this perspective. With high frequency electromagnetic fields, vortices are set in oscillatory motion around their pinning sites, thus experiencing simultaneously both the pinning force, in terms of the so-called pinning constant (Labusch parameter) k_p and a viscous drag, in terms of the vortex viscosity η [1]. Since the latter depends on the quasi-particle mass, it provides direct access to the intrinsic anisotropy. Hence, the measurements of the microwave surface impedance as a function of an applied static magnetic field with different tilting angles with respect to the crystallographic axes, allow to separately determine the intrinsic anisotropy and the anisotropy in the pinning action [2]. We report on surface impedance measurements performed through a dielectric-loaded resonator, operated at 47.7 GHz, on various YBCO samples grown through Chemical Solution Deposition (CSD) [3] and Pulsed Laser Deposition methods [4], giving rise to defects with different geometries and distributions. Measurements are performed in the temperature range between 77 K and the critical temperature T_c, with applied fields up to 1 T. We extract the intrinsic anisotropy γ of the various samples, consistently obtaining values $\gamma = 5.0 \pm 0.5$ [5] irrespectively of the samples and of the pinning centers type, supporting its intrinsic nature. On the other hand, we obtain different pinning anisotropies reflecting the different directional behaviours that we relate to the various geometries.

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Influence of hydrostatic pressure and of Eu/Bi substitution on the magnetic properties of $Eu_2Ir_2O_7$

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The arrangement of magnetic moments at the vertices of a pyrochlore lattice leads to a great variety of electronic ground states for $R_2M_2O_7$ materials. One important finding common to several families of these oxides is that changes in r_I, the ionic radius of the rare-earth ion R^{3+}, gradually tune the local crystalline environment around the transition metal ion M^{4+} and the overall electronic behavior of the compound in turn. For M = Ir, the characteristic temperature T_{MI} for the development of a metal-to-insulator transition is directly controlled by the average value r_I related to a gradual chemical substitution. Moreover, the metal-to-insulator transition in $R_2Ir_2O_7$ is associated with a dramatic change in the magnetic behavior as well.

Here, we report on the magnetic properties of $Eu_2Ir_2O_7$ under pressure, both from dc magnetometry and μ^+SR [1]. The absence of a localized magnetic moment from *f* shells in $Eu_2Ir_2O_7$ is a great advantage in the study of the intrinsic magnetic properties of the Ir sublattice. We deduce a markedly nonmonotonic pressure-dependence of the critical transition temperature to the antiferromagnetic state (T_N) hinting at its departure from T_{MI}. The behavior recently reported for T_N from relativistic LDA+DMFT calculations closely reproduces our data under the assumption that pressure influences the U/W ratio (U and W representing the Coulombic repulsion and electronic bandwidth, respectively). Our μ^+SR data confirm that the Ir^{4+} magnetic moment and/or the local magnetic configuration are only weakly perturbed by pressure in the P < 24 kbar range. Accordingly, our measurements strongly support the preservation of a 4-in/4-out ground state.

We also report on our recent study of the pyrochlore series $(Eu_{1-x}Bi_x)_2Ir_2O_7$ for polycrystalline samples for $0 \leq x \leq 1$ [2]. We show that the lattice undergoes an anomalous contraction for $x \leq 0.05$ but that the magnetic all-in/all-out state remains robust in that limit of chemical dilutions. For small x values, the resistivity approaches a 1/T dependence at low temperatures, suggesting a proximity to the Weyl semimetallic phase, as predicted theoretically. At x = 0.1 a qualitatively new ground state emerges, which is characterized by a metallic behaviour and absence of magnetic ordering at least down to 20 mK. For higher Bi-doping values, the resistivity remains metallic and it evolves gradually from T-like to T^2-like and, eventually, to $T^{3/2}$-like, suggesting the possibility of a variety of novel exotic phases.

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Superconductivity in Mercury

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Despite being the first superconducting element discovered, the fundamental physical properties of Mercury were not deeply investigated in the literature and many fundamental questions still remain unanswered.

The first one is surely related to the origin of the superconducting phase. To the best of our knowledge, although the conventional nature of superconductivity is not questioned, the microscopic origin of the electron-phonon interaction was not properly disclosed. In addition, considering the complex structural phase diagram of Mercury and its peculiar thermodynamical properties, the crystal phase of the superconducting system is still debated. Ultimately, we still do not know how modern theoretical and computational techniques perform on what is considered "the prototype BCS superconductor".

In order to definitively answer these questions, we present first-principles investigation of the structural, electronic, dynamical and superconducting properties of Mercury. We calculate the superconducting critical temperature from first-principles including all the interaction from ab-initio calculations, without any semi-empirical parameters. Our calculations underline the crucial role played by spin-orbit interaction on electronic, dynamical and superconducting properties, and the peculiar effects of repulsive Coulomb interaction in the Cooper pairs.

Isotope effect, the fingerprint of conventional superconductivity, is predicted and compared with available experiments.

All the discrepancies between experimental and theoretical results will be discussed and analyzed in view of both experimental and computational refinements, indicating that Mercury can not be considered a "simple" BCS superconductor.

Nano-XRD mapping of structural modifications induced by high-power density irradiation of Bi-2212 single crystals

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In the framework of the development of X-ray nano-patterning (XNP) technique, we have carried out a combined structural and electrical investigation of changes induced by controlled X-ray irradiation in Bi-2212 whisker-like single crystals. Several Bi-2212 microcrystals, mounted on electrical chips, have been monitored upon successive irradiation sessions employing a synchrotron nanobeam (250×250 nm^2 in size at 14.85 keV and 7.53×10^8 photons s^{-1}). Nano-XRD mapping (200×200 nm^2 in spatial resolution) has revealed that a series of irradiations with a cumulative fluence of the order of 10^{10} Jm^{-2} (corresponding to a cumulative dose of the order 10^{11}Gy) induces the appearance of multiple crystal subdomains (see Fig.1). Moreover, a detailed analysis of the map of the position of the diffraction peaks as a function of the coordinates of the crystals allowed the localization of these subdomains, showing that crystals tend to physically bend around the irradiated points. From the electrical point of view, the same irradiations induce a superconducting critical temperature T_c decrease from 71.5 K to 40 K and a corresponding exponential increase of the normal state resistivity with increasing the cumulative dose. All of these data suggest that local softening of the chemical bond takes place during the irradiation, leading to an increased crystal mosaicity and to a local atomic rearrangement that also includes a partial release of interstitial oxygen atoms. Deepening the knowledge of the structural and chemical variations induced by heavy X-ray irradiation is mandatory to develop the ability to fine-tune the properties of materials by means of XNP, and consequently is a crucial point in order to exploit such technique for practical purposes.

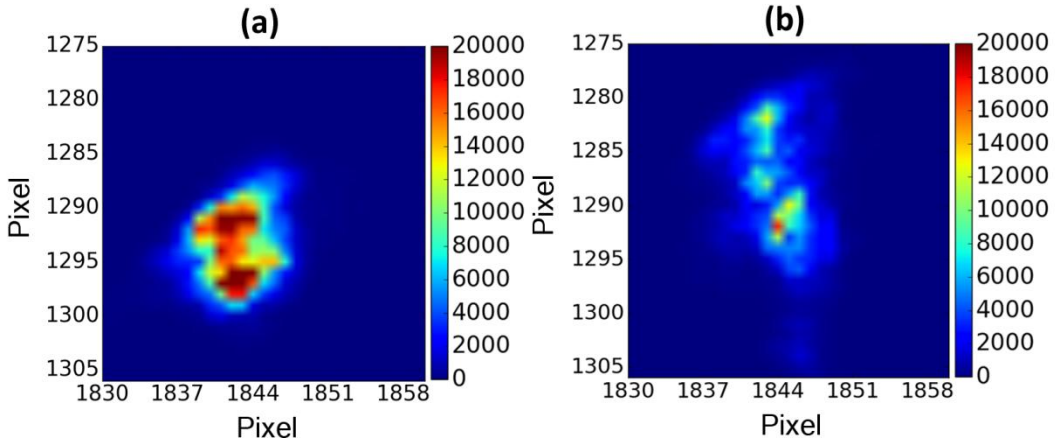

Fig. 1: Maximum projection pattern of the peak of interest: (a) in pristine Bi-2212, and (b)after a cumulative fluence CF = 3.19 $10^{10}$$Jm^{-2}$(cumulative dose CD=1.80 10^{11}Gy), corresponding to a total irradiation time Δt = 1110s. Both patterns have been collected exactly at the same position of the same crystal: the original single peak splits into 3 sub-peaks corresponding to 3 sub-domains.

