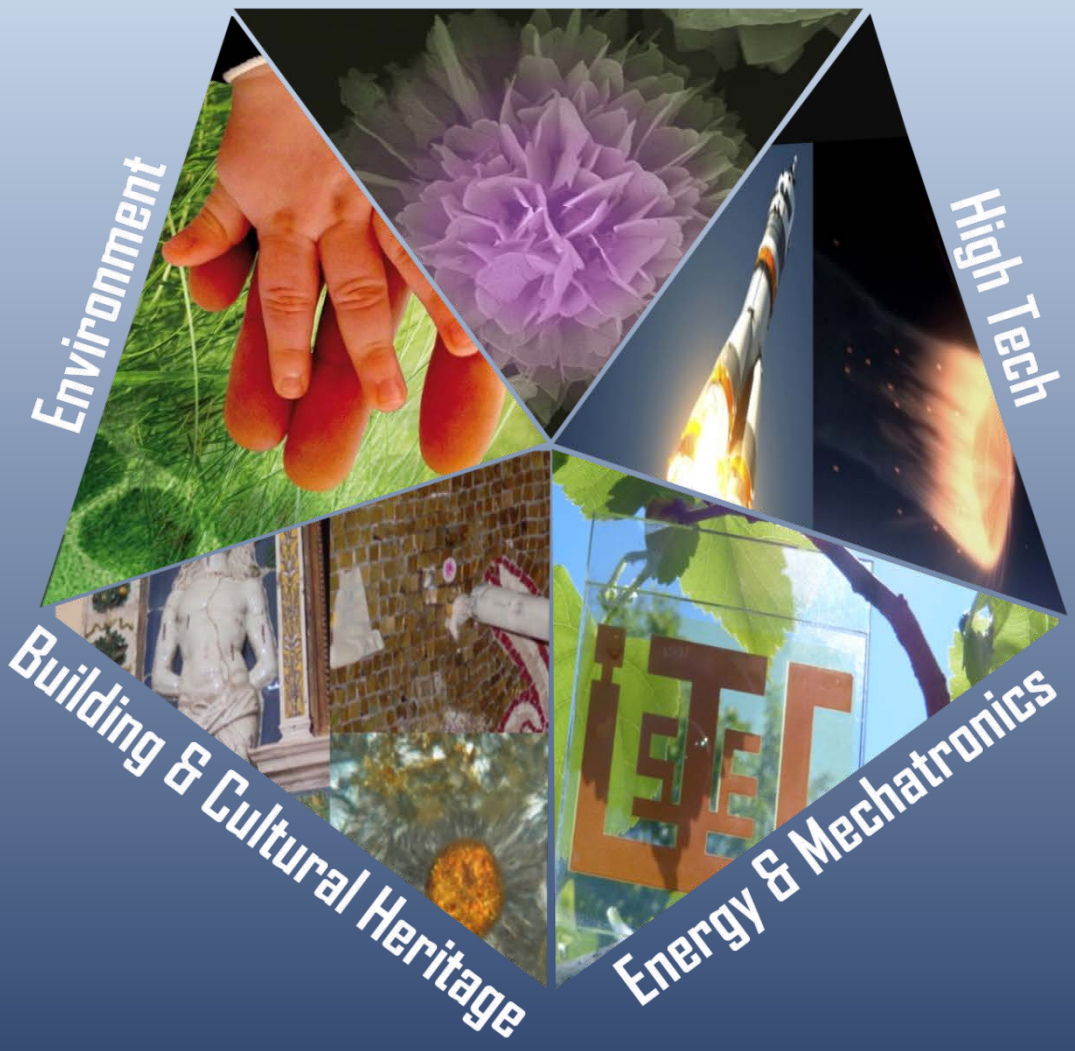
National Research Council of Italy

istec Institute of Science and Technology for Ceramics



ISTEC-CNR

Via Granarolo, 64 - Faenza - Italy

July 2017

ISTEC-CNR: The History

Speaking about the Institute of Science and Technology for Ceramics of the CNR definitely means evoking the relationship between ceramics and the City of Faenza. The historic journey that has given rise to the establishment of this particular institute of the National Research Council in Faenza and its evolution over the years is the result of experiences that cannot be easily forgotten.
Above all, Dr. **Tonito Emiliani**,

memorable guide in the ceramic work, was the founder in 1965, within the Art Institute for Ceramics, of the first CNR Research Group in Faenza that has directed for fifteen years until its evolution into an established Research Laboratory.
Deep gratitude is due also to those who have successively pursued, with tenacity and foresight, relevant goals of development, strengthening and adaptation to new needs, for this new Laboratory that finally became a prestigious institute of excellence at the International level for research on advanced ceramic materials and technologies.
Our thoughts go to Dr. **Gian Nicola Babini**,

to his firmness and perseverance in pursuing the eminence goals that led to the enlargement of ISTEC headquarters: since then, ISTEC has been the protagonist of a strong growth at National and International level and has been appreciated in his sector all over the world. Thanks to Dr. Babini, who has been the Director of ISTEC for 23 years, an ambitious project for the development of a Scientific and Technological Park in Faenza has been developed, following the example of similar European cases, as a facility dedicated to innovation, exploitation of research results, incubation of new start-ups and training at every level.
Currently, ISTEC belongs to the CNR Department of Chemical Science and Technology of Materials, and represents the largest structure in the country for the study of ceramic materials. ISTEC has achieved also an institutional accreditation, a qualification tool conferring the role of member of the High

Technology Network of the Emilia Romagna Region, enhancing the ability to professionally respond to the needs of customers such as companies and other public or private subjects needing external support for research and innovation.

The new global competitive environment testifies an increasing burden of effective integration between the politics and the research tools. The current international scenario is changing, as regards the scientific technological context, characterized by a non-linear growth of the innovative process and the integration of different scientific disciplines well distinct until a few years ago. A major goal of the National Research Programme is to favour the process of "transforming the knowledge into an economic value".

ISTEC is active in this scenario, and its activities deal with research and initiatives supporting the training, exploitation and dissemination of results. ISTEC is characterized by unique ability to bring to the market advanced materials and devices developed during funded research projects focused on goals relevant for the transnational economic growth. The main subjects addressed range from basic studies with extensive characterization of raw materials to the development and the innovation of materials, devices and production processes.

Main purpose of these studies is to tailor the properties and performance of ceramic devices by controlling the process conditions and by the engineering of materials addressed to specific applications. Different solutions are also offered to modify traditional products and provide them with new advanced features and performances.

Main sectors of reference are: **high-tech industrial applications, biomaterials for nanomedicine and tissue regeneration, energy and environment, mechatronics, building, cultural heritage, new nanotechnologies and surface functionalizations.**

ISTEC has collaborations with qualified international institutions and companies through collaborative European projects, and is ready to respond to the needs for new knowledge of the manufacturing companies of the entire ceramic industry in various application sectors. ISTEC participates to education and training initiatives at all levels: it hosts a Degree course at the University of Bologna and owns a Doctoral School in association with the University of Parma. At ISTEC there are over a hundred people with 36 permanent employees, 32 fixed-term employees and 23 associates; it also hosts students, graduates, scientists from all over the world.

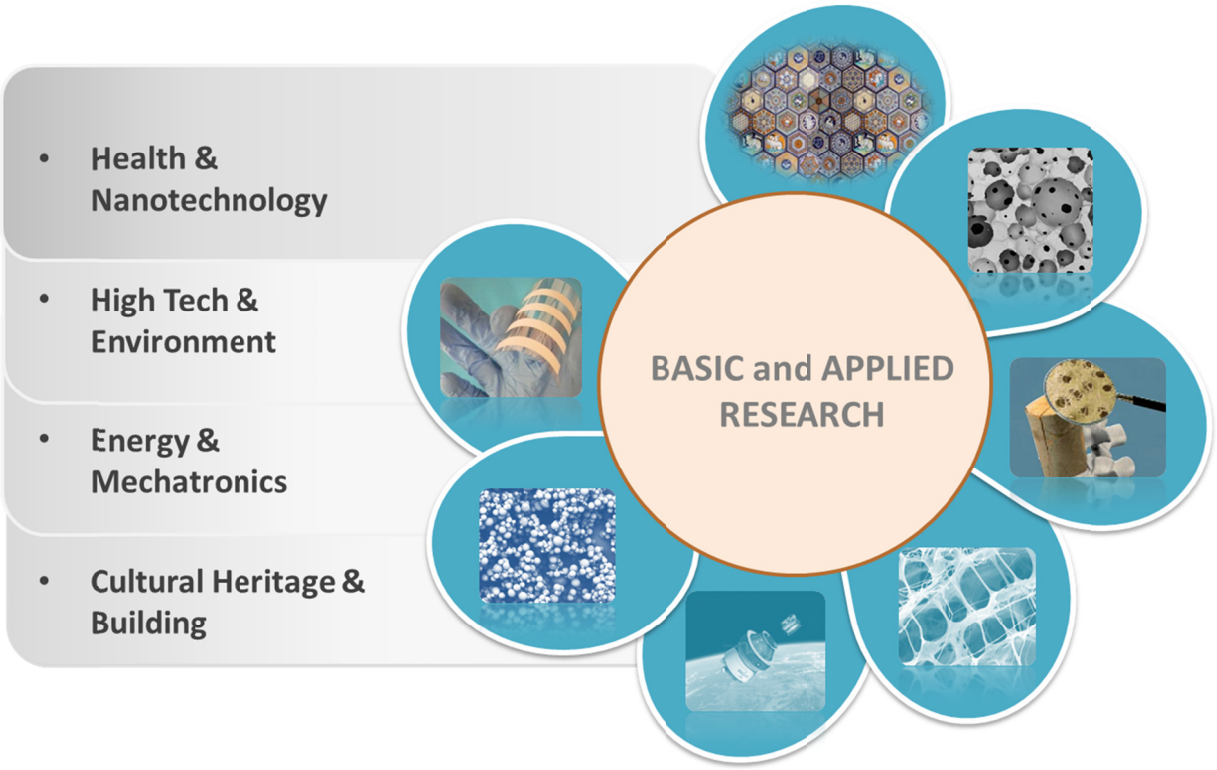
7th of July 2017

Director
Dr. Anna Tampieri

Mission of ISTEC:

