The new Italian CNR Institute SPIN (Superconductors, Oxides and Other Innovative Materials and Devices)

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Abstract - **Recently a new CNR Institute named SPIN has been created in Italy. It is fully devoted to the study of superconductors and other "innovative" materials and of their application in the fields of electronics and energy. In this paper, I briefly review the Institute's history, mission, organization, human resources and equipment. Research objectives are also presented and examples given of recent scientific achievements. The Institute collaborates internationally and is interested in initiating additional collaborations.**

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I. INTRODUCTION

On February 1st, 2010, the Italian CNR Institute INFM (Istituto Nazionale per la Fisica della Materia) was formally closed. On the same day, three new Institutes were created inside CNR (National Research Council). One of these is "SPIN", an evocative name as well as an acronym for "SuPerconductors, oxides and other INnovative materials and devices".

SPIN includes four previous INFM structures: Coherentia (Naples), LAMIA (Genova), SUPERMAT (Salerno) and CASTI (l'Aquila)[*]. Accordingly, SPIN has now four "Operative Units" (UO), one in each of these cities. The Institute headquarters are in Genova, in Villa Balbi-Brignole, Corso Perrone 24, where INFM and LAMIA were previously located (see Fig.1). The other UO are hosted inside University locations. A fifth UO may be opened within the next few months in Rome. All the research institutions and groups merged in SPIN derive from the Italian historically leading groups in superconductivity. The Institute assembles a team of 40 CNR staff researchers, 80 associated university professors, 12 employees in administration and general services, and a good number of post-docs and PhD students (about 40 at this juncture).

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[*] LAMIA = LAboratorio Materiali Innovativi Avanzati ; SUPERMAT = Laboratorio regionale SUPERconducting MATerials; CASTI = CASTI : Centro ASsistenza Tecnologica alle Imprese.

Fig. 1. Villa Balbi-Brignole, the Headquarters of SPIN.

SPIN is endowed with an impressive set of advanced scientific instruments, including nearly 20 thin film deposition systems, 3 clean rooms, 3 high-field and-low temperature STM systems, numerous laser sources emitting from IR to UV and ranging from CW mode to femtosecond pulses, and numerous other equipment. The scientific research is supported by well-equipped electronic and mechanical workshops, library, www, e-mail, network-storage services and GRID computing.

Collaboration with industrial partners and technology transfer activities will be developed, also through the participation in local networks (for example, in Naples-Salerno, SPIN is an associated partner of the Centre of Competence “New Technologies” with all local Universities and Research Centers). Training and education at undergraduate and PhD level will be carried out in close collaboration with the Universities hosting the local SPIN Units.

The Institute overall institutional budget is on the order of 4 million € per year (including the employee payroll) , and a further budget on the order of 2 million € per year is expected through participation in competitive research calls (projects funded at regional, national and European level). In the start-up phase SPIN will be directed by Prof. Ruggero Vaglio, formerly the INFM Director Delegate for Coherentia. The Director is supported by an elected Internal Advisory Board of nine members (Consiglio di Istituto) and by a five-member International Advisory Board, to be named shortly.

In the following overview, I provide examples of references to our relevant and in many cases collaborative recent work. I also show few figures as examples of work performed, without, however, discussing these figures in any detail.

II. MISSION

The mission of the Institute is the study of superconductors and of other “innovative” materials and of their application in the fields of electronics and energy: oxides, organic, hybrid and other complex materials exhibiting superconducting, magnetic and other properties for the development of novel nano- and micro-device concepts and prototypes.

By following the trend firmly established in the last years at an international level, the original SPIN expertise in superconductivity and high-T_c superconductor oxides has gradually evolved by shifting emphasis towards novel advanced materials. A strong push was given in the last decade to research in fields such as multifunctional oxides, organic and hybrid materials, and nanostructured systems. Analogous trends can be, indeed, observed in important European, US and Japanese laboratories.

A relevant characteristic of the Institute is the extensive use of linear, nonlinear and ultrafast laser techniques for materials synthesis and characterization. This very successful approach provides added value to the research in the SPIN fields of study.

The Institute scientific activities can be schematically grouped into three main areas:

- Physics and applications of superconductivity,
- Oxides (including magnetic systems) and oxide electronic applications,
- Hybrid organic-inorganic and nanostructured materials.

III. PHYSICS AND APPLICATIONS OF SUPERCONDUCTIVITY

A. Unconventional Mechanisms of Superconductivity

The discovery of high-temperature superconductivity (HTS) in cuprate oxides, was followed by discoveries of superconductivity in borocarbides, diborides, pnictides, and prediction of it in graphene. Some of these superconducting systems, which are characterized by multiband nature and antiferromagnetic ordering, present new challenges and opportunities for understanding of high-temperature superconductivity. Thanks to the skills developed in sample synthesis in the form of bulk, thin films and tapes, the SPIN researchers established a fruitful network of national and international research collaborations: this started with the HTS, continued first with transition metal borocarbides, later with a highly successful activity on magnesium diboride (MgB_2) and finally with the newly discovered and very promising Fe-based superconductors (oxypnictides).