Thermal and mechanical properties in single-crystal VO_2 micro-structures

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Vanadium dioxide (VO_2) is a strongly correlated electron material that show a metal-insulator transition combined with a structural phase transition. This phenomenon takes place slightly above room temperature, with orders of magnitude change in conductivity and showing a significant deformation of the primitive cell, from a monocline to a rutile structure.

This phase transition occurs in ultrafast time scale and in a sharp temperature window, with hysteresis between heating and cooling branches. These characteristics make VO_2 a promising active material for the fabrication of micro-actuators and micro-switches.

Due to the anisotropy in the structural transition, VO_2 tends to show different behaviors depending on the crystallographic directions. Upon heating, a characteristic shrink of the specimens on the direction parallel to the rutile c-axis and an expansion on the perpendicular direction is observed. Our study investigates these anisotropies in thermal and mechanical properties of the material, comparing the differences between mono-crystalline microstructures with different crystallographic orientations.

Over-critical current resistivity characterization of ReBCO commercial coated conductors: improved E-J characteristic at high electric fields

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A good knowledge of the resistivity $\rho(J,T)$ of commercial high-temperature superconducting (HTS) tapes for currents well above the critical current is required in order to adequately model superconducting devices operating in the overcritical current regime ($I > I_c$). In these cases, widely used models such as the critical state model or the power-law model are not reliable. However, it is difficult to obtain the resistivity of HTS tapes at high electric fields from experiments, since Joule heating can destroy the sample if the applied current is not limited in time. In addition, complex current sharing phenomena make it difficult to obtain the intrinsic behavior of the superconductor.

In our previous works [1,2], we showed that the combination of fast-pulsed current measurements and finite element analysis allows extracting accurate resistivity data from pulsed current measurements, in order to retrieve the correct current and temperature dependence of ReBCO resistivity. We also showed that this resistivity is different from a power-law model. In addition, we showed by simulation that using the resistivity curve obtained with our method instead of the widely used power-law model affects the electro-thermal performance practical devices such as superconducting fault current limiters.

In this work, we present the resistivity curves in the over-critical current regime of state-of-art HTS coated conductors from various manufacturers. The presented data show that all measured samples present a remarkable deviation from the power-law resistivity model. In particular, we show that there is a significant decrease of the slope of the $E - J$ curves in the over-critical current regime ($I > I_c$). We show that it is possible to fit the resistivity curves with a piecewise function as follows: below a certain current threshold, a power-law model is used, while above this threshold, a new non-linear relationship $\rho_{OC}(J,T)$ in the (J,T) space can be used to complete the fit. Finally, we also present simulations carried out in COMSOL in a relevant case scenario involving a superconducting fault current limiter.

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Electric field exfoliation and high-T_c superconductivity in field-effect hole-doped hydrogenated diamond (111)

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In 2004 it was shown [1] that diamond, if doped with boron, can achieve first an insulator to metal phase transition and then, by tuning the dopant concentration, a superconductive phase transition with a critical temperature of 4 K. Even if theoretically [2] it is possible to raise the superconductive transition temperature, there is a limit to the amount of boron which can be chemically incorporated in the closely packed crystal structure of diamond.

In a recent work [3] we investigated if it was possible to induce a superconductive phase transition in hole doped hydrogenated diamond surfaces oriented along the (111) crystallographic direction in the field effect transistor (FET) geometry.We take into account the presence of the electric field in the FET configuration in a self consistent way both for electronic and vibrational calculations as well as electron-phonon interactions with the proper periodic boundary conditions as recently implemented [4] in the Quantum ESPRESSO [5] package.

We first show that the electric field performs an "exfoliation" of electronic states as a function of doping, meaning that they pass from being bulk-like to surface-like. This correspond to induced charges being progressively confined in the first few layers of our sample.

From vibrational computations we show the presence of a Kohn anomaly at the center of the Brillouin zone, which becomes more and more pronounced as a function of doping. Moreover, we perform electron-phonon computation both at $\mathbf{q}=\mathbf{\Gamma}$ and, more accurately, by interpolating the electron-phonon matrix elements using Wannier functions [6]. We first get an estimate of the supeconducting critical temperature using the Allen-Dynes formula [7] and then we get a more accurate result solving linearized isotropic single-band Migdal-Eliashberg [8] equations.

We find high-T_c superconductivity at a hole doping level of 6×10^{14} cm^{-2} where T_c~29-36 K (depending on the value of the Coulomb pseudopotential).

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Synthesis and study of Tl-1223 Superconducting Thin Films for the Future Circular Collider (FCC-hh) Beam Screen

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A vast area of research has been initiated for the future circular collider, which is concentrated at achieving a 100 TeV center-of-mass energy through the collision of particles (steered by superconducting magnets: 16 T) in a 100 km long tunnel [1]. In the future accelerator, circulating high-energy proton beams will emit 28 W/m/beam of synchrotron radiation and which will perturb the beam bunches. To avoid any kind of instability, a beam screen, operating at 50 K is required to absorb the radiations and shield the magnets. In LHC, a copper coating is being used to absorb the radiation, but theoretical calculations show that the surface resistance of copper at 50 K might not be sufficiently low to guarantee a safe operation for the FCC-hh beams.

The choice of a high-temperature superconductor is suggested as an alternative to copper to minimize the surface impedance of the beam screen. In the family of high-temperature superconductors, thallium-based superconductors appear to have some advantages worth to be explored as a candidate for the beam screen coating [2].

In this research, we synthesize thallium based thin films and bulk samples by using different techniques. For the deposition of highly reactive thin-film precursors, we use the electrodeposition technique. We will also show considerable progress made in the synthesis and characterisation of thin films.

Furthermore, we will report that the thallium-based superconductors (bulk samples and thin films) are not only vacuum compatible, but also the secondary electron yield (SEY) falls off to a significantly low level after coating the Tl-1223 superconducting samples with the amorphous carbon.

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Quasi-2D-oxides spintronics and quantum electronics

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The dramatic developments in information technology is driving a steady dimensional scaling of components to achieve larger capacity data storage, faster data processing and lower energy consumption. There is now a consolidated motivation to go beyond silicon-based CMOS technology which is coming to the end of its technological roadmap. Although it is likely that conventional Si-based field effect transistors will remain at the basis of the consumer technology for many years to come, **spintronics** and **quantum electronics** are emerging as candidates for future high performance computing and information processing platforms. Recent developments in these fields have shown that the exploitation of **the spin- and orbital momentum locking through Rashba-type Spin Orbit (SO) coupling in unconventional materials is an innovative and attractive solution in both spintronic and quantum electronics[1].** Instrumental to the application of these advanced ideas into a scalable technology, is the design of a single-material platform which shows simultaneously magnetism, superconductivity, gate-voltage and strain switchable magnetism, and large and tunable Rashba SO coupling. Two dimensional (2D) electronic systems, like 2D-electron gas (**2DEG**) and topological insulators, are being considered as promising candidates for the realization of Spin-Orbitronic devices and "fault tolerant" qubits, where the quantum state of the spin of the electrons is controlled by a fine manipulation of the Rashba SO coupling.