- ✓ **to perform basic and applied research**
- ✓ **to promote innovation and competitiveness in the industrial system**
- ✓ **to contribute to the qualification of human resources**
- ✓ **to promote internationalization**
- ✓ **to advice government and other public bodies**
- ✓ **to provide technological solutions for emerging public and private needs**

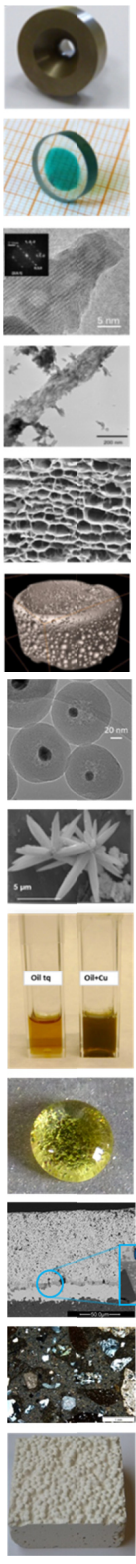
Basic & applied Research:

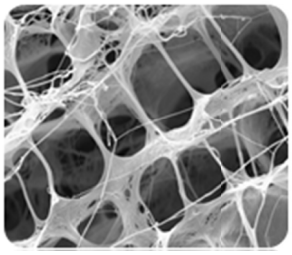


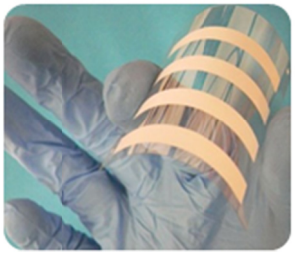
Research

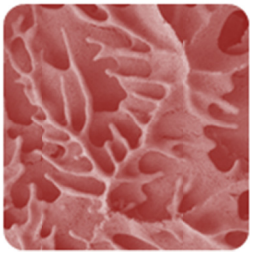
Innovative Materials and Processes

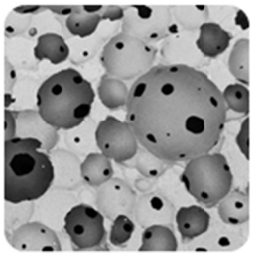
- **Ultrarefractory flaw tolerant ceramics:** sintered borides (ZrB_2, HfB_2) and carbides (ZrC, HfC) ceramic matrices reinforced with short or continuous C/SiC fibers.
- **Wear, corrosion resistant and textured hard ceramics:** sintered oxide and Non-oxide ceramics (SiC, HfC, ZrB_2) with textured surfaces via chemical / physical etching.
- **Solid oxide cells and electrolyzers materials**: ionic conductors (anionic (Zr,Y)O2, (Zr,Sc)O2, Ce1-xGdxO2-d; protonic Ba(Ce,Y)O3, (La,Sr,Ga,Mg)O3), mixed electronic-ionic conductors (NiO-based, (Sr,La,Ti)O3 -based, (La,Sr,Cr,Mn)O3, (LaSrFeCo)O3-based, (LaSrMn)O3-based).
- **Gas separation membranes materials**: oxygen separation ((LaSrFeCo)O3-based, (LaSrMn)O3-based), hydrogen separation (Ba(Ce,Y)O3-based).
- **All solid ceramic sodium batteries materials**: anode (Na2Ti3O7 –based), electrolyte (Na-β''alumina; YSZ -Na-β''alumina), cathode (Na(Mn, Fe, Ti)O).
- **Transparent Ceramics:** sintered polycrystalline optically isotropic transparent oxides like YAG ($Y_3Al_5O_{12}$) and spinel ($MgAl_2O_4$) and Sc_2O_3, Lu_2O_3; pure or doped with rare earth ions in tailored architectures and controlled dopant distribution.
- **Dual Composites:** sintered ceramic bulk composites with multi-scale architectures for multiple uses in extreme environments.
- **Bioactive ceramics and multifunctional bioresorbable phases:** multisubstituted apatitic phases MgCHA, SrHA, FeHA, TiHA, FeTiHA.
- **Hybrid bioceramics and nano-composites:** nanocrystalline ceramic phases nucleated and grown on natural templates and synthetic polymers.
- **Polymeric hydrogels and conducting polymers:** natural, synthetic and biohybrid materials tunable by means of cross-linking reactions.
- **Bioresorbable porous biomimetic ceramics:** biomorphic transformation of natural templates into CaP phases for load-bearing bone segments.
- **Biomimetic bioresorbable bone cements** for vertebral body regeneration.
- **Geopolymers and geopolymer based composites:** syntetic alkali-aluminosilicates and chemically bonded phosphate ceramics for high temperature applications, chemical engineering and recycling.
- **Nano-particles and Micro-beads:** magnetic bioactive phases, electro-conductive and catalytic ceramics.
- **Superhydrophobic and superhydrophilic materials:** ceramics, glasses, metals and alloys with extreme water repellence/affinity.
- **Oleophobic, Amphiphobic** (superhydrophobic + oleophobic) **materials**.
- **Nanolubricants:** metallic- and oxide-based nanoparticles incorporated in oils.
- **Ceramic textile:** anti-pollution textile functionalised through sol-gel deposition of dispersed ceramic nanophases (Ag, TiO_2…).



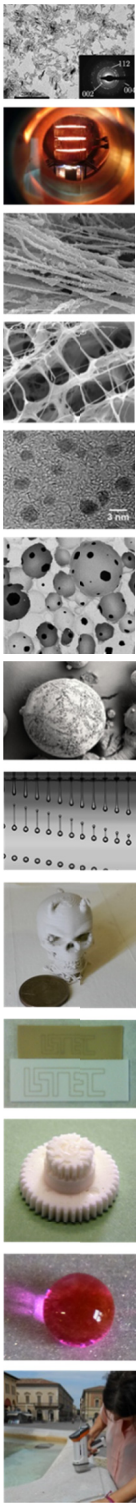


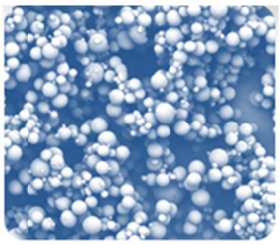






- **Engineered colloidal phases:** nano-metal, nano-metal oxide, core-shell structures, nano-pigments, ceramic inks.
- **Multiferroic composites:** particulate and laminate.
- **Hydraulic mortars based on lime (CL or NHL) and metakaolin,** with different physical-mechanical properties, for restoration interventions and green building.
- **Non-conventional and wet synthesis: sol-gel synthesis, hydrothermal synthesis, geo-polymerization, MW assisted, microemulsion, co-precipitation.**
- **Sintering: pressureless sintering under high vacuum, hot pressing.**
- **Biomineralization processes**: **heterogeneous nucleation of inorganic nanophases on self-assembling natural and synthetic polymers.**
- **Cross-linking processes: chemical treatment, Michael click enzymatic reaction, thermal process.**
- **Colloidal processing: heterocoagulation, surface powder functionalization.**
- **Biomorphic transformation: ceramization processes** (multi-step process that enables the natural structures to be transformed into hierarchically organized ceramics); **PIP** (polymer infiltration and pyrolysis); **flash pyrolysis** (ultrafast pyrolysis of thin layers of ceramic precursors).
- **Forming processes: freeze-granulation, emulsion processes, tape-casting, infiltration & vacuum bagging, gel casting, ink jet printing, 3D printing, foaming processes** (direct and indirect foaming)**, freeze casting** (porosity graded structures, isotropic/anisotropic porosity).
- **Molecular imprinting techniques:** tailored microstructure for specific molecule interaction (sensing, conduction, etc..).
- **Powder engineering: core-shell synthesis, matrix encapsulation, spray-drying and spray-freeze drying technologies, powder granulation, cold isostatic pressing, pelletizing.**
- **Digital control and additive manufacturing: 3D printing, 3 axis dispensing system, decoration, glazing, smart surfaces.**
- **Thick film deposition: screen printing, tape casting.**
- **Thin film deposition: spray coating, spin coating, dip coating, electrophoretic deposition, ink jet, physical vapor deposition, roller printing.**
- **Composite's architecture engineering: particulate, laminated, functionally graded materials etc.**
- **Surfaces functionalization: linking of organic molecules, coating with inorganic nanoparticles (dip or spray coating, electrophoretic deposition, plasma coating).**
- **Archaeometry and diagnostic investigations for Cultural Heritage: studies of provenance, reconstruction of working-production methodologies, identification of deterioration forms and mechanisms for ceramic, stone and mosaic materials.**





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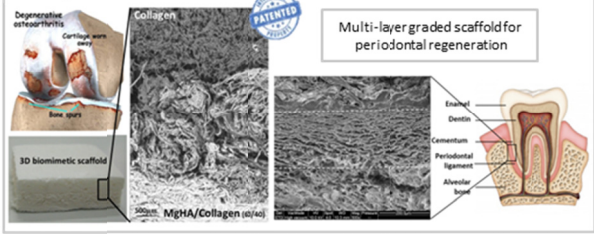
Bioceramics and Hybrid Composites for Health

The concept inspiring the Research Group on Bioceramics and Hybrid Composites for Health is the development of biomimetic materials in form of 3D structures or nanoparticles able to be recognized by the human body as quasi-autologous, to perform their reparative and/or regenerative action, and to be recruited in the natural metabolic processes. The nature-inspired approach generates innovative materials able of unprecedented smart performances.
The investigation of the interaction between the 3D structure and cells is a key topic, as well as the research on new functionalities triggering remote activation and/or enabling guiding in vivo. This approach, finalized to the recruitment of endogenous biologic factors, paves the way towards personalized medicine.