The discovery of these latter superconductors, in the early 2008, sparked a huge interest because of the occurrence of superconductivity in presence of iron. The many similarities with cuprates (layered structure, charge transfer mechanisms, proximity to a magnetic transition) could give the chance to understand the unconventional mechanisms of superconductivity occurring in HTS and in these compounds as well. Oxypnictides and HTS show the highest T_c among superconductors. This suggests that unconventional mechanisms are more effective than conventional electron-phonon coupling. Better understanding of these issues could disclose the path towards the discovery of superconductors with an even higher critical temperature, possibly up to room temperature Figure 2 from our recent work illustrates the effect of fluorine doping in an oxypnictide [1].

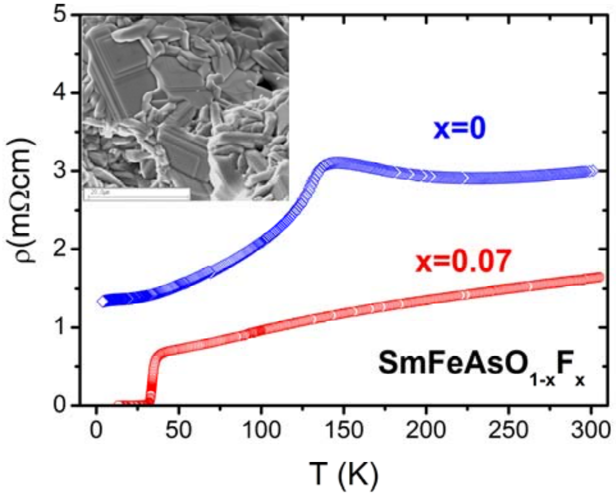

Fig. 2. Resistivity curves of oxypnictide superconductor $SmFeAs(O_{0.93}F_{0.07})$ with T_c=35 K and of the parent compound SmFeAsO which exhibits a magnetic ordering at T_N=140 K. In the inset SEM image (secondary electrons on fractured sample) showing lamellar crystals of SmFeAsO.

B. Study of MgB_2

The development of superconducting materials for power applications is part of the mission of the Institute. While we keep an eye on the emerging materials and on their current carrying capability, our research in the field has been recently focused on MgB_2 [2, 3]. This activity is of interest for many SPIN industrial partners and in particular for Columbus Superconductors, born as a spin-off company of the former LAMIA-INFM, and now present worldwide in the production and commercialization of MgB_2 cables. The MgB_2 compound shows, in fact, competitive properties at relatively low magnetic field values, which are interesting and useful for biomedical applications such as conductors for MRI magnets. The effort and success in improving MGB_2 performance in high magnetic fields might make it competitive with NbTi, the most widely employed superconductor for high field power applications. Therefore, enhancing the critical current of MgB_2 in high magnetic fields remains one of the main goals to be pursued through the control and manipulation of the structure at a nanometer level to increase the flux pinning. Innovative and unconventional ways of introducing nanometer-scale defects will be developed in a way compatible with the mechanical deformation process used in the fabrication of MgB_2 cables. Innovative solutions and geometrical configurations for the multifilamentary wires and tapes will be studied and developed at SPIN, also for AC applications. To illustrate our technical achievement to date, Figure 3 shows the photo of coiled 1.6 km length of stabilized multifilamentary MgB_2 tape.

Fig. 3. 1.6 Km of stabilized multifilamentary MgB2 tape fabricated in our laboratory by the powder in tube method; now this technology is used by Columbus Superconductors.

C. Quantum Electronics and Qubits

The study of the macroscopic quantum nature of the superconductive state represents both one of the most stimulating fields for fundamental research and the basis for the development of advanced technologies, including quantum computation and quantum communication. Moreover, in recent years, the interplay between superconductivity and magnetism attracted a large scientific interest due both to the complex underlying physics and to its unique potential for emerging applications, such as advanced superconducting spintronics and quantum electronics. Novel technologies offer unique possibilities for depositing thin films of magnetic nanostructured multi-functional materials and superconductor/ferromagnet hybrid structures with highly controlled physical properties. As a consequence, besides the highly sensitive Superconducting Quantum Interference Devices (SQUIDs), the possibility of using innovative magnetic sensors (Giant Magneto-Resistance GMRs) opens a new potential towards emerging applications in various industrial areas ranging from aeronautics to biomedicine, which are considered highly strategic for R&D development in the “Regione Campania”, where SPIN has two important Operative Units (Napoli and Salerno).