In this contribution we will make on overview of the properties of oxide **2DEGs** formed **at the interface between transition metal oxides (TMO)**, like $LaAlO_3$ and $SrTiO_3$ (LAO/STO), **as promising candidates for the realization of a new class of spin-orbitronic devices. We will show that oxide-2DEGs**, beside exhibiting relatively **high-mobility[2]** (in excess of 100000 $cm^2 V^{-1} s^{-1}$) **strong Rashba spin-orbit coupling [3] and low temperature superconductivity (SC) [4,5]** , **can be engineered to induce other functionalities, like interfacial 2D-magnetism[6-9]**. Moreover, **oxide 2DEGs show a very large spin to charge conversion efficiency[10]**, larger than the record values of topological insulators like α-Sn, **and spin-diffusion lengths in the range of hundreds on nanometers even at room temperature [11-12].** All these properties are widely tunable by electric field effect and by strain, due to the multi-orbital nature of the electronic structure, dominated by d-orbitals derived bands.

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Self-formed, conducting $LaAlO_3/SrTiO_3$ micro-membranes

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The discovery of 2D conductivity at the $LaAlO_3/SrTiO_3$ (LAO/STO) interface has been linking for over a decade two of the major current research fields in Materials Science: correlated transition-metal-oxide systems and low-dimensional systems. A full merging of these two fields requires nevertheless the realization of LAO/STO heterostructures in the form of freestanding membranes. Here we show a completely new method for obtaining oxide hetero-membranes with micrometre lateral dimensions. Unlike traditional thin-film-based techniques developed for semiconductors and recently extended to oxides, the concept we demonstrate does not rely on any sacrificial layer and is based instead on pure strain engineering. By a proper tuning of the pulsed laser deposition (PLD) parameters, we are able to impose a growth regime in which nucleation of dislocations is almost suppressed. By preserving the strained state of LAO and STO well above the critical thickness, we induce a devastating strain relaxation process, that fragments the surface in regularly-shaped freestanding epitaxial LAO/STO micro-heterostructures (μHSs) showing metallic conductivity down to cryogenic temperatures.We analyze the breaking mechanism and characterize the individual μHSs in terms of curvature, microstructure, strain, strain gradient and transport.

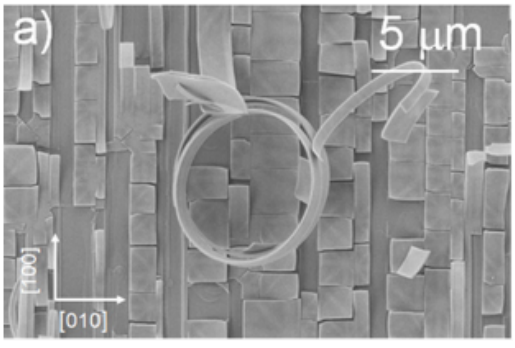

Figure 1: SEM picture showing membranes with typical lateral dimensions of 2-3 μm and, more rarely, tapes with lengths up to several tens of microns, rolled up in helices.

Structural and electrochemical and characterization of $La_{0.4}Sr_{0.6}Co_{0.2}Fe_{0.8}O_{3-\delta}$ electrospun electrode for solid oxide cell applications

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The term solid oxide cells (SOCs) includes both solid oxide fuel cells (SOFCs) and solid oxide electrolysis cells (SOECs). In fuel cell mode, SOFCs directly convert a fuel's chemical energy to electrical energy, through an electrochemical reaction. An SOEC is an SOFC running in 'reverse' mode: electrical current, normally the surplus electricity generated by, e.g., wind turbines, is supplied to the device, allowing the splitting of water molecules into hydrogen and oxygen.

The core of an SOC is the electrolyte, a solid oxide material featuring oxygen ion conductivity. The electrolyte is coupled to two electrodes, which are also based on solid oxide materials, featuring simultaneous electron and oxygen ion conductivity. Compared to other types of electrochemical cells, SOCs present the unique characteristic of having all-solid-state components, and this feature makes it possible to overcome many of the problems associated with liquid electrolytes, such as corrosion, flooding and maintenance of stable electrode-electrolyte coupling. On the other hand, the traditional electrolyte is the same material used in 1899 in the Nernst glower lamp: $(ZrO_2)_{0.92}(Y_2O_3)_{0.08}$ (YSZ), which exhibits satisfactory ionic conductivity at 850-900°C. This high operating temperature results in materials limitations and operating complexity for the SOC. Alternative electrolyte materials are currently under study, such as $Ce_{0.9}Gd_{0.1}O_{1.95}$ (CGO), presenting satisfactory ionic conductivity at lower operating temperature. In parallel, new materials and architectures are being investigated for the electrodes, in particular the air electrode, which causes the highest internal loss. Regarding new materials, mixed ionic-electronic conducting (MIEC) perovskites and fluorite structures are currently the most promising candidates. Among them, $La_{0.4}Sr_{0.6}Co_{0.2}Fe_{0.8}O_{3-\delta}$ **(**LSCF) has demonstrated to be particular promising due to its high conductivity, high electro-catalytic activity and good chemical compatibility with CGO. Regarding new architectures, electrode scaffolds formed by a number of one-dimensional nanostructures (fibers) are intensively investigated [1].

In this work [2], we present the results of our research focused on SOC air electrodes, based on LSCF fibers deposited onto CGO electrolytes. We propose electrospinning as the manufacturing technique, since it produces continuous fibers with diameters down to a few nanometres, providing a highly favourable microstructure in terms of continuous porosity and relatively abundant reaction sites. Structural characterization of the LSCF nanofibers is discussed, carried out through X-ray diffraction and Raman spectroscopy. Electrochemical characterization is discussed as well, carried out through electrochemical impedance spectroscopy (EIS) in the temperature range 600-950°C and with oxygen partial pressure varying in the range 0.05-0.2 atm.

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Physical and structural properties of electron-doped 5d[1] double perovskites

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In 5d systems spin-orbit coupling (SOC) is of similar magnitude to crystal field and electron correlation effects, making the prediction of properties more complex than for compounds containing more well-known 3*d* transition metals. They belong to the novel class of *quantum materials*, the physical properties of which are greatly influenced by the quantum mechanical nature of interactions between constituent electrons.

Here we present an extensive experimental and theoretical study on the effect of chemical electron doping on the electronic and structural properties of the osmium-based $Ba_2Na_{1-x}Ca_xOsO_6$ double perovskite via the substitution of monovalent Na with divalent Ca cations in the whole range $0<x<1$.

Muon spin spectroscopy and magnetization measurements indicate that the magnetic ground state changes from FM-canted for x=0 to AFM for x=1 with a monotonic increase of the magnetic transition temperature from 5 to 40 K [1,2]. We study the evolution of the local magnetic properties as a function of Na/Ca substitution by using ^{23}Na nuclear magnetic resonance. The local atomic and electronic structure is investigated by using x-ray absorption spectroscopy.

These experimental results are compared to the local electronic structure derived from *ab-initio* simulations in order to understand the role of the electronic doping in the evolution of the physical and structural properties of this double perovskite material [2].

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Improvement of J_c and further enhancement of B_{c2} in Ta-doped Nb_3Sn with internally oxidized ZrO_2 particles

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The development of high-field accelerator magnets capable of providing 16 T dipolar fields is an indispensable technological breakthrough needed for the 100 TeV energy-frontier targeted by the Future Circular Collider (FCC). To reach a field level that is almost twice that of the magnets installed in the Large Hadron Collider (LHC), the dipole magnets for the FCC will need to rely on niobium-tin (Nb_3Sn) superconductors. This translates into a requirement of a minimum critical current density of more than 1'500 A/mm^2 at 16 T and 4.2 K, which is substantially beyond state-of-the-art for industrial Nb_3Sn wires. Reaching this target requires work on novel methods: the inhibition of grain growth in the presence of ZrO_2 nanoparticles and the consequent introduction of additional pinning centers appear to be the most promising method for pushing the critical current densities to the desired levels.