1. Regenerative medicine

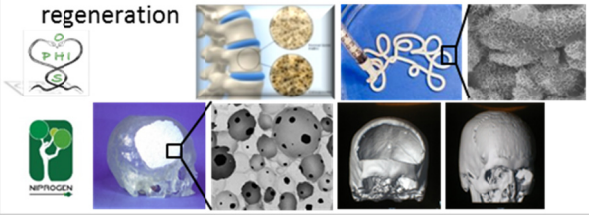
Hybrid biomimetic nano-composites:

3D scaffolds for the regeneration of multi-functional anatomical regions like **osteochondral** and **periodontium**



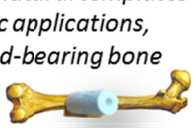
Biomimetic bioactive multi-substituted hydroxyapatite:

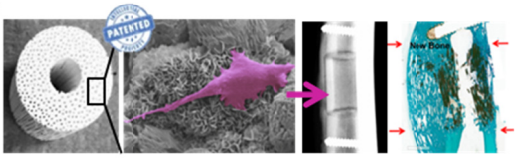
- to customize porous ceramic scaffolds for **cranial** and **maxillofacial** defects
- to develop bone **cements for vertebral body** regeneration



Hierarchically organized scaffold for long bone regeneration

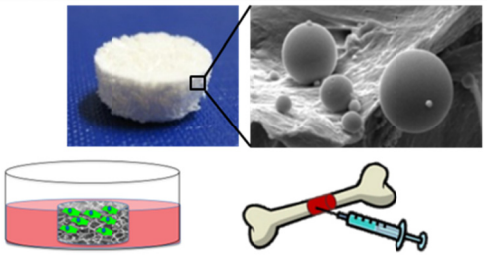
Biomorphic transformation of natural templates into CaP phases: for orthopedic applications, targeted to regeneration of load-bearing bone segments.





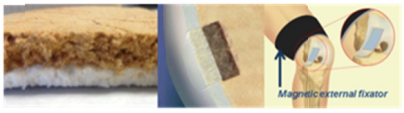
Biomimetic matrices:

- **3D porous scaffold and injectable hybrids gels for bone tissue regeneration**
- **3D bone-like matrix incorporating functionalized hybrid nano-beads**
- **3D model resembling bone marrow niche to predict tumors**
- **in vitro predictive analyses for *myeloid leukemia***

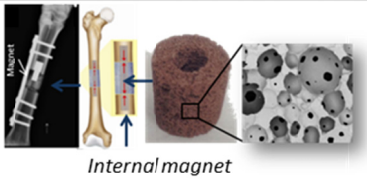


Ceramic and hybrid magnetic implants based on Fe(II, III)- substituted hydroxyapatite:

- ***3D scaffolds for bone and osteochondral regeneration with controllable bioactivity and vascularization***
- ***new fixator system using magnets activator***

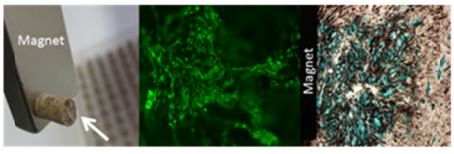


Three-layer graded osteochondral scaffold



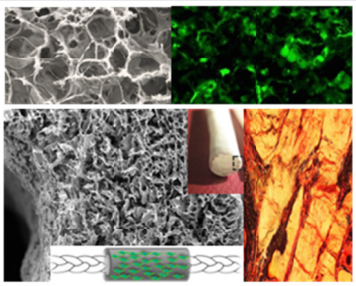
Internal magnet

Magnetic ceramic and hybrid (FeHA/Coll) bone devices



Smart polymeric blends and cross-linking agents with multiple functions:

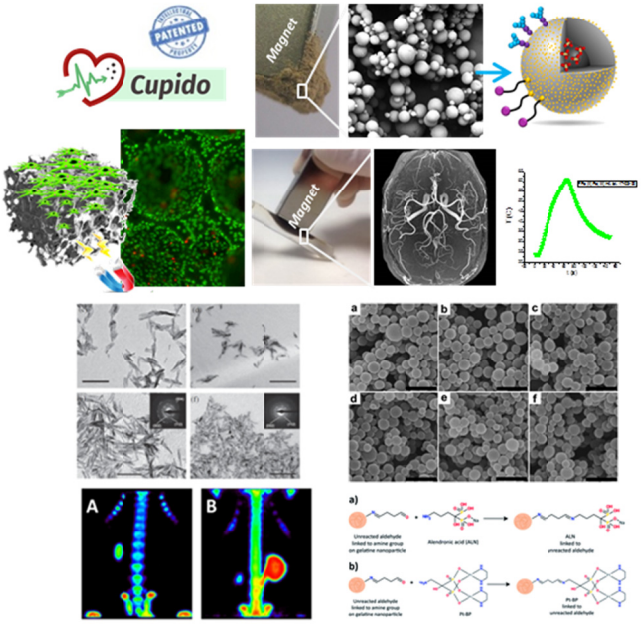
- engineered (stroma-like) organomorphic scaffolds for ex-situ regeneration of tissues and organs (thyme, thyroid…)
- functionalized membrane for cardiac function restoration
- scaffolds for tendon replacement and regeneration
- scaffold for cartilage regeneration



2. Nanomedicine

Biocompatible and bio-inspired functionalized micro and nanoparticles:

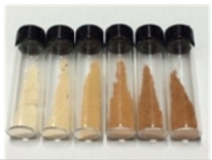
- biodegradable drug delivery systems for *targeted therapy*
- smart *pH-sensitive* drug nano-carriers
- magnetic Fe-HA as contrast agent for *imaging* (MRI)
- *theranostic* agents for *personalized nanomedicine*
- endowed with hyperthermia effect for *cancer therapy*
- for *cells magnetization* and cell therapy
- for *magnetofection* and genetic therapy
- for *early diagnosis* in tumor (μ-RNA recruitments)



3. Cosmetic

Bioactive multi-substituted hydroxyapatite:

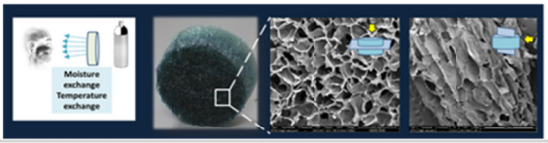
- basic material for make-up
- skin rejuvenation
- increasing of skin permeability
- physical filter in sunscreen lotion



4. Health disposable

Smart filters for gases and liquids

- HME filter for tracheostomized patient (Medical field)
- Filter for nanoparticles capture (Mask for military)
- Water remediation



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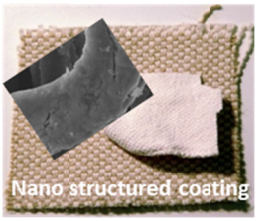
NanoTechnology and NanoSafety

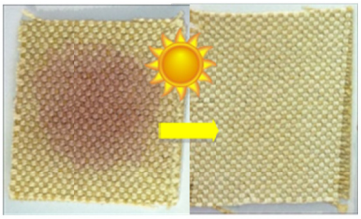
The main goal of the Research Group on Nanotechnology and Nanosafety is the development of nano-enabled products, focusing on the upscaling from molecular to nano-, micro-, up to macro-scale. Technologically relevant applications have been developed in the field of clean-technology and protection of human health and environment, with a special attention to new composite materials (ceramic textiles).
The investigation of properties and mechanisms at the nano/micro scale allowed the engineering of active nano-phases and the control of their interaction with embedding matrices and biological targets, under a nano-safety prospective. The safety-by-product design is now a key topic of the group but also of the European nanosafey community, due to its ability to prevent and control potentially adverse effects generated by nano-objects handling.