The Institute activity is also strongly focused on the theoretical and experimental investigations of macroscopic quantum phenomena in Josephson structures, including macroscopic quantum tunneling in both LTS and HTS Josephson junctions and aspects of mesoscopic physics in superconducting devices [4, 5]. Figure 4 shows SEM pictures of investigated submicron structures.

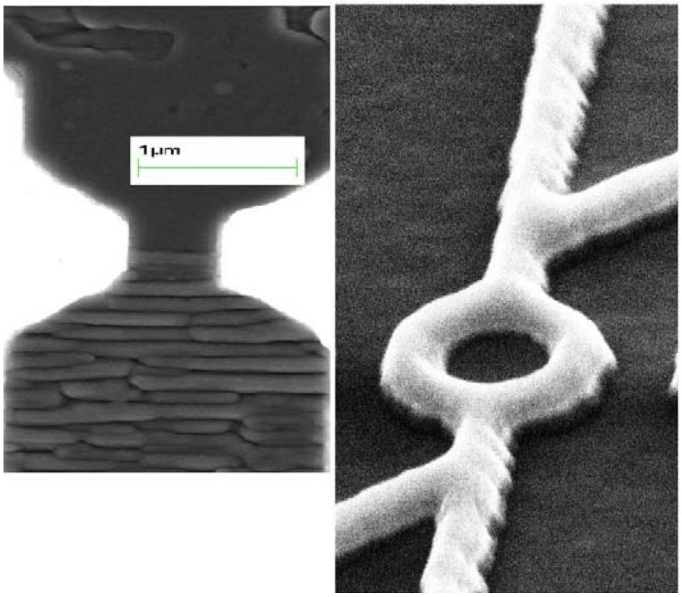

Fig. 4. SEM pictures of a submicron YBaCuO biepitaxial grain-boundary Josephson junction and a YBaCuO nano-ring realized and characterized to investigate quantum properties of superconducting systems.

One of the most relevant long term targets is to develop novel superconducting/hybrid devices and potential innovative protocols for quantum computation and quantum sensors. In solid state qubit architectures, superconducting devices can be considered as “atoms with wires”, which display energy-level quantization and interact strongly with electromagnetic environment. In this framework, coherent free oscillations were measured at mK temperature in a flux qubit based on a Josephson interferometer, manipulated by pulses of magnetic flux instead of microwaves. This research activity combines experimental capabilities to realize unique nano-devices-and to perform low-noise quantum measurements in the range of a few tens of millikelvin.

Clusters, granular superconductors superconducting very thin films containing a nanometer-sized array of antidots and hybrid proximized superconductor/ferromagnet structures will be also investigated in SPIN. Attention will be dedicated to theoretical aspects of the superconductor-insulator transition and fluctuations phenomena in superconductors.

A further important issue of the activity will be the study of ultrafast phenomena in condensed matter by femtosecond optical pump-probe, novel temperature gradient sensors based on the giant Nernst effect, novel aspects of superconductive optoelectronics including integrated on-chip waveguides for superconductive optically controlled Josephson devices.

Several types of superconducting radiation detectors are developed within SPIN, covering a wide range in the electromagnetic spectrum: superconducting tunnel junctions, transition edge sensors, nanowires, hot-spot bolometers, single photon detectors [6-8], with and without antenna coupling. Applications range from space missions to quantum cryptography and lately security, namely the THz detection for body scanners. As an example, Figure 5 shows plots of the response by NbN nanowire detectors to absorption of a single infrared photon. The signal amplitude increases with the number of parallel nanowires.

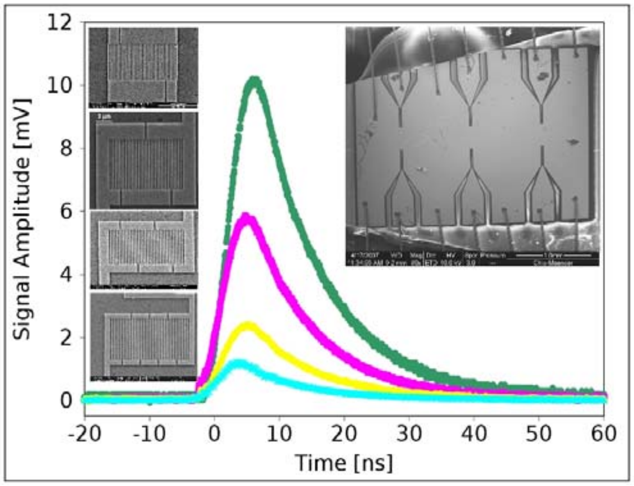

Fig.5. Response to an infrared single photon absorption from NbN parallel nanowire superconductive detectors in different nanowire configurations (from the bottom up plots for 4, 8, 12 and 24 parallel nanowires). In the left insets microphotographs of the detector layouts used. In the right inset a picture of a single photon detector test chip.