In this work, we investigated the effect of ZrO_2 nanoparticles formed by the internal oxidation of Zr on the superconducting properties and microstructure of Nb_3Sn and Ta-doped Nb_3Sn. Small diameter (0.22 mm) mono-core wires consisting of a Nb-Zr or Nb-Ta-Zr alloy tube in contact with a metal oxide (SnO_2 or CuO) and successive layers of Cu and Sn were reacted at 650 °C for 200 h. The internal oxidation of Zr leads to a finer grain structure than in Nb_3Sn based on standard Nb-Ta alloy, with the lowest average grain sizes being close to 50 nm, i.e. two to three times smaller compared to the optimized industrial conductors. Interestingly, critical field measurements performed at the 35 T facility of EMFL-LNCMI Grenoble showed that the combined presence of Ta and Zr further increases B_{c2} of Nb_3Sn to higher values than obtained with the standard Ta-doping, achieving a record-high value of 29.2 T at 4.2 K. The implications of these results towards the development of practical multifilamentary Nb_3Sn wires reaching the FCC specification will also be discussed.

Structure and superconductivity in the binary $Re_{1-x}Mo_x$ alloys

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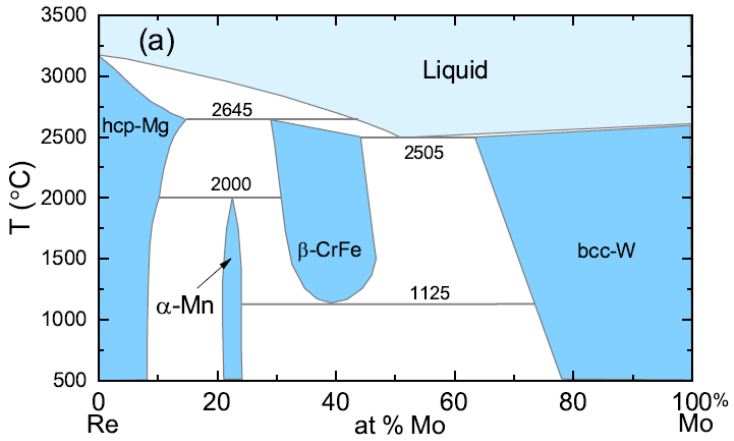
In noncentrosymmetric superconductors (NCSCs), the relaxed space-symmetry requirements lead to an anti-symmetric spin-orbit coupling (SOC), possibly inducing a mixture of spin-singlet and spin-triplet pairing. In addition, some NCSCs break also the time-reversal symmetry (TRS). Although, in principle, time-reversal and space-inversion symmetries are independent, their unusually frequent occurrence in many Re-based NCSC compounds remains puzzling.

To trace the origin of time-reversal symmetry breaking in Re-based superconductors, we performed an extensive study of numerous cases [1]. Among these, the $Re_{1-x}Mo_x$ alloys [2,3], which are all superconductors, yet with either centro- or non-centrosymmetric structure, represent one of the best systems for studying the *interplay of space-inversion, gauge-, and time-reversal symmetries*. By performing comparative muon-spin relaxation/rotation (μSR) measurements, we address the key question of TRS breaking in Re*T* systems. The observation of a gradual increase of ZF-μSR relaxation rate below T_c, yet its independence of crystal-structure symmetry, suggests the rhenium presence as a key factor for the appearance and the extent of TRS breaking in Re*T* superconductors.



The binary phase diagram of $Re_{1-x}Mo_x$ alloys comprises both centro- and noncentrosymmetric superconductors with different structures. Its systematic study gives powerful clues on the role of Re in time-reversal symmetry breaking.

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YBCO coated conductors and thin films for high frequency applications in dc magnetic fields.

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High frequency applications for high-critical temperature (T_c) superconductors like $YBa_2Cu_3O_{7-\delta}$ (YBCO) have been for a long time essentially limited to the superconducting electronics field. As a consequence, no particular demands have been placed on their rf performances in intense magnetic fields. Recently this situation is changing, due to a revamped interest originating in some frontiers of the science. In the search for galactic axions [1], resonating cavities in medium-high static magnetic fields (1-2 T) are deemed as necessary to detect those elusive particles. Since high enough quality factors cannot be obtained through normal metals, superconductors are the unavoidable choice. Another application scenario is given by high energy hadron colliders presently under study: for example, the so-called future circular collider will require a beam shield with low enough dissipation in the GHz range at cryogenic temperatures within magnetic fields as high as 16 T [2].

The requirement for low losses conflicts with the short-range oscillatory vortex motion [3]. Vortex dynamics is governed by a main characteristics frequency, the (de)pinning frequency ν_p, which separates low-frequency, small dissipation regimes from high frequency, large dissipation ones. A measure of ν_p represents an essential step for the evaluation of a superconductor performance in magnetic fields at high frequencies. In thin films the evaluation of ν_p is relatively straightforward when one measures both the real and imaginary part of the surface impedance Z_s [3], but in coated conductors the complex, multilayered (YBCO film / buffer layers / metal substrate) structure [4] makes the task rather intricate [5].

In this work we report on surface impedance measurements performed on various YBCO coated-conductors in the 60-T_c temperature with applied fields up to 1 T. We show how to reliably extract their main parameters and we report on values for ν_p that are promising towards high-frequency, high-fields applications. We finally present measurements in thin YBCO films on single crystal substrates up to 12 T, to set at least an order-of-magnitude evaluation of the losses to compare to the needs for very-high field applications.

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Impact of Annealing on Titanium Thin Films T_C and Crystalline Structure

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Transition-edge sensors [1](TES) are superconducting devices used for detecting particles and electromagnetic radiation, ranging from γ-ray, X-ray, optical and far-infrared to mm wavelengths. A TES is operated by voltage biasing it in the narrow transition between its normal and superconducting state. A fundamental parameter to set in order to use the TES for the desired application is the critical temperature of the film, in our case titanium. In literature, electron-gun-deposited titanium films present a critical temperature over 500 mK when the substrate temperature is controlled and kept below some threshold during deposition. Titanium TES sensors used by many experiments report discordant critical temperatures (500 mK [2], 450 mK [3], 390 mK[4], 300 mK [5]), and very little information is available in literature regarding how such different critical temperatures are achieved. For instance, in Posada et al. [6] it is stated that the T_C of Ti/Au bilayer films is affected by deposition base pressure and processing conditions after patterning and they also observed that heating the samples result in a decrease in T_C. In the past we tried to tune the critical temperature of titanium thin films by post annealing the sample in argon atmosphere [7]: we obtained a span in T_C from 540 mK down to 360 mK. We used the same process of annealing electron-gun-deposited titanium films in a controlled atmosphere. In this work time we will study indeep the dependence of the T_C on the annealing temperature time profile and how this affects the crystalline structure of the film.

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Mesostructured silica/spinel iron Oxides nanoarchitectures: investigation of the magnetic properties

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Abstract: Magnetic mesoporous silica (MNPs/MSN) nanocomposites open new opportunities to generate multifunctional platforms with applications in different technological areas and mostly in biomedical field[2, 3]. γ-Fe_2O_3 nanoparticles have been synthesized under air (FeO_a) and under nitrogen (FeO_N) using coprecipitation [1]. Maghemite was produced at 60C° with an average size estimated by Scherrer's formula around 7 nm. The saturation magnetization (M_s.) of the nanosized γ-Fe_2O_3 at 300K was almost 76 Am^2 kg^{-1}, slightly lower with respect to the bulk value (91 Am^2 kg^{-1}). Additionally, a significant variation in interparticle interactions was also observed according Henkel Plot (HP) analyses [4] for the sample prepared under nitrogen. It was found that δm=1.6 for sample produced in the air and around 0.68 for sample prepared under controlled atmosphere. FeO_N nanoparticles has been embedded in in mesoporous silica matrix prepared by a green synthesis method. Transmission Electron Microscopy (TEM) shows nanoparticles inside mesoporous ordered silica matrix. Field dependence of magnetization recorded at 5 K shows a saturation magnetization (Ms) close to bulk value for both bared particles and FeO_a/MSN nanocomposite, indicating that the presence of silica doesn't affect magnetic features of nanoparticles. Particular attention has been devoted to the effect of silica coating on interactions among magnetic particles. This issue has been investigated by meaning of field dependence of remanent magnetization (i.e. δM plots) at low temperature: a decrease of interaction is shown in MNPs/MSN sample, indicating that mesostructured silica induces a better dispersion of nanoparticles.