1. Ceramic Textile (self cleaning, flame retardant, antimicrobial)

Self-cleaning textile (stain removal, anti-odor):

- Nano-TiO_2 based coated textile catalyze UV-light degradation of pollutants and bacteria adsorbed into

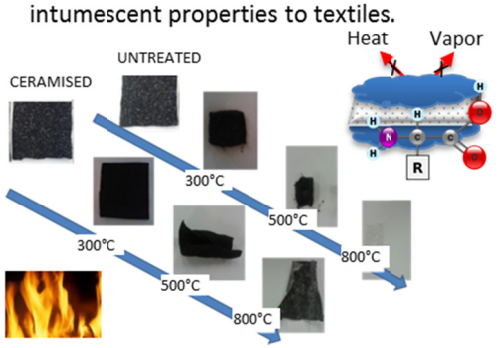




Self-cleaning properties demonstrated by decoloration of wine stain under sunlight; Production of 1000 m of solar light activated self-cleaning textile (**TRL 6**)

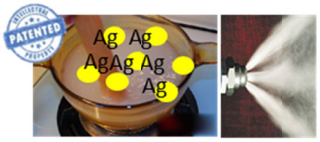
Flame retardant textile:

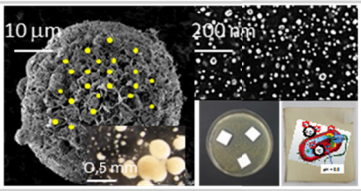
- Ceramic and protein-based coating confers intumescent properties to textiles.



Green Matrix Encapsulating Structures for the Controlled Release of Antimicrobials

- Nano Ag reservoir nucleated on a hydro-gel of soluble cellulosic templating agent.

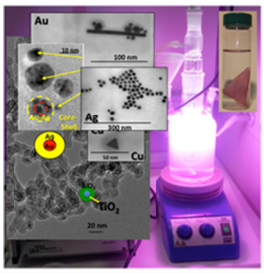




2. Nanocatalysis

Supported Nano-Catalysts for:

- Photo-degradation of Air and Water pollutants
- Bio-mass treatments



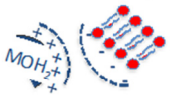
Pilot plants from 6L , 10L to 100L volume, for the advanced oxidation treatment of water

3. Nano-Safety by Design

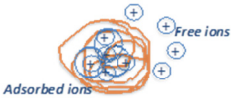
EU Projects: Sanowork SUN protect

Design alternatives for the preventive control of potential nanomaterial RISK

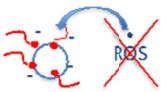
***GRANULATION** for the **CONTROL** of EMISSION POTENTIAL (aereosolisation)*



***SURFACE CHARGE MODIFCATION** for the **CONTROL** of the interaction with CELLS membranes*



SURFACE COATING** for the **CONTROL** of ions **RELEASE



***SURFACE COATING** with **ANTIOXIDANT MOLECULES** for the **CONTROL** of ROS*

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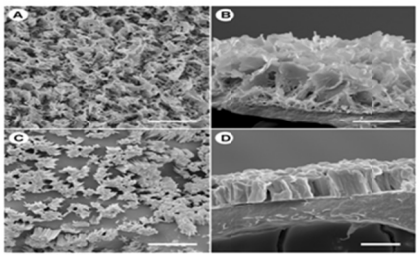
Smart Surfaces

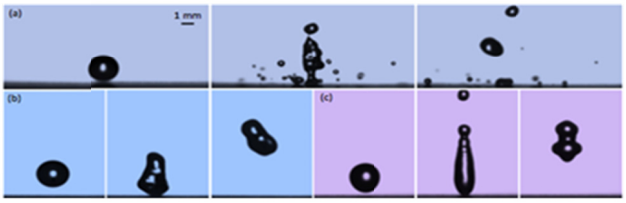
In the field of wetting control, ISTEC has developed a significant know-how in terms of design strategies, materials and processes to enhance the static and dynamic repellence of metals, alloys, natural fibers, glass against water, oils and lubricants. Contact angles (CAs) with water as high as 179° coupled with oils/lubricants (surface tension < 30 mN/m) contact angles up to 140°, CAH < 10° (leading to efficient drop rebound) and surface energy < 1 mN/m are obtained. The design and application of superhydrophobic (SHS), oleophobic and amphiphobic (AMP=oleophobic+superhydrophobic) surfaces involve great advantages in many industrial sectors where i.e. anti-soiling, drag and friction reduction, anti-fouling, de-frost, anti-icing properties are required.

1. Lotus-like and SLIPS surfaces: biomimetic approaches



- ***AMP surfaces obtained by Lotus leaf approach. Solid surface working in a solid-liquid-air interface***
- ***"Infused" AMP surface: SLIPS approach, generation of Liquid surface working in a liquid-liquid interface***

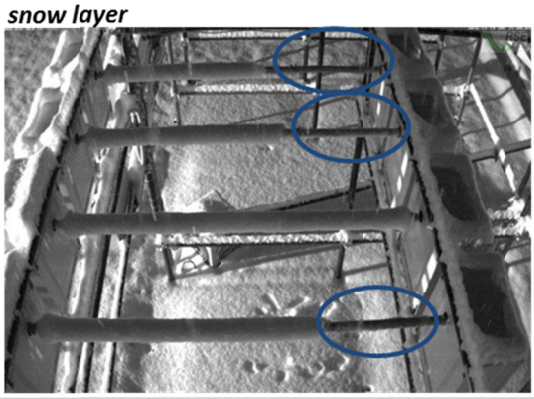
2. Liquid drop rebound on AMP surfaces



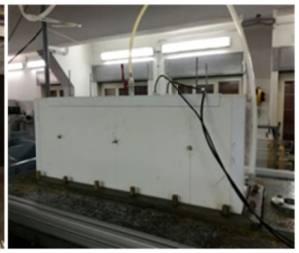
- ***Extreme dynamic repellence of liquids on the surfaces***
- ***Enhanced sliding or rolling motion of droplets***
- ***Liquid (water) drop rebound of few ms***
- ***Receding angle values up to 150-160°***
- ***CAH lower than 5°***

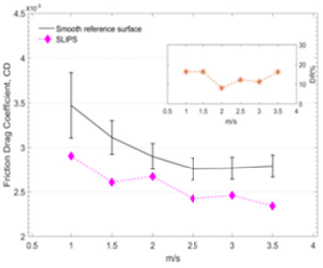
3. Icephobic AMP surfaces

- ***AMP coatings deposited on smooth and rough Al electric cables, exposed in outdoor facility***
- ***Icephobic attitude in terms of an easy detachment or a delay in the accumulation of the snow layer***



4. Friction and drag reduction





- ***AMP surfaces by SLIPS approach perform better than the Lotus-like***
- ***Frictional drag reduction provided by SLIPS up to 10-15%***

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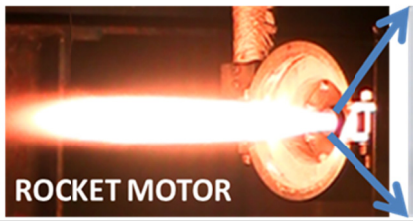
Hi-Tech Ceramics and Composites for Severe Environments

Since 2000, a team of researchers has devoted a great effort to study and develop innovative hi-tech ceramics and composites operating in severe conditions. The combination of extremely hot temperatures, chemically aggressive environments and rapid heating and cooling is beyond the capabilities of current materials. New concept composites design enables to overcome the ceramics brittleness, merging damage tolerance and capacity of withstanding ultra-high temperature regimes in chemically aggressive environments. Added-value materials with self-repairing capability are under development. The R&D activities span from the fundamental understanding of the process-microstructure-property correlations to the realization of technological demonstrators to be validated in relevant envelopes.

1. Near Zero-ablative oxidation-resistant UHTC for reentry and propulsion

Ultra-high temperatures ceramics (UHTCs)

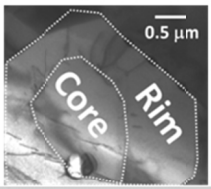
- **Compositional design** and sintering by PLS, hot-pressing (HP) and SPS of IV-V group transition metal borides or carbides;
- Lab-scale **leading edges and nozzles** were fabricated and tested in **relevant conditions;**

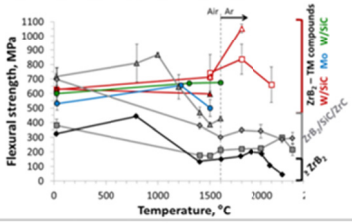


2. Super-strong materials at temperatures exceeding 2000°C

Addition of **W-based phases** to transition metal diborides (MeB_2) to

- develop **core-rim** sub-structures
- increase **refractoriness**
- improve **high temperature strength and toughness**
- provide **oxidation resistance**
- enable **self-healing capability**

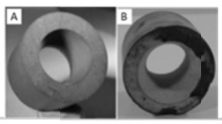




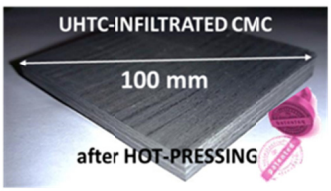
3. Damage tolerant UHTCMCs

Ceramic matrix composites (CMCs) and ultra-high temperature ceramics (**UHTCs**) are combined to obtain materials with outstanding resistance to

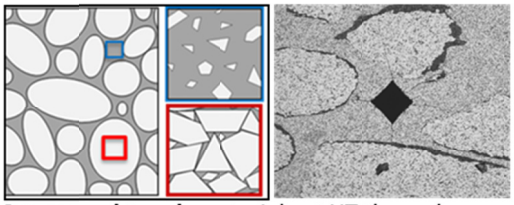
- erosion, ablation and oxidation
- thermal shock



C3HARME HORIZON 2020

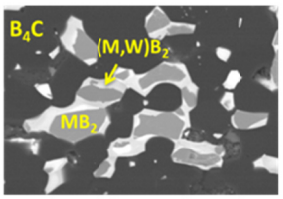


4. Dual Composites



Strong and tough materials at HT through **multiscale** length microstructure architectures

5. Super-hard light ceramics



Machinable B_4C-based composites for wearable **ballistic protections**

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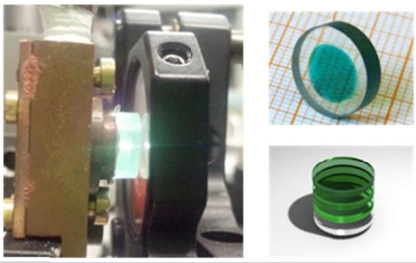
Transparent Ceramics

The concept driving the Research Group on Transparent Ceramics is the development of polycrystalline oxide ceramics that allow light in a wide spectral range to pass through them without scattering losses. By the addition of appropriate ions these materials absorb, emit or transmit light at different wavelengths and can be used in solid state lasers, IR windows, light conversion or detection of radiation and particles, as well as operate in harsh and extreme environments with good mechanical resistance. The elimination of residual porosity, secondary phases and of the difference in optical behaviour between grains and grain boundaries are key topics, as well as the purity and morphology of raw materials. This approach, together with doping with rare earth ions in tailored architectures and controlled dopant distribution, paves the way towards emerging applications in optics and photonics.