Recently, a new type of superconductive device has been developed, which is based on nanoscale-size stripline. Such devices are the base of innovative and performing radiation detectors, capable to resolve single photons in the IR spectral region. This research will be actively developed in SPIN as a key technology for single photon quantum information and computing, as well as toward a wider spectrum of applications, from mass spectrometry to superconducting digital electronics.

Special attention will be paid in SPIN to the development of advanced technologies. In particular, we expect to acquire a new facility for nano-patterning of nano-sized devices, an unique tools for studying in details many intriguing physical aspects of the mesoscopic physics we mentioned above.

Finally, a great effort will be also spent for the set-up and the optimization of a low temperature (mK) facility equipped with all relevant electronics useful for quantum measurements, including noise shielding, advanced filtering, optical and microwave inputs. This advanced equipment will become also a tool for studying the physical behavior of unconventional materials and structures in a temperature region where many physical properties show special features.

IV. OXIDES (INCLUDING MAGNETIC SYSTEMS) AND OXIDE ELECTRONIC APPLICATIONS

A. Fabrication techniques and Seed Activities

In the near future, development of novel devices which exploit functional properties of innovative materials will represent one of the most challenging objectives for the applied research in condensed matter physics. At SPIN, this area of activity will be focused on the synthesis of unconventional oxides, their theoretical modeling and experimental investigation, and on the fabrication of demonstrators and prototype devices.

The core activity will be the engineering and characterization of thin films and heterostructures based on strongly correlated oxides with special emphasis on oxide surfaces and interfaces. From the viewpoint of oxide synthesis, most of the activities will be carried out by advanced Physical Vapor Deposition (PVD) techniques available in SPIN. For example, femtosecond (fs) laser ablation will be used. It leads to the growth of layers that are very different in terms of morphology, composition, and structure from those obtained by conventional nanosecond pulsed laser deposition (PLD).

Materials currently under investigation are, mostly, strongly correlated oxides such as a) “magnetic” manganites and ruthenates, b) superconducting cuprates, c) di/piezo/ferro-electric titanates, *etc*.

New seed activities based on novel materials classes have been recently initiated, which include:

- Nanostructured materials by fs PLD: synthesis of nanoparticles (NPs) and of NPs-assembled films of simple and complex oxides, as well as mixed films of metal oxide NPs and metallic NPs, magnetic NPs and ceramic NPs.
- Oxides for energy production: deposition of thin films and heterostructures based on ionic and ionic-electronic oxide conductors, mostly perovskites or fluorites, for the engineering of micro Solid Oxide Fuel Cells (μSOFCs) for energy applications.
- Magnetic sensors employing innovative nanostructured materials and multi-functional thin films for advanced spintronics and engineering (elasto-magnetic, magneto-resistive, micro-electromechanical) applications. In particular, novel nanostructured materials will be investigated for advanced sensors based on the coupling of elasto-magnetic and magneto-resistive effects.

For the study of physics and chemistry of condensed phases, it is often crucial to obtain good quality single crystals. The crystal growth program at SPIN is a consequence of the large experience on the synthesis of superconducting and magnetic oxides acquired in the recent years. The main equipment for single crystal growth activity is the infrared image furnace. Efforts of researchers involved in the field of single crystal growth are focused on the growth of large superconducting and magnetic oxide crystals.

A specific research activity will be directed at understanding of the complex phenomenology of strontium ruthenates. The main goal of this research is to link the control of the single crystal growth with the development of materials whose physical properties can be tailored and understood within a suitable theoretical frame [9-11]. Figure 6 (a) shows strontium ruthenate crystal growth, while Figure 6 (b) shows a cleaved crystal with zones of Sr_2RuO_4 and $Sr_3Ru_2O_7$ indicated by arrows. Junctions of Sr_2RuO_4/$Sr_3Ru_2O_7$ have high quality interfaces.

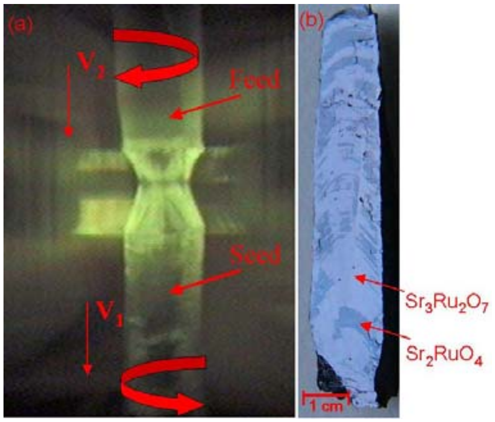

Fig. 6. (a) image of a single crystal growth of strontium ruthenate by floating zone technique. (b) cleaved crystal with junctions of $Sr_2RuO_4/Sr_3Ru_2O_7$ having high quality interfaces.