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Magneto-optical Kerr switching properties and spin configurations of magnetic 2D heterostructures

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We explore the magneto-optical Kerr effect (MOKE) for different spin configurations of $(CrI_3)_2$ bilayer and $(CrBr_3/CrI_3)$ mixed bilayer, using symmetry arguments and first-principles electronic structure calculations. Starting from CrX_3 (X=I,Br) monolayers, we considered collinear ferromagnetic (FM) and layered antiferromagnetic (AFM) states for $(CrI_3)_2$ and $(CrBr_3/CrI_3)$ bilayers. The AFM $(CrI_3)_2$ bilayer does not show MOKE, consistent with the presence of a symmetry operator combining inversion (I) and time reversal (T) symmetries. The FM state preserves I symmetry but breaks the T symmetry, thus allowing a non-zero Kerr angle, which is reversible by switching the FM spins. The $(CrBr_3/CrI_3)$ bilayer breaks both the I and T symmetries and thus exhibits MOKE both in the FM and, remarkably, in AFM states. In both FM and AFM configurations, the Kerr angle switches by reversing the spins in both layers. Our study demonstrates that MOKE spectra can help characterize different magnetic configurations in these emerging two-dimensional materials due to a different stacking of the monolayers, even in the AFM case. Furthermore, we propose $(CrBr_3/CrI_3)$ bilayer as a promising candidate for AFM spintronics, since the two time-reversed AFM states are associated with opposite Kerr rotation, *i.e.* they could be used as memory elements.

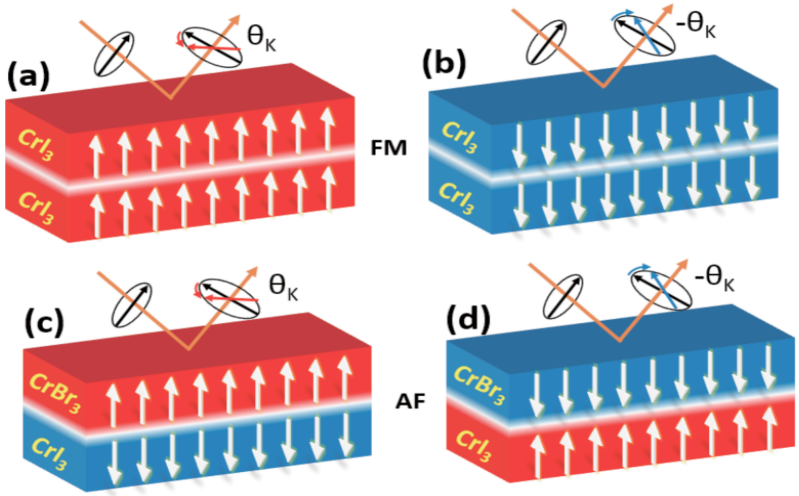

Figure caption: Schematic diagram of MOKE and its switching upon reversal of the magnetization in (a) up-up (u-u), (b) down-down (d-d) FM states of $(CrI_3)_2$ bilayer and (c) up-down (u-d), (d) down-up (d-u) AF states of $(CrBr_3/CrI_3)$ bilayer.

Optical properties of Transparent Conductive Oxides (TCOs)-based Systems

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TCOs are a unique class of materials characterized by high visible-light optical transparency combined with low electrical resistivity. Their properties can be further tuned by means of suitable dopants in wide-band gap semiconductors matrix over a large range of concentration.

In this work, the optical properties of aluminum-doped ZnO (AZO) and tantalum-doped TiO_2 (TaTO) films obtained by magnetron sputtering [1] and Pulsed Laser Deposition (PLD) [2], respectively, were investigated. We studied the consequences of the thickness and the doping level of AZO and TaTO on their optical properties, in particular concerning the carrier density, by means of Spectroscopic Ellipsometry (SE) (200-1700 nm spectral range). In addition, the electrical-bias-dependent optical response of thin AZO films was investigated within a parallel-plane capacitor configuration. We sought to control their optical and electric performances upon gating, monitoring the effect of charge injection/depletion in the AZO layer by means of in-operando SE vs applied gate voltage. SE data are backed by extensive electrical characterization of the devices.

This new class of TCO-based materials is promising for optoelectronic applications and telecommunications as low-loss plasmonic materials.

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Fe(Se,Te) Coated conductors on simple RABiTS templates

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Among all the Iron-based Superconductor (IBS) families, the iron chalcogenide $FeSe_xTe_{1-x}$, also called 11 phase, is the simplest, and it is quite attractive because of its relatively ease of fabrication and the absence of toxic arsenic. 11 thin films have been successfully grown on single crystalline substrates and on technical metallic templates with complex architectures developed and already commercially available for the deposition of $YBa_2Cu_3O_{7-x}$. In particular, 11 thin films have been grown either on Ion Beam Assisted Deposition (IBAD) [1] and Rolling-Assisted Biaxially Textured Substrate (RABiTS) templates, showing values of critical current densities J_c as high as 10^5 A/cm^2 up to 30 T [2]. In IBS the exponential decay of J_c across misoriented grain boundaries seems to be less severe than for YBCO. Moreover, Fe(Se,Te) thin films are deposited without the presence of oxygen in a temperature range between 230°C and 550°C [3], much below the deposition temperature required for YBCO. These features have a strong impact on the development of a suitable CC technology relaxing significantly the film texture constraint and the role of the buffer layer architecture. Hence, it is possible to think about the development of much simpler metallic templates, reducing essentially the complexity and the manufacturing cost of IBS-CC, which may make them more attractive on the cost-performance basis.

In this work we show the development of 11 CCs with simpler and cost-effective RABiTS. The simplicity of the substrates could derive from both from the employment of commercial metallic alloys and also from the modification of the architecture of buffer layer. Buffer layers can be deposited with simple and scalable methods, can be reduced in number or even completely removed. These possibilities singularly or combined together contribute to the simplification and consequently to the cost reduction of 11 CCs. The different CC architecture studied will be presented, starting from the development of simpler metallic substrates made of a commercial alloy and without any buffer layer [4] to more complicated substrates which comprises NiW5% metallic tapes and different nitrides and oxides buffer layers [5], studying the properties of the Fe(Se,Te) thin films deposited on these substrates.

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0-π transition and odd-frequency pairing in Rashba superconducting nanowire junction

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In this poster presentation, we report the 0-π transition in Rashba superconducting nanowire junction. An s-wave superconductor with Rashba spin-orbit coupling and Zeeman field, called the Rashba nanowire, is equivalent to a p_x-wave superconductor, effectively. The Rashba nanowire is attracting attention due to the appearance of Majorana fermion in the topological phase.

Although the 0-π transition in a Rashba nanowire Josephson junction is investigated[1], the relation between the transition and the symmetries of Cooper pairs is not clear. In a 2-dimensional superconductor/ferromagnet insulator/superconductor junction, Asano *et al.* show that the symmetries of Cooper pairs are related to the 0-π transition[2, 3].