1. Solid state laser sources

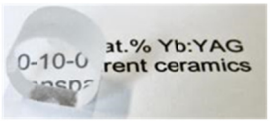
High efficiency solid state high power lasers for:

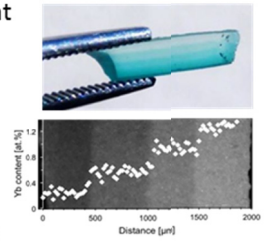
- medical diagnostic and therapy
- laser-driven fusion power plants



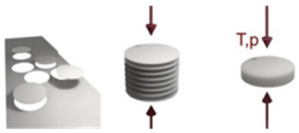
YAG ($Y_3Al_5O_{12}$) ceramics doped with rare earth ions

- complex architectures, controlled dopant distribution
- highly efficient and compact laser sources
- better thermal management

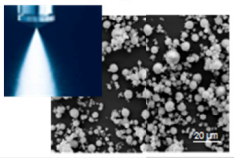




- different shaping methods: tape casting

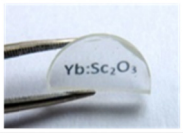


spray drying



Transparent sesquioxides doped with Yb^{3+} ions

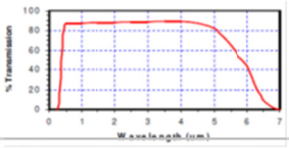
The combination of excellent optical and thermal properties makes Sc_2O_3 and Lu_2O_3 attractive host materials



2. Transparent armor

Magnesium aluminate spinel:

- optically transparent from near-UV through mid-IR frequencies
- to manufacture high performance optical components, such as lenses and IR windows
- protective windows for aircraft, ship and submarine sensors
- bulletproof windows

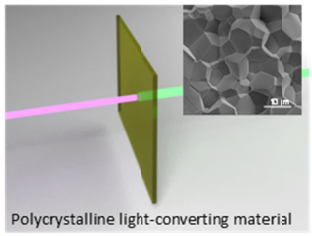


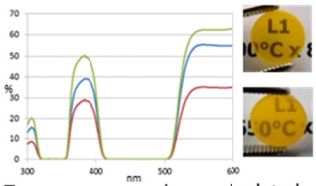
$MgAl_2O_4$

3. Optical materials, Photonics

Ceramic devices:

- transparent ceramic scintillators
- waveguides
- light converters
- LEDs





Transparency can be manipulated through the ceramic process

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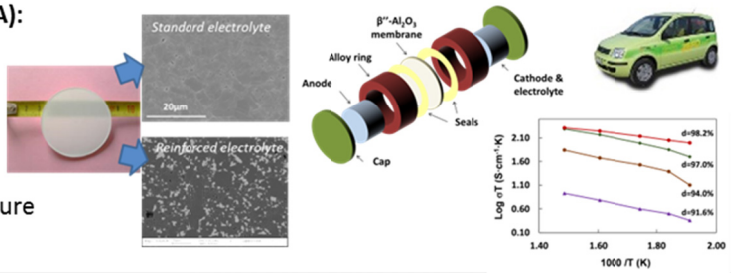
Materials and Devices for Energy Production and Storage

The increasing concern about the CO_2 emission and consequent global warming have pushed the research towards efficient materials and devices for energy production and storage, able to shift the fossil fuel economy towards a more sustainable one. In this sense, the group is strongly involved in developing new materials and devices produced with low cost, easily up-scalable and environmental friendly techniques. Great attention is paid moreover on using abundant and low cost raw materials and to the production of almost completely recyclable devices following the concept of an integrated circular economy.

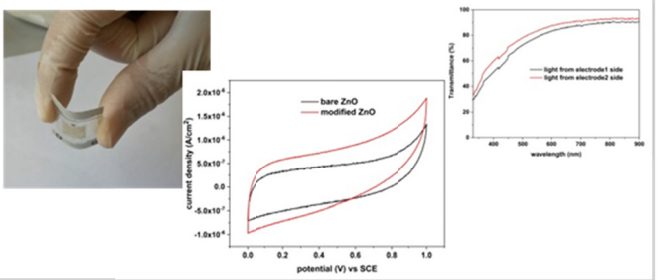
1. Energy Storage

High Temperature Ceramic Batteries (ZEBRA):
Large area planar beta-alumina electrolytic membranes with suitable conductivity and improved mechanical performances

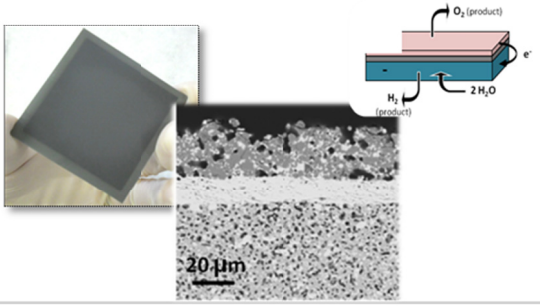
All-solid state ceramic sodium batteries:
Multilayer anode/electrolyte/cathode structure



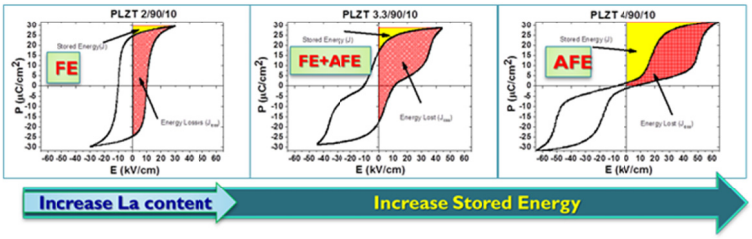
Supercapacitors:
- Micro-device architecture
- Transparent and flexible for portable applications
- Low costs materials and low temperature processes



Solid Oxide Electrolysis Cell (SOEC):
- Prototypal multilayer size
- Innovative one step sintering processes

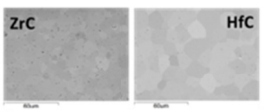


Ferroelectric/antiferroelectric materials:
- strain actuators
- high energy storage capacitors
- pulsed power generators

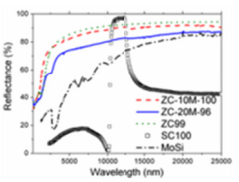


UHTCs ceramics for concentrating solar power systems

Dense and porous Ultra High Temperature ceramics as solar absorber to improve radiative properties and chemical stability at high temperature



Dense mirror-like polished materials



Reflectance spectra collected at INO for ZrC, SiC and $MoSi_2$

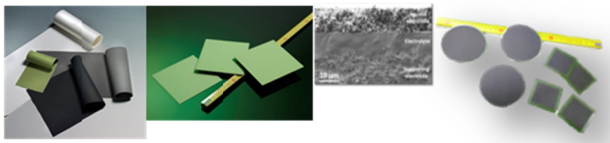
2. Energy Production

Dye-Sensitized Solar Cells (DSSCs):

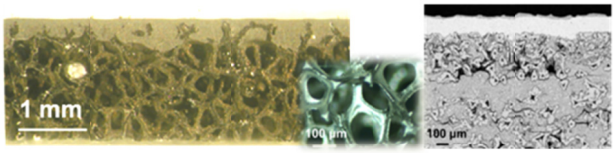
- Prototypes on rigid and fiber-shaped substrate
- Replacing Platinum at the counter-electrode
- Low costs processes developed
- Complete characterizations

Solid Oxide Fuel Cell (SOFC):

- Electrode-supported cells, prototypal size

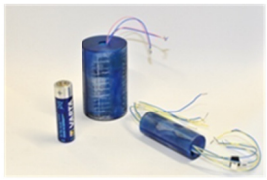


- Metal-supported cells, prototypal size



Energy conversion from vibrations:

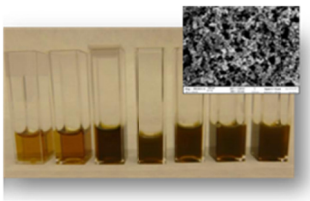
- core of smart structures and systems for wireless, self-powered sensor nodes
- High-energy density at relatively low mechanical strain–stress levels
- Portable electronics
- Domotics