B. Strongly Correlated Oxides

The most relevant property of strongly correlated oxides is the possibility of modifying profoundly their physical properties through external controllable parameters, such as electrical, magnetic fields, optical radiation, temperature, pressure or strain. Moreover, novel functionalities have been proved to arise from the interaction at interfaces leading to epitaxial heterostructures exhibiting physical behavior qualitatively different from the single building blocks (*e.g.*, metallic, magnetic, dielectric, superconducting, multiferroic, *etc*, behavior). SPIN researchers involved in this activity investigate the wide class of phase transitions and other peculiar physical phenomena, typical of oxide compounds and heterointerfaces, such as Mott transitions in superconducting cuprates and related materials, magnetic-field-induced transitions in colossal magnetoresistance and multiferroic systems, electric-field-induced transitions both in heterostructures and in colossal electroresistance systems, metal insulator transitions triggered by charge transfer at interfaces, structural phase transitions, charge and orbital ordering phenomena, or charge density waves [12-13].

C. Sensors and MEMS

The study and the development of sensors, MEMS and device prototypes based on innovative materials is also a key objective of SPIN. Two different approaches are pursued: a) all-oxide devices, and b) hybrid devices, where oxide layers have to be integrated with other non-oxide materials. In the former case, major effort will be directed towards designing and growing epitaxial heterostructures of functional oxides, while in the latter case a major technological clue will be the growth of epitaxial oxide films on mismatched and often chemically ill-compatible substrates (mostly silicon wafers), also making use of suitable buffer layers. This twofold approach should open the way to the fabrication of perovskite-oxide epitaxial structures with integrated magnetic/ferroelectric, magneto/elastic and magnetic/superconducting properties, of interest in several fields of application such as electronics, biology, environment and security [14-15]. Figure 7 shows a SEM picture of a $SrTiO_3(001)$ epitaxial thin film. This cantilever is used as flexible substrate for the epitaxial deposition of a wide class of oxide compounds.

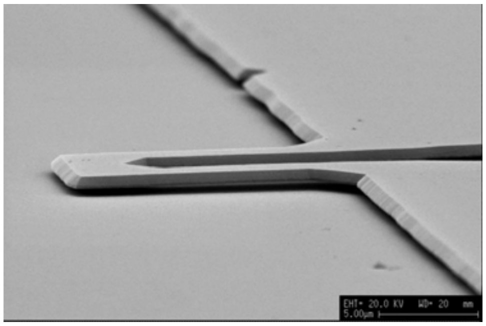

Fig. 7. Scanning Electron Microscope (SEM) image of a microcantilever made by micro-machining a $SrTiO_3(001)$ epitaxial thin film. This cantilever is used as flexible substrate for the epitaxial deposition of a wide class of oxide compounds.

D. Spectroscopy

Advanced spectroscopic characterization of oxides and interfaces represent a strategic issue for this area. In addition to the large number of established techniques already available within SPIN (advanced STM/AFM techniques, RHEED/LEED, XPS/UPS, IR transmission and reflection spectroscopy, Raman spectroscopy, etc..), often employed with innovative approaches, other intrinsically innovative techniques have been set up. In this framework, ultrafast and often surface/interface-sensitive spectroscopies have been developed, with the aim of covering a large photon energy range from THz to UV. This includes ultra-broadband time domain THz spectroscopy, frequency-resolved surface second harmonic generation, other time-resolved nonlinear and linear spectroscopies (*i.e.*, CARS and luminescence).

Our Institute devotes a special attention to techniques based on large-scale facilities, especially synchrotron radiation sources. Current research carried out by SPIN using synchrotron radiation spectroscopic techniques includes three main lines: infrared spectroscopy, resonant soft x-ray spectroscopies, and in-situ ARPES on epitaxial thin films. Figure 8 is an example of far infrared conductivity spectroscopy [16].