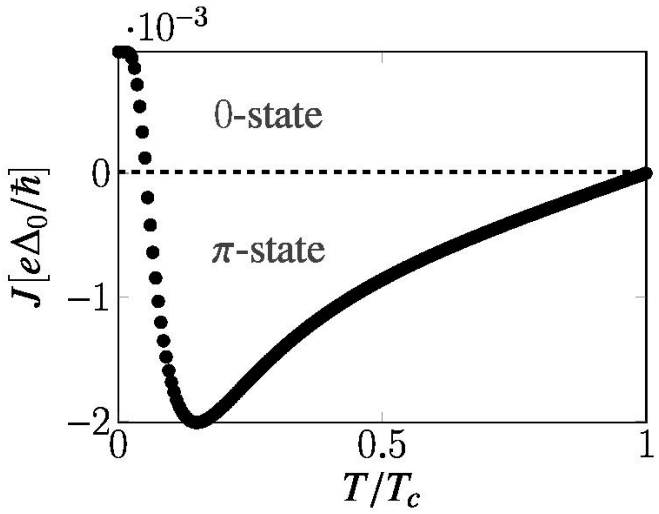

Figure1: Temperature dependence of Josephson current amplitude. The 0-π transition occurs due to the temperature change. Positive (Negative) amplitude means the 0- (π-) state.

In the Rashba nanowire junction, we demonstrate the temperature dependence of the Josephson current. With the increase of the temperature, the 0-junction transitions the π-junction in the non-topological phase as shown in Figure 1. Additionally, the even-frequency cooper pairs are dominant in the 0-junction, whereas the even-frequency Cooper pairs are mixed with the odd-frequency Cooper pairs in the π-junction.

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THz Nonlinear Response of the Weyl Semimetal WTe_2

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The emergent functions of topological materials revolve around the formation of band structures near the Fermi level, resembling the linear Dirac and Weyl fermionic dispersions introduced a century ago in the high-energy physics context. For many years Graphene and 2D materials have been the prototype material to host these topological structures. However, with the discovery of topological insulators (TI) [1] and the three-dimensional Weyl nodes in the bulk of Weyl semimetals like TaAs [2], the research for the anomalous responses of these relativistic electrons has shifted toward the topological 3D materials domain. Weyl materials like TaAs, TaP, NaP, WTe_2 or $MoTe_2$ [3][4] are now the best candidates to highlight topological emergent responses through THz-TDS measurements [5][6]. Following the theoretical predictions, room temperature robustness and the plethora of nonlinear responses predicted rise these topological systems to the status of next functional materials to overcome the THz gap [7][8][9]. In particular, the study of the nonlinear effects in the THz spectral range has already been highlighted for TI [10][11] and graphene [12]. However, in Weyl semimetals, the Berry curvature monopole associated to the bulk linear structures suggests the existence of tuneable responses that could permit a development of the present techniques for the manipulation of THz light. In this talk, we discuss the electromagnetic response of the WTe_2 Weyl type-II semimetal, showing a robust nonlinear behaviour when excited through high-intensity THz radiation, resembling the predicted response of the topological bulk Weyl nodes under strong electric fields. Experiments performed at the Free Electron Laser ISIR at the Osaka University, TeraFERMI@Elettra and Rome La Sapienza will be presented [13].

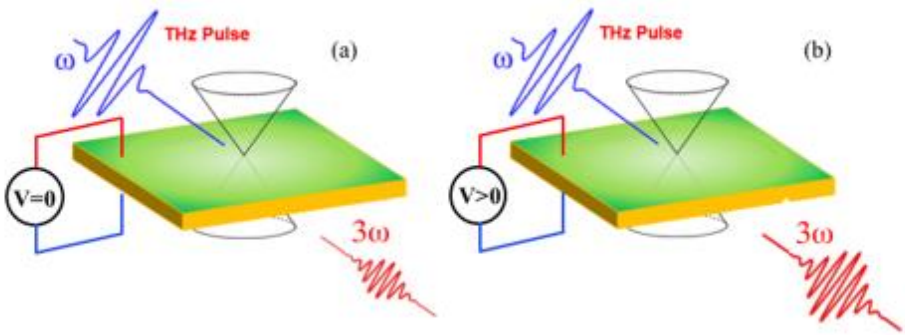

Figure caption: Multiple harmonic generation appears as a tunable nonlinear response in Weyl semimetals, associated to the interband transitions between the cones connected by the bulk Weyl nodes. A chemical potential control is expected to enhance positively or negatively this nonlinear behavior, suggesting practical applications to the THz radiation modulation.

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Analysis of the London penetration depth in $CaK(Fe,Ni)_4As_4$

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We report on the combined experimental and theoretical analysis of superconductivity in $CaK(Fe_{1-x}Ni_x)_4As_4$ (CaK1144) for x=0, 0.017, and 0.034 [1].

The CaK1144 family of iron-based superconductors (IBS) is particularly suitable for the study of fundamental superconducting properties due to the stoichiometric composition of the "optimal" compound $CaKFe_4As_4$, exhibiting clean-limit behavior and having a fairly high critical temperature $T_c \approx 35$ K. This allows working with a system where unwanted effects caused by a large amount of chemically substituted ions are minimal. Moreover, a rich and intriguing T-x phase diagram emerges upon electron doping of the parent compound, for example, by a partial substitution of Ni for Fe [2].

The London penetration depth λ_L was measured with three different techniques, allowing their validation and a complete characterization of this quantity. Its temperature dependence $\Delta\lambda_L(T)$ was measured by using a tunnel-diode resonator (TDR) [3] and the results agreed with the microwave coplanar resonator (MWR) [4] with small differences accounted for by considering a three orders of magnitude higher frequency of MWR. The absolute value of $\lambda_L(T<<T_c) \approx \lambda_L(0)$ was measured by using MWR yielding $\lambda_L(5K)\approx 170\pm 20$nm, and with the Nitrogen-Vacancy centers in diamond optical magnetometry technique [5] that gave $\lambda_L(5K)\approx 196\pm 12$nm, in agreement with MWR.

From the low temperature experimental data it was possible to exclude the presence of line nodes in the superconducting gaps and to verify the increase of pair breaking scattering with Ni content. Unfortunately, these pair breaking scattering centers hinder the possibility to observe the presence of the proposed [2] quantum critical point (QCP) in the phase diagram of Ni doped CaK1144 by investigating the low temperature value of the penetration depth as a function of doping [6].

The experimental results were analyzed within an effective two band $s_\pm$ Eliashberg model [7,8], showing that the whole experimental dataset can be fitted satisfactorily with gap values in agreement with literature, and therefore that superconductivity of CaK1144 is well described by the nodeless $s_\pm$ order parameter.

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Bi-2212 wire development for Canted Cosine Theta solenoids

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The first step towards high critical currents in Bi-2212 wires was the comprehension that the supercurrent is blocked over long lengths by filament-diameter bubbles growing from the porosity of the powders during the melting stage [1, 2]. The Over Pressure (OP) process led to the realization of dense Bi-2212 wires with a J_E performances far beyond the minimum application requirements, set at 500 A mm^{-2} at the operative magnetic field. While several efforts are under way to demonstrate that is possible to apply such a process to real coils, researchers at CNR-SPIN are developing a quite standard and scalable process [3] based on mechanical deformation (the GDG process) to realise dense Bi-2212 wire with performances good enough for the applications. Initial evidences of the effectiveness of the process has already been reported, but now we are able to realize wires with a J_E satisfying the above-mentioned application requirements.

The achievement of this goal may pave the way to a more feasible development and realization of coils made by Bi-2212 wires. In collaboration with the Genoa and Milan sections of National Institute of Nuclear Physics (INFN), University of Bologna (UNIBO) and CNR-SPIN a project started with the general aim of developing the key technologies to be involved in the design and construction of a superconducting Canted Cosine Theta (CCT) solenoid using high temperature superconductors. There are several important motivations and interesting application fields, from the particle physics to medical applications, and the development of a CCT solenoids based on HTS would open new horizons in these areas.

Here we will explain the development and the results in terms of critical current density of Bi-2212 wires performed at CNR-SPIN as well as our progress on the CCT magnet design.