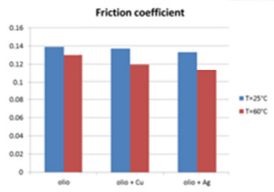


Micro energy Harvesting

3. Energy Smart Applications

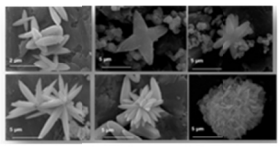
Nanolubricants & Catalytic Nanopowders

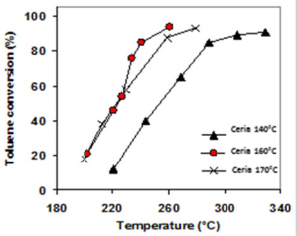




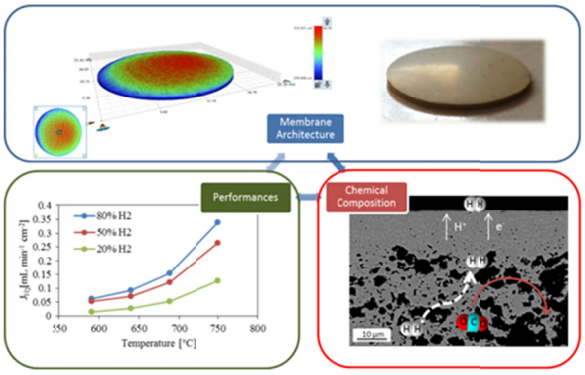
- Commercial oils additivated with Cu, Ag, TiO_2 nanoparticles for tribological applications

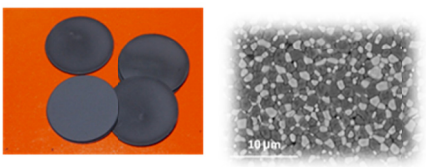
- Nanoparticles with enhanced catalytic properties





Gas separation membranes





- All-ceramic membranes with asymmetrical architecture devices for electrochemical O_2 and H_2 separation at high temperatures

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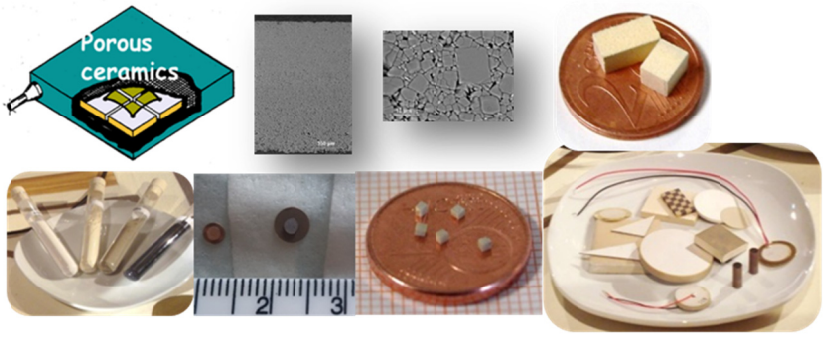
Multifunctional Electroceramics

Through a multidisciplinary approach and the design of innovative micro-nano-structures, we aim at combining several functions in the same structure in view of specific applications . The study is aimed at: i) materials with specific compositions for structural, electric, dielectric and anelastic characterization for basic studies, ii) piezoelectric materials for application in miniature wearable devices, III) engineered multi-functional structures of piezoelectric, conductive and magnetic (multiferroic) materials with different architectures (particulate, layered, compositional gradients etc), IV) process development related to the scale up (reliability of performance and reproducibility).

1. Mechatronics

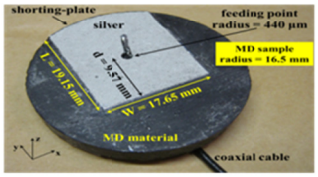
Smart piezoelectric ceramics:

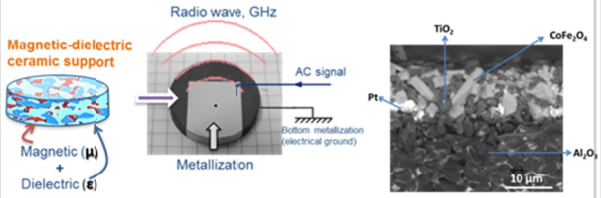
- Sensors and Actuators
- Flow metering
- Underwater acoustics
- Structural health monitoring
- Vibration dumping
- Portable devices



2. Communication

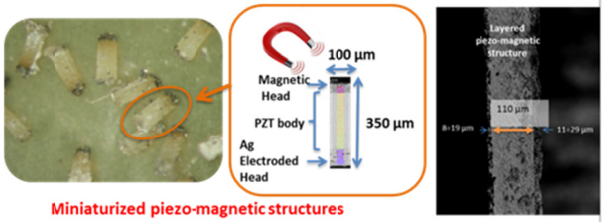
Magneto-dielectric composites for Antenna's miniaturization



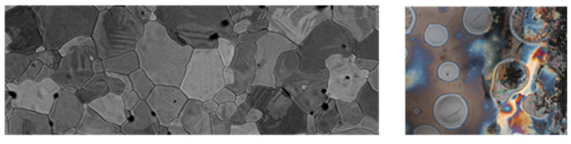


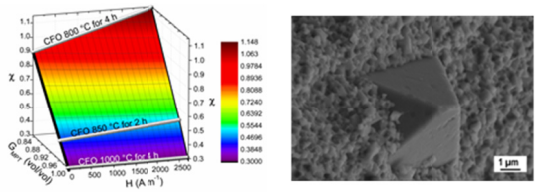
3. Data storage

Multiferroics :
Ultrahigh-density magnetic random-access memory, ultralow-power tunable radiofrequency/microwave magnetic devices, spintronic devices, and sensors for applications in the view of Internet of Things (IoT), Big Data, Mesh Networks, etc. scenario



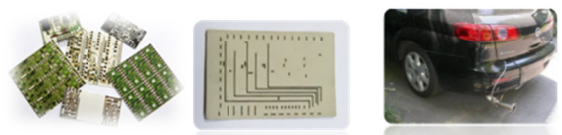
Miniaturized piezo-magnetic structures





5. Electronic Circuits & Gas Sensors

- High power microelectronic
- Conventional electronic circuits
- Oxygen sensors able to stand the aggressive conditions of the engine exhausts



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Geopolymers and Materials for Environment

Geopolymers are environmentally friendly ceramic-like materials, namely chemically bonded ceramics. A chemical reaction at T<100°C produces alkali-aluminosilicate or phosphate based synthetic inorganic polymers. The process is cheap because it avoids high temperature and industrial wastes and by-products can be recycled as raw materials or inert fillers.
Depending on the composition, geopolymers can be used for several applications exploiting their excellent high temperature and fire resistance, good chemical stability and mechanical properties. This technology was developed by mix design and studying raw materials reactivity, by tailoring the porosity or functionalizing the composition with secondary phases.

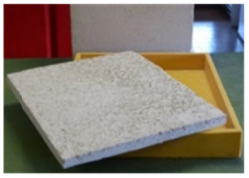
1. High Temperature Composites

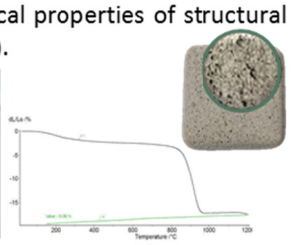
Refractories, insulation and thermal barriers for foundry, casting, transports, building and construction

- Thermal barriers: long fiber composites with vacuum bagging process (mix design and pot life).

Complex-shape prototypes realized by Air Force Service: exhaust pipe

- Casting – Insulation - Fire Proofing: fiber or particulate composites (evaluation of insulating and thermo-mechanical properties of structural and porous materials).

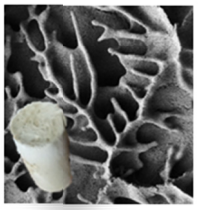


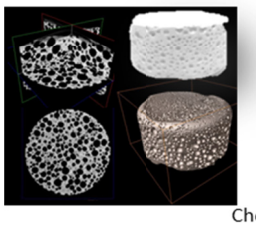


2. Chemical Engineering

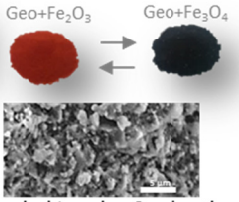
Hierarchically porous materials, sorbents and membranes for wicking, catalysis, filtration, gas separation

- Hierarchically porous matrices: process conditions for direct and indirect foaming, microstructural and textural characterization.
- Micro-meso-macro composites: mix design and process conditions, microstructural textural and functional characterization.

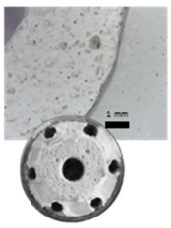




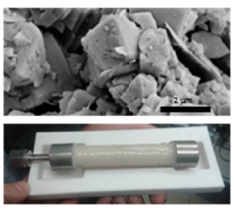
Freeze-casting and direct foaming



Chemical Looping Combustion and Tar Reforming (POR-FESR "TERMOREF")



Wicks in Loop Heat Pipe (PON Project «PANDION»)



Solid adsorbent for CO_2 and gas separation

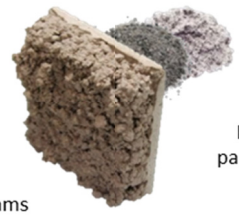
3. Recycling

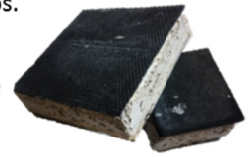
Chemically bonded ceramics and composites from recycled raw materials:

- Short fibers: basalt, natural wool, exhausted tires.
- Waste powders and coarse fillers: biomass ash, bottom ash, fly ash, silica fume, porcelain stoneware scraps.