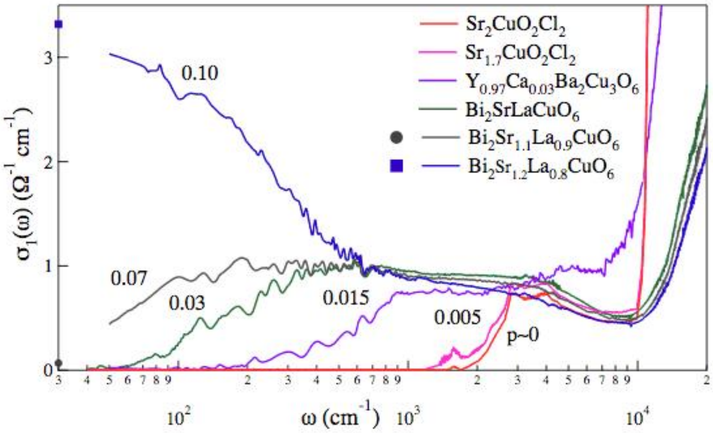

Fig. 8. Far infrared spectroscopy of the insulator-to-metal transition in the Cu-O plane of high-T_c superconductors. Here, it is monitored through the evolution of the low-T optical conductivity of single crystals of single-layer cuprates having different hole concentration p, from 0 to 0.10. The insulating gap is seen by the edge of a band in the mid-infrared (probably polaronic in nature). The gap fills up the gap as p increases from 0 to 0.7. At p = 0.10 the band becomes the Drude absorption typical of free carriers and the Cu-O plane is metallic. The vertical scale is normalized to the conductivity of the sample with p = 0 at 3000 cm^{-1}.

V. HYBRID ORGANIC-INORGANIC AND NANOSTRUCTURED MATERIALS

A. Focus of Activities

This area of SPIN activity is devoted to the design, the synthesis and the characterization of novel organic materials, functional nanostructures and hybrid organic/inorganic systems, with improved functional properties or multi-functional response for applications in optoelectronics and sensing. The activities focus on:

a. Electronic states at surfaces and interfaces, including surface/interface states formation, Fermi level alignment, band-bending and charge injection in electrode/semiconductor junctions for charge and spin transport devices.
b. Electronic and optical properties at nanoscale, *.i.e.*, in functional nanostructures, as building blocks in hybrid systems or optoelectronic devices.
c. Phase transitions: including metal-insulator, piezoelectricity, superconductivity, glass transition electrical bistability.
d. Devices of new generation with improved multifunctional characteristics in which two or more functionalities are present and can be independently activated.

Several classes of materials, characterized by strong correlations and multi-functionality, will be under investigation in SPIN: Semiconductor nanostructures, with special reference to semiconductor oxides (ZnO, TiO_2, SnO_2 doped with other metals to induce functionalities, like magnetism and p- or n-doping) and their interactions with organic molecules; organic compounds, including p and n type π-conjugated oligomers and polymers (T6, pentacene, perylene, Polyaniline, P3HT, …) or allotropic forms of carbon (graphene, fullerene, carbon nanotubes); organic-inorganic interfaces and organic-inorganic hybrids presenting phase transitions, improved properties or multifunctional behavior, *e.g.*, polyaniline or P3HT doped with metallic or oxides nanoparticles; OFET with ferromagnetic electrodes or photoluminescent conductors; perovskites based on tin halides. Figure 9 illustrates examples of organic devices, a n-transistor and light-sensitive memory device [17].

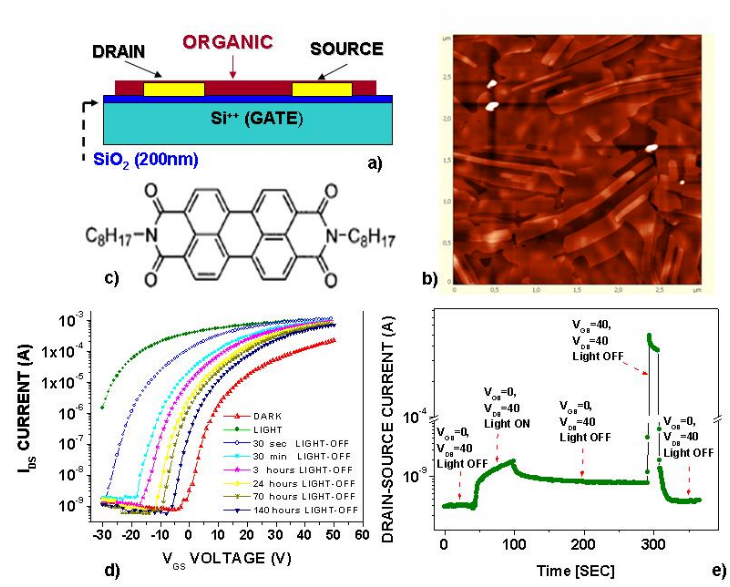

Fig. 9. The electrical response of n-type organic transistors (a) based on polycrystalline substrate (b). Perylene films of structure (c) have been demonstrated to be highly sensitive to light illumination (d). This feature has been exploited to fabricate a novel memory device (e), which can be optically programmed and electrically read and erased.