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Theory of coherent-oscillations generation in terahertz pump-probe spectroscopy: from phonons to electronic collective modes

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Time-resolved spectroscopies using intense THz pulses appear as a promising tool to address collective electronic excitations in condensed matter [1]. In particular, recent experiments showed the possibility to selectively excite collective modes emerging across a phase transition, as is the case for superconducting and charge-density-wave (CDW) systems. One possible signature of these excitations is the emergence of coherent oscillations of the differential probe field in pump-probe protocols [2,3,4]. While the analogy with the case of phonon modes suggests that the basic underlying mechanism should be a sum-frequency stimulated Raman process [5], a general theoretical scheme able to describe the experiments and to define the relevant optical quantity is still lacking. Here we provide this scheme by showing that coherent oscillations as a function of the pump-probe time delay can be linked to the convolution in the frequency domain between the squared pump field and a Raman-like nonlinear optical kernel [6]. This approach is applied and discussed in a few paradigmatic examples: ordinary phonons in an insulator, and collective charge and Higgs fluctuations across a superconducting and a CDW transition. Our results not only account very well for the existing experimental data in a wide variety of systems, but they also offer a useful perspective to design future experiments in emerging materials.

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Theoretical explanation of electric field-induced superconductive critical temperature shifts in Indium thin films

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We calculate the ffect of a static electric field on the superconductive critical temperature of Indium thin films in the framework of proximity effect Eliashberg theory [1,2], in order to explain 60 years old experimental data [3]. Since in the theoretical model we employ all quantities of interest can be computed ab-initio (i.e. electronic densities of states, Fermi energy shifts and Eliashberg spectral functions), the only free parameter is in general the thickness of the surface layer where the electriceld acts. However, in the weak electrostatic field limit Thomas-Fermi approximation is still valid and therefore no free parameters are left, as this perturbed layer is known to have a thickness of the order of the Thomas-Fermi screening length. We show that the theoretical model can reproduce experimental data, even when the magnitude of the induced charge densities are so small to be usually neglected.

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Epitaxial $La_2Zr_2O_7$ and Zr-doped CeO_2 films by chemical solution deposition as buffer layers for Fe(Se,Te) film growth

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Iron based superconductors (IBS) are being intensively studied worldwide due to their interesting properties such as the low anisotropy and the very high upper critical field. As a consequence, IBS are candidate materials for very high magnetic field applications. Among the various families of IBS, Fe(Se,Te) system is attractive due to the low lattice anisotropy and the absence of toxic elements. The best performances of Fe(Se,Te) were so far reached as epitaxial thin film grown on oriented substrate. Recently, high critical current density Fe(Se,Te) film has been obtained on single CeO2 buffer layer deposited by pulsed laser deposition (PLD) on cube-textured Ni-W substrate. A fundamental step toward process simplification and cost reduction is the possibility of using inexpensive chemical solution deposition (CSD) methods to grow epitaxial buffer layers. In this contribution, the epitaxial growth of La2Zr2O7 (LZO) and Zr-doped CeO2 (CZO) films by CSD on commercially available (100) single crystal substrates such as SrTiO3 and Y2O3-stabilized ZrO2 (YSZ) and their use as buffer layers for Fe(Se,Te) film growth is shown. Preliminary results on Fe(Se,Te) film deposited on LZO or CZO grown on (001) SrTiO3 and Y2O3-stabilized ZrO2 (YSZ) single crystal are reported. The influence of deposition conditions on LZO and CZO film microstructure was investigated and reported. It is revealed that sharp epitaxial growth can be achieved for both films in a large range of temperature. Conversely, the film surface roughness and grain coalescence are more complex and deserve a more careful control. Preliminary results on FST films deposited on CSD buffer layers show encouraging superconducting properties, although

The Nernst Effect in Corbino Geometry

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We study the manifestation of the Nernst effect in the Corbino disk subjected to the normal external magnetic field and to the radial temperature gradient. The Corbino geometry offers a precious opportunity for the direct measurement of the magnetization currents that are masked by kinetic contributions to the Nernst current in the conventional geometry. The magnetization currents, also referred to as the edge currents, are independent on the conductivity of the sample which is why they can be conveniently described within the thermodynamic approach. They can be related to the Landau thermodynamic potential for an infinite system. We demonstrate that the observable manifestation of this, purely thermodynamic, Nernst effect consists in the strong oscillations of the magnetic field measured in the center of the disk as a function of the external field. The oscillations depend on the temperature difference at the edges of the disk. Dirac fermions and 2D electrons with a parabolic spectrum are characterized by oscillations of different phase and frequency. We predict qualitatively different power dependencies of the magnitude of the Nernst signal on the chemical potential for normal and Dirac carriers.

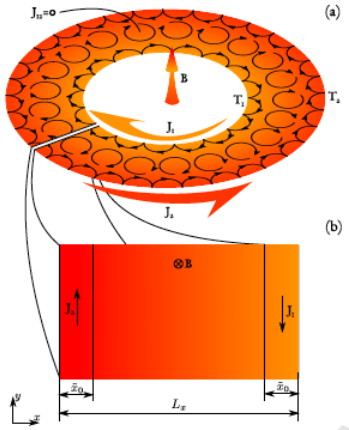

Fig. 1. a). The schematic showing the edge currents flowing in a Corbino disk subjected to an external magnetic field normal to its plane and to a radial temperature gradient. b). The schematic showing the edge currents flowing in a conducting strip subjected to an external magnetic field normal to its plane.

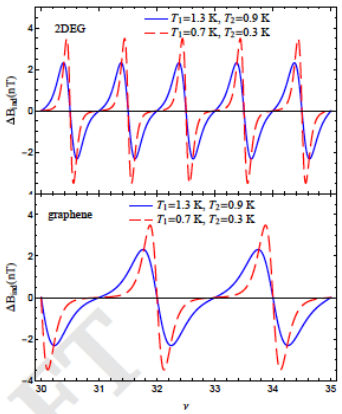

Fig. 3. The contribution to the induced magnetic field ΔB_{ind} at the center of the Corbino disk that is induced by a temperature gradient in nT plotted as a function of the filling factor ν. The upped panel is describing the 2DEG characterised by a parabolic dispersion of charge carriers while the lower panel corresponds to the case of graphene characterised by the linear dispersion of charge carriers. The blue curves are calculated with $T_1 - 1.3K$, $T_2 - 0.9K$ and the red curves correspond to $T_1 - 0.7K$, $T_2 - 0.3K$. The other parameters used in this calculation are $R_1 - 100\mu m$, $R_2 - 110\mu m$, $E_F - 500$ K, $\Gamma - 0.5$ K.

Designing new ferrite/manganite nanocomposites

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Nanostructured transition metal oxides represent a very interesting class of materials due to their cross-correlated electronic and magnetic properties [1,2] and for their important technological applications (magnetic recording and spintronic devices, biomedicine, ferrofluid technology, catalysis, etc.).
Here we propose a new approach to synthesize nanocomposites of the soft Colossal Magneto-Resistance (CMR) manganite $La_{0.67}Ca_{0.33}MnO_3$ (LCMO) and hard ferrite $CoFe_2O_4$ (CFO), to maximize interphase interactions.
A comparison between such a novel nanocomposite (NC) and a composite obtained by mechanical mixing (N-MIX) of the same two phases is carried out by a complete structural and morphological characterization, together with in-depth magnetometry studies. All the results suggest that a strong coupling only occurs for the NC sample, whose magnetic behavior resembles that of an exchange-spring system, as clearly indicated by both the M(H) curve and the switching field distribution measured at 5 K (Figure 1d) [3].