Keratin-based composites for thermal insulation and agri-food applications

Silica fume geopolymer foams





Porous cores and sandwich panels from industrial wastes and by-products (POR-FESR «EEE-CFCC»)

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National Research Council of Italy
istec Institute of Science and Technology for Ceramics

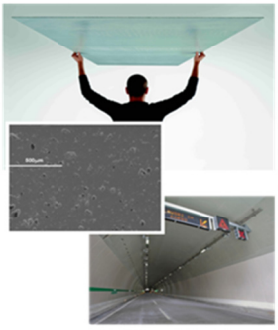
Ceramics for Construction and Cultural Heritage

Different approaches are behind research and development in the fields of ceramic building materials and cultural heritage. A strong emphasis on product and process innovation is required to support the needs of the ceramic industry, while in cultural heritage the knowledge of the material that constitutes the artworks is fundamental for their preservation and enhancement.
More efficient industry-academia cooperation in R&D is the key to strengthen the technological leadership of the Italian ceramic industry, particularly in the fields of ceramic tiles, sanitary ware, bricks and roof tiles, and connected sectors, like glazes and decoration, raw materials and machinery.
Cultural heritage: Studies of provenance, reconstruction of production methodologies, Identification of deterioration forms and mechanisms; development of innovative products for restoration.

Innovation in Ceramic Materials for Building and Construction

Advanced manufacturing:

Supporting industry in the development of **ceramic large slabs** (>5 m^2) by modelling technological behavior in **powder compaction** and **sintering**.
Design and development of **novel ceramic-based composite materials** for building and construction.



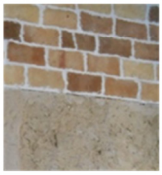
Resource efficiency:

- Valorization of **new raw materials** for ceramics.
- Promoting **recycling and waste-based** bodies.
- Improving the **efficiency in the use** of resources.
- Fostering **circular economy** in the ceramic chain.

Where Industry and Cultural Heritage Meet

Engineered solutions for urban renewal:

- *Ceramic-based composite panels with improved thermal, thermo-hygrometric, acoustic, and technological performances*
- *Hydraulic lime mortars and plasters as structural and aesthetic solutions for green building*



Novel ceramic materials for creative industries and art:

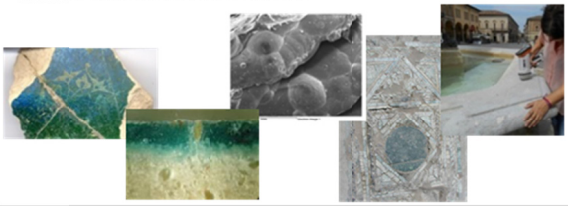
- Ceramic pigments, dyes and inks
- Ceramic glasses and glazes
- Colored geopolymers for art applications

Cultural Heritage

Archaeometry and diagnostics

Microstructural, chemical and physical characterization of ceramics, mosaics and mortars.

Diagnostic studies as support to conservation interventions.



New products and technologies for restoration

Mortars: *Hydraulic mortars based on lime (CL or NHL) and metakaolin, with different physical-mechanical properties, for restoration interventions*

Functionalized geopolymers: *Lightweight and reinforced multi-layers support for mosaic fragments; pivots for the joining of natural stone artifacts; restoration tesserae to fill lacunae.*

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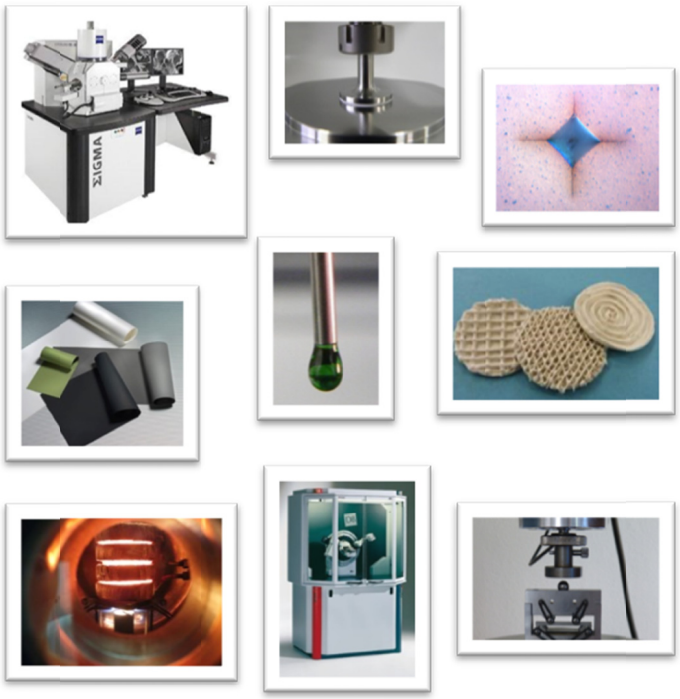
davide.gardini@istec.cnr.it

Technological Laboratories

- Rheology Laboratory
- Forming Laboratory
- Sintering Laboratory
- X-ray Diffraction Laboratory
- Thermal Analyses Laboratory
- Mechanical properties Laboratory
- Nano-indenter Laboratory
- Optical Microscopy Laboratory
- Electric & Magnetic Laboratory
- Cell/biomaterial interactions Laboratory
- Smart surfaces Laboratory
- 3D Printing Laboratory
- High Resolution Electron Microscopy Laboratory (FE and ESEM™)
- Porosity and Powder Characterization Laboratory
- Chemical Synthesis Laboratory
- Analytical Chemistry Laboratory
- Nanoceramics Laboratory



Contracts with Industries

- ALIVA Srl
- AMG INGEGNERIA DI GINO MARTONE
- AREA IMPIANTI SpA
- BETTINI Srl
- CURADEN HEALTHCARE spa
- CURASEPT ADS Srl
- ECAMRICERT Srl
- EUROARCE Srl
- European Central Bank
- FINCANTIERI
- FIN-CERAMICA SpA
- GREEN BONE ORTHO Srl
- INDUSTRIE BITOSSI SpA
- INNOVARCILLA FOUNDATION
- INTERCOS SpA
- ITT ITALIA Srl
- JODOVIT Srl
- KALICHEM ITALIA srl
- Keser Italia
- LAMINAMP SpA
- MEDIA LARIO Srl
- MECCANOTECNICA UMBRA
- MONTERESEARCH Srl
- MTK Srl
- PHOENIX ARCHEOLOGIA
- POLYGLASS
- POZZI-GINORI SpA
- RICERCA SUL SISTEMA ENERGETICO -RSE SpA
- SAB AEROSPACE Srl
- SACMI IMOLA SC
- SICER SpA
- SITI -B&T GROUP SpA
- SYSTEM SpA
- TAMPIERI ENERGIE Srl

European Projects (2012-2017)

- **Cupido:** H2020-NMBP-10-2016-RIA–EU(2017-20) *Cardio Ultraefficient nanoParticles for Inhalation of Drug prOducts.* Coord. CNR. Ref. person: anna.tampieri@istec.cnr.it
- **PROTECT:** H2020-NMBP-PILOTS-2016-720851 (2017-21) *Pre-commercial lines for production of surface nanostructured antimicrobial and antibiofilm textiles, medical devices and water treatment membranes.* Ref. person: anna.costa@istec.cnr.it
- **C^{3}HARME:** H2020-NMP-19-2015-RIA-685594 (2016-20) *NEXT GENERATION CERAMIC COMPOSITES FOR COMBUSTION HARSH ENVIRONMENTS AND SPACE* Coord. ISTEC. Ref. person: diletta.sciti@istec.cnr.it
- **STAGE-STE:** EERA-ENERGY.2013.10.1.10 (2015-18) *SCIENTIFIC AND TECHNOLOGICAL ALLIANCE FOR GUARANTEEING THE EUROPEAN EXCELLENCE IN CONCENTRATING SOLAR THERMAL ENERGY.* Ref. person: diletta.sciti@istec.cnr.it
- **BIO-INSPIRE:** PITN-GA-2013-607051 (2013-17) *Bio inspired bone regeneration.* Ref. person: simone.sprio@istec.cnr.it
- **LIGHT-TPS:** SPACE-2013-1-CP-FP-607182 (2013-17) *Super light-weight thermal protection system for space application* Ref. person: laura.silvestroni@istec.cnr.it
- **SUN:** NMP4-LA-2013-604305 (2013-17) *Sustainable Nanotechnologies.* Ref. person: anna.costa@istec.cnr.it
- **SMILEY**: NMP-2012-SMALL-6-310637 (2012-15) *Smart nano-structured devices hierarchically assembled by bio-mineralization processes.* Coord. ISTEC. Ref. person: anna.tampieri@istec.cnr.it, alessanda.sanson@istec.cnr.it
- **SANOWORK:** NMP4-SL-2012-280716 (2012-2016) *Safe nano worker exposure scenarios*. Coord ISTEC. Ref. person: anna.costa@istec.cnr.it
- **EVOLVE**: FCH-JU-2011-1 (2012-2016) *Evolved materials and innovative design for high performance, durable and reliable SOFC cell and stack*. Ref. person: alessandra.sanson@istec.cnr.it
- **NANoREG**: contract n. 310584 (2012-15) *A common European approach to the regulatory testing of Manufactured Nanomaterials.* Ref. person: anna.tampieri@istec.cnr.it
- **THE PIEZOINSTITUTE:** NMP-2011-CSA-5 (2010-14) *European Expertise Centre for Multifunctional and Integrated Piezoelectric Devices.* Ref. person: carmen.galassi@istec.cnr.it
- **SENERES:** REGPOT-2011-1 (2011-2014) *Sustainable Energy research and development center.* Ref. person: carmen.galassi@istec.cnr.it
- **BFUNTEX:** NMP-201-2-3-3 *Networking of materials laboratories and innovation actors in various industrial sectors for product or process innovation.* Ref. person: anna.costa@istec.cnr.it
- **OPHIS**: NMP-FP2466373-2 (2010-14) *Composite Phenotypic Triggers For Bone and Cartilage Repair.* Coord. ISTEC Ref. person: anna.tampieri@istec.cnr.it
- **E2PHEST2US:** ENERGY-2009-2-5-1 (2010-12) *Enhanced energy production of heat and electricity by a combined solar thermionic-thermoelectric unit system.* Ref. person: diletta.sciti@istec.cnr.it
- **MAGISTER**: NMP3-LA-2008-214685 (2008-13) *Magnetic Scaffolds For In Vivo Tissue Engineering.* Ref. person: anna.tampieri@istec.cnr.it
- **IDEAL-CELL:** ENERGY-2007-1.1-03 (2007-12) *Innovative dual membrane fuel cell.* Ref. person: alessanda.sanson@istec.cnr.it
- **TEM-PLANT:** NMP4-CT-2006-033277 (2008-12) *New bio-ceramization processes applied to vegetable hierarchical structures.* Coord. ISTEC. Ref. person: anna.tampieri@istec.cnr.it