B. Synthesis and Characterization

The synthesis of the materials and devices (deposition of films and multilayers, realization of nanostructures and hybrids, photolithography, nano-imprinting, doping, …) is pursued following different routes: Chemical synthesis (spin coating, nano-imprinting, nano-lithography, dipping), in strong collaboration with regional and national multidisciplinary partners; Physical Vapor Deposition (PVD) synthesis of thin films and heterointerfaces. Already available deposition systems are an evaporation based UHV system and the newly developed laser ablation techniques of the Matrix Assisted Pulsed Laser Evaporation (MAPLE). Nanostructure inorganic materials will be also available through the already described femtosecond laser ablation technique.

Advanced materials and devices characterization will be pursued by several techniques, such as: nanoscale microscopy and spectroscopy (STM, near-field optical microscopy, scanning Kelvin probe force microscopy), microscale and interface-sensitive techniques (μ-EFISH[†], surface photovoltage spectroscopy, ultraviolet and X-ray photoemission spectroscopy, scanning confocal microscopy, luminescence and nonlinear microscopy, impedance spectroscopy, optical linear spectrophotometry (FTIR, UV, VIS-NIR).

Motivated by the strong need of clean and well-characterized interfaces, the synthesis and in-situ characterization of the materials will be further enforced by the design and installation of a new dedicated deposition UHV multichamber system.

Specific tasks requiring the use of more advanced facilities will be addressed by experiments using synchrotron radiation at the ESRF[‡] thanks to a long-standing collaboration with different groups.

C. Metamaterials

In recent years, the discovery of novel electrodynamic properties of artificial materials (metamaterials), allowed researchers to develop structures showing extraordinary properties. The research is aimed at the design and realization of metamaterials on nanometer scale with new geometries showing a magnetic response and a negative refraction index up to optical frequencies. The same goal is pursued *via* the study of artificial materials with a photonic bandgap based on aperiodic structures, realized using deterministic mathematical rules (Fibonacci, Thue-Morse, *etc.*) or quasi-crystalline tiling like Penrose, dodecagonal or others with an even higher rotational symmetry.

We expect our investigations to permit improving the knowledge of the basic physical mechanisms determining the structural and functional properties of the metamaterials under study. The ability to control and manipulate them, even on a meso- and nano-scale, with the aim of designing and realizing devices and systems exploiting new concepts, *e.g.*, electromagnetic metamaterials for microwave photonics and plasmonics, passive (polarizers, switches, cavities, filters, lenses) and active photonic devices (light sources, DFB lasers), *etc.* Figure 10 shows an example of simulated and measured field intensity maps of a dodecagonal PQC slab [18, 19].

Finally, SPIN will also carry out advanced research on polymer gels and colloidal gels. One way to obtain a variety of different materials is by tailoring a suitable interaction between hard sphere colloids. Granular materials are indeed the objects most manipulated by industries. Nevertheless, laws governing the behavior of such materials need still to be understood. One of the fascinating open problems is to understand the phenomenon of

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[†] Electric-field-induced second harmonic (generation) spectroscopy

[‡] ESRF = European Synchrotron Radiation Facility.

compaction, jamming, segregation and the rheological properties, compared to a solid or a liquid.

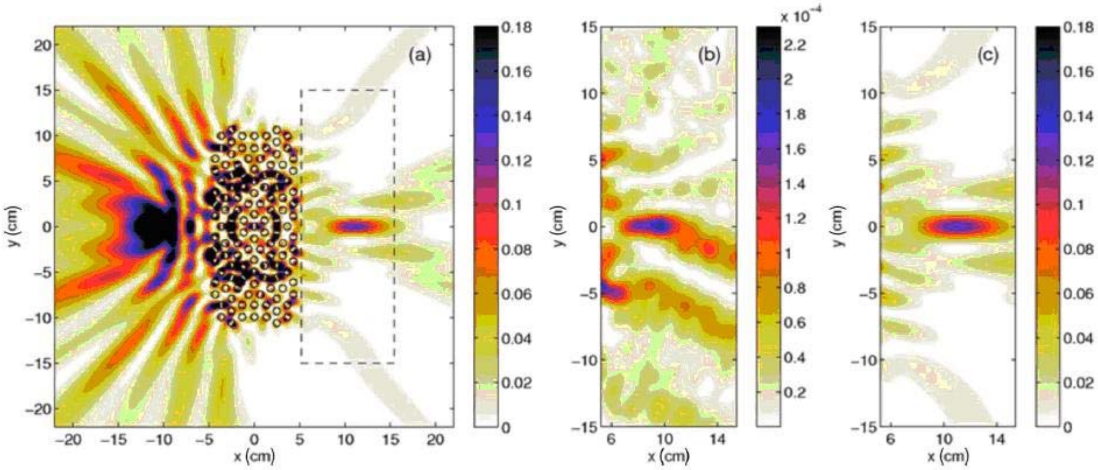

Fig. 10. (a) Simulated field intensity map at 8.836 GHz of a dodecagonal PQC slab (with lateral width less than 6 wavelengths). The dashed rectangle delimits the scanned area in the image-side measurement. (b) and (c): details of the measured and simulated field intensity maps at the image side.