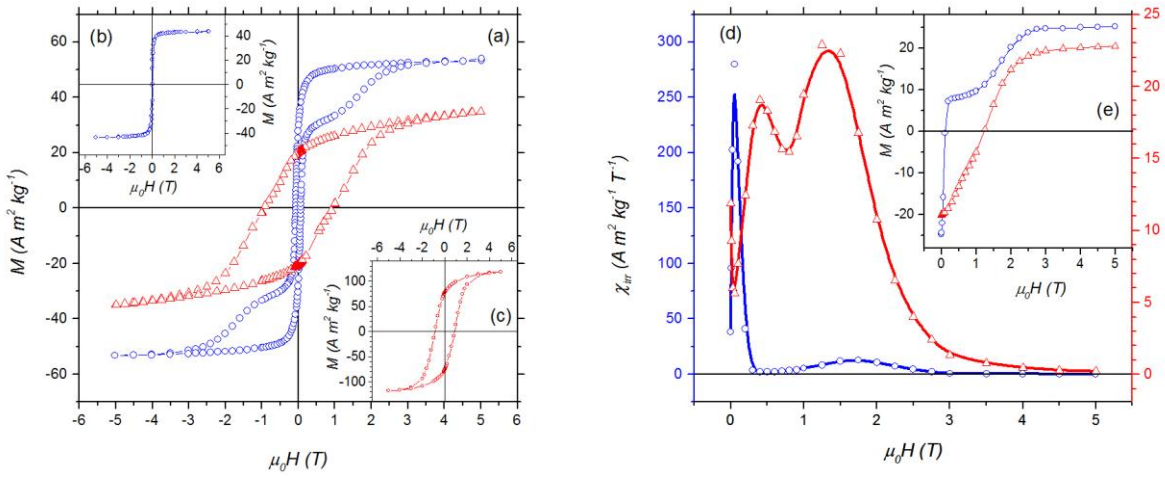

Figure 1: M Vs H curve of N-MIX (blue circles) and NC (red triangles) are reported in panel a. The single nanocrystalline phases N-LCMO (b) and N-CFO (c) are reported for comparison. For N-MIX (blue circles) and NC (red triangles) the switching field distributions are reported in panel (d), while the original DCD curves are reported in inset (e).

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Transport properties, superfluid stiffness and intrinsic inhomogeneity in two-dimensional superconductors

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The progress in material science has made nowadays available a wide class of systems with thickness ranging from few nanomenters down to the atomic-layer limit. In some remarkable cases, the ground state can be continuously tuned from metallic/insulating to superconducting (SC). How the reduced dimensionality influences both phases is still a largely open question. In this environment, some materials show interesting geometrical and topological properties, where the presence of spatial disorder and inhomogeneities can play a central role. The cause and the effects of inhomogeneities are still debated, and can be different in different materials.

A particularly interesting issue about two-dimensional (2D) SC materials regards the very nature of the SC transition, that is expected to belong to the same Berezinskii-Kosterlitz-Thouless (BKT) universality class of the 2D XY model [1,2]. The relevant excitations in this case are topological vortex-like configurations of the phase, and the energy scale is set by the superfluid stiffness J_s .

Nonetheless, the experimental observation of the BKT transition in real systems is far from being straightforward. Indeed, disorder can partially hinder those signatures that can indicate the presence of an eventual BKT transition. In some interesting cases, such as the 2D electron gas in STO-based interfaces, the mesoscopic inhomogeneities are the main responsible for the odd features observed in transport measurements, e.g., the anomalous broadening of the resistive metal-to-SC transition or the non-linearity in the *IV* characteristics. By modelling the system as a sheet of resistors, we can well describe the experimental data with a random resistor network (RRN) model, allowing us to talk about a percolative transition.[3,4]

Here, while our results question the possibility to observe BKT physics in this extremely confined 2D electron gas, they also suggest that the odd features observed in transport measurements can actually be used as a benchmark for emergent inhomogeneity in a wide class of superconductors.

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Planar defects and vortex pinning in $EuRbFe_4As_4$ iron-based superconductor

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We successfully synthesized $EuRbFe_4As_4$ single crystals by a "self-flux" technique. The systematic AC susceptibility and magnetic moment M(H,T) measurements were performed to investigate the vortex pinning in the $EuRbFe_4As_4$ superconducting single crystal. We show that Eu^{2+} magnetic ordering shifts to 5K in external magnetic fields of roughly 1T and find evidence of insignificant interaction between magnetic and superconducting layers. We found $U_0(H)$ follows an $H^{-0.47}$ dependence in magnetic fields above 0.1T and reaches 6700K at low fields along ab plane. Therefore, collective pinning with $U_0 \sim H^{-1}$ is not the case. According to the very recent TEM observations in Ca-1144 was found the presence of planar defects along the ab plane [1]. Given a similar synthesis method and the same structure of $EuRbFe_4As_4$, it can be assumed that $(Rb/Eu)Fe_2As_2$ layers may act as planar defects. Thus, the pinning mechanism here, considering $U_0 \sim H^{-0.47}$ at $H > 0.1T$, is maybe due to the planar defects [2]. However, additional investigation is needed to confirm our assumption.

The isothermal magnetization measurements M(H) were provided in Eu-1144 single crystal along ab plane. Our data shows that the $\Delta M(T) \sim J_c(T)$[3] width did not vastly change above or below Eu^{2+} magnetic ordering at 15 K. Thus, the influence of Eu^{2+} magnetic ordering on the ΔM values is insignificant compared to SC signal even at low temperatures. The $J_c(H)$ behaviour at different temperatures show that at low fields, typically about $100 - 350$ Oe, J_c is independent of external field - single vortex regime is observed. At higher magnetic fields, from 0.01-0.1T up to 1.5 T, the critical current follows a power-law behaviour $J_c \propto H^{-a}$ with $0.55 < a < 0.68$. The *a* exponent values obtained in this work are in a good agreement with the theoretical prediction of $H^{-5/8}$, which indicates strong vortex pinning [4]. Considering the structural conformance with other compounds in this family, the Eu-1144 can be used as a source of strong pinning centres for the CaKFe4As4-based superconducting material to improve critical current density for practical applications.

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Ising Superconductivity

in transition metal dichalcogenides

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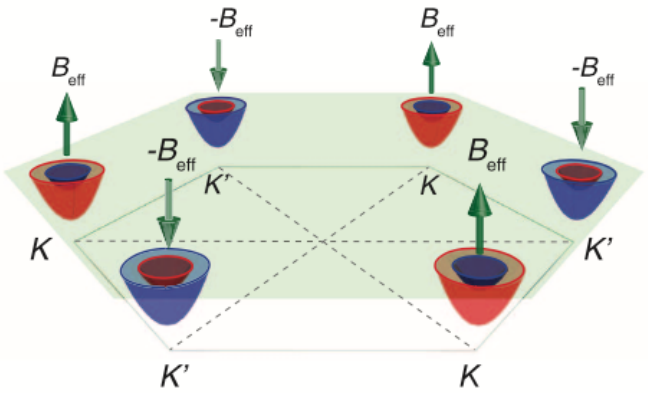
2D materials have been a fruitful field for many recent discoveries of novel electronic state. Especially by making artificial bilayer systems, new electronic states such as superconductivity and moiré modulated interlayer excitons have been reported. This talk will discuss Ising superconductivity induced in 2D transition metal dichalcogenides, where the Ising-like paring states can be controlled by having materials with different spin-orbit interactions and applying external stimulants such as field effect [1,2]. Also, we will discuss how to couple two Ising superconducting states through Josephson coupling by inducing superconductivity symmetrically in a suspended bilayer accessing electronic states with broken local inversion symmetry while maintaining the global inversion symmetry [3]. Controlling the Josephson coupling and spin-orbit coupling is an essential preparation for realizing many exotic electronics states predicted for the coupled bilayer superconducting system with strong spin-orbit interactions.



Conduction-band electron pockets near the *K* and *K'* points in the hexagonal Brillouin zone of monolayer MoS2. Electrons in opposite K and K' points experience opposite effective magnetic fields B_{eff} and $-B_{eff}$, respectively (green arrows).

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