D. Modeling

A relevant theoretical activity that is also developed within SPIN involves material design and modeling of the basic structural, electronic, transport, magnetic, ferroelectric and optical properties and is carried out in strong interplay with the experimental activities. Several approaches are pursued: effective models, semi-empirical calculations, allowing one the atomistic description of large systems; first-principles density functional calculations, allowing one a chemically accurate description of the electronic properties in bulks, as well as at functionalized surfaces and interfaces, or in hybrid or nanostructured systems as a function of the organic/inorganic phase, shape, dimension, *etc.*

Topics of interest are:

- strongly correlated transition-metal oxides; we take into account the effect of strong electron-phonon and electron-electron interaction on the phase coexistence and optical properties.
- Organic semiconductors, where we focus on the transport and spectral properties at the molecular level.
- Hybrid organic-inorganic materials and interfaces, where we show from first principles the interplay between the organic and inorganic phase in determining the electronic and optical properties.
- Graphene, for which we have investigated the effect of defects and functionalization at nanoscale, with particular reference to the transport properties.
- Multiferroics and magnetoelectrics where our work is aiming at the discovery, modeling and understanding of novel electronic mechanisms (i*.e.*, charge, spin or orbital order) that can efficiently induce ferroelectricity, and at performing an efficient ab-initio materials design of bulks, interfaces and nanostructures, where magnetoelectric effects or multiferroicity can be optimized for technological purposes

Figure 11 illustrates the interplay between electronic (charge, spin, orbital) and structural degrees of freedom to induce ferroelectricity in multiferroics [20, 21].

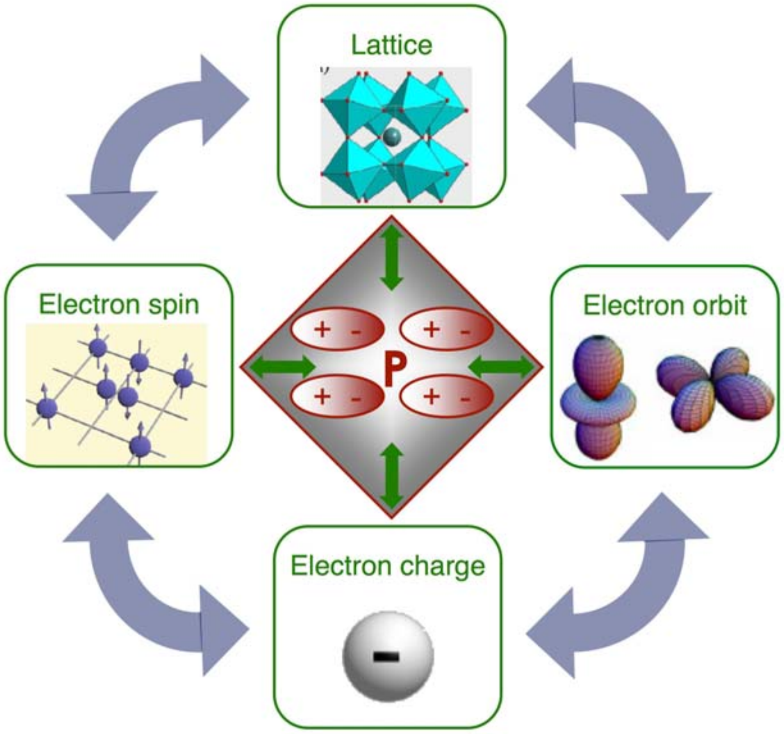

Fig. 11. Interplay between electronic (charge, spin, orbital) and structural degrees of freedom to induce ferroelectricity in multiferroics.

Finally a theoretical activity in the field of quantum transport in correlated nanodevices is ongoing within SPIN with particular emphasis on coherence, fluctuations and dissipative effects [22 - 25].

VI. CONCLUSIONS

The new Institute SPIN set up by CNR brings together most of the Italian research groups active in superconductivity, novel oxide and hybrid and nanostructured materials. The Institute derives its strength from the strong tradition in materials synthesis and in large-scale applications of superconductivity present in the Genova area, strongly encouraged by Prof. Carlo Rizzuto, with the internationally recognized activities in Josephson effects and devices historically present in the area of Napoli and Salerno due to the pioneering work of Prof. Antonio Barone.

The high level of its researchers and the rich set of advanced scientific instrumentation, should make CNR-SPIN a potentially relevant European institution in the area of superconductors, oxides and innovative materials, fully open to collaboration with all groups active at international level in these fields.

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