National Projects (2017)

- **SUPERSOLAR:** *Ultra-refractory ceramic absorbers for thermodynamic solar energy generation at high temperature.* Ref. Person: Dr.ssa Laura Silvestroni
- **PROBIOPOL:** *Innovative and sustainable production of biopolymers.* Ref. Person: Dr.ssa Anna Luisa Costa
- **Accordo di Programma MiSE-CNR**: *Sistemi elettrochimici per la generazione e l'accumulo di energia.* Ref. Person: Dr.ssa Alessandra Sanson
- **Accordo di Programma MiSE-CNR**: *Materiali e tecnologie abilitanti per la ricerca di sistema elettrico: materiali e componentistica.* Ref. Person: Dr.ssa Alessandra Sanson
- **PIACE**: *Piattaforma intelligente, Integrata e Adattativa di microCogenerazione ad elevata Efficienza per usi residenziali.* Ref. Person: Dr.ssa Alessandra Sanson

Projects of Defense and Foreign Affair Ministry (2017)

- **P. Grande Rilevanza Italy-USA**: *Utrahigh temperature ceramic matrix composites by additive manufacturing using polymer precursor.* Ref. Person: Dott.ssa Diletta Sciti
- **FabricSafe**: *Difesa dell'individuo tramite fabbricazione di tessuti agenti da protezione attiva e passiva.* Ref. Person: Dr.ssa Anna Luisa Costa
- **BALTIC**: *Sviluppo e ingegnerizzazione di protezioni balistiche ad alta prestazione a base di composti ceramici TiB2-B4C.* Ref. Person: Dr.ssa Diletta Sciti
- **CeMiLAP:** Ceramiche Microstrutturate trasparenti per applicazioni Laser di Alta Potenza: sviluppo e validazione. PNRM project. Ref. Person: Jan Hostasa
- **T-SC:** *Transparent Spinel-based Ceramic materials for strategic aerospace applications.* ***Italy-Israel*** bilateral technological cooperation. Ref. Person: Valentina Biasini

Regional Projects (2017)

- **NIPROGEN**: *La natura ispira processi innovativi per lo sviluppo di impianti per la medicina rigenerativa a elevato grado di vascolarizzazione e performance meccaniche.* Persona di contatto: Dr. Simone Sprio
- **TERMOREF***: Integrazione di processi termochimici e reforming su biomasse di scarto e valorizzazione dei prodotti con un approccio a rifiuti zero.* Ref. Person: Dr. Francesco Miccio; Dr.ssa Elena Landi
- **NANOCOATINGS:** *Nuovi film antibatterici nanostrutturati per applicazioni in campo biomedicale.* Ref. Person: Dr. Simone Sprio
- **EEE CFCC:** *Evoluzione Economicamente ed Ecologicamente sostenibile di Compositi Fibrorinforzati a matrice Ceramica in forma Complessa*. Ref. Dr.ssa Valentina Medri
- **Hi-SCORE**: *Hi Performances Sustainability and COst REduction in machine tool industry.* Ref. Person: Dr. Frederic Monteverde
- **MATER_SOS:** *Materiali sostenibili per il ripristino e la realizzazione di nuovi edifici.* Ref. Person: Dr.ssa Chiara Zanelli
- **IPERCER:** *Innovazione di processo per la filiera della piastrella ceramica sostenibile.* Ref. Person: Dr. Michele Dondi
- **HEAT:** *Nano coated Heat ExchAnger with improved Thermal performances.* Ref. Person: Dr.ssa Mariarosa Raimondo
- **INVOLUCRO:** *Sistemi innovativi, adattativi e sostenibili per l'involucro edilizio ad alte prestazioni energetiche ed acustiche.* Ref. Person: Dr.ssa Chiara Zanelli

Training & Education

ISTEC CNR is involved in higher education initiatives at all levels, Master degree, post graduate courses, Ph.D. collaborations, European union initiatives to promote excellent Scientists

Ph.D. in «Science and Technologies of Materials» ISTEC ownership with University of Parma
Ph.D. in «Chemistry» - course "Processes and applications of ceramic materials" in collaboration with University of Bologna

MASTER Degree in «Chemistry and Technologies for the Environment and Materials»
Curriculum: Traditional and Innovative Materials, Faenza, in collaboration with University of Bologna

BiotechMA: Master Doctoral Multinational Course in Medical Biotechnology [2014-1-IT02-KA203-003482]
ISTEC: WP Leader

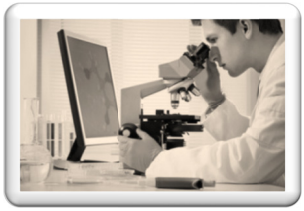
EUCERMAT: European Ceramic Material Project

The aim of the project is to significantly contribute to changing the general opinion about ceramics materials in Europe [2015-1-FR01-KA203-015209] ISTEC: WP Leader

Three year international joint Doctoral School in Sustainable Industrial Chemistry for the projects related to Photocatalytic production of chemicals and H2 from biomass

«Initial Training Network», BIO-INSPIRE Project
Bio-inspired bone regeneration
***Marie Curie Action* European Program**
ISTEC: WP Leader and Project Scientific Advisor

Ph.D. collaborations: Universidad Federal de Santa Catarina (Brazil); University of Ferrara (IT); University of Bologna (IT); University of Parma (IT); University of Trieste(IT); University of Prague (Czech Republic); Polytechnic of Turin (IT); University of IASI (Romania); University of Tor Vergata Roma (IT); University of Trento (IT); ISIA-Institute for artistic industry (IT); University of Palermo (IT); University of Chieti-Pescara (IT).



Technological Transfer

Creation of new enterprises through know how transfer and licensing of patents

ISTEC Patents (2000 – 2017)

- **[IT2003MI00186]** *Procedimento di sintesi di tessuto osseo artificiale, tessuto osseo artificiale ottenibile mediante tale procedimento e relativo uso.*
- **[IT2010MI02070]** *Impianti per sostituzioni ossee "load bearing" ad architettura gerarchicamente organizzata derivante dalla trasformazione di strutture vegetali.*
- **[IT2010MI01420]** *Idrossiapatite intrinsecamente magnetica.*
- **[IT2011RM00104]** *Metodo per il trattamento di superfici ceramiche per conferire alle stesse una elevata idrofobicità e oleofobicità.*
- **[IT2012TO00029]** *Impianto dentale od osseo, in particolare in nanocomposito allumina-zirconia.*
- **[IT2012MI00583]** *Materiale ceramico per ultra alte temperature (UHTC) a porosità gerarchica.*
- **[IT2012RM00291]** *Metodo per il trattamento di superfici metalliche per conferire alle stesse elevata idrofobicità e oleofobicità.*
- **[IT2014RM00326]** *Cemento iniettabile apatitico ionicamente multi sostituito per vertebroplastica rigenerativa.*
- **[ES20140031091]** *Process for obtaining fluoride-doped citrate coated amorphous calcium phosphate nanoparticles.*
- **[IT2014MI02207]** *Prodotti per la veicolazione di composti terapeutici/diagnostici al cuore.*
- **[MI2014U000387]** *Domanda di brevetto per modello di utilità: Pannelli compositi.*
- **[IT2015MI00130]** *Procedimento per la preparazione di nanoparticelle di metalli nobili in idrogel e nanoparticelle così ottenute.*
- **[IT2015UB02443]** *Processo e impianto a potenziale alternato per separazione di gas con membrane capacitive.*
- **[IT2015UB02962]** *Large 3D porous scaffolds made of active hydroxyapatite obtained by biomorphic transformation of natural structures.*
- **[102016000023596]** *Materiale composito costituiti da supporti organici e idrossiapatite sostituita con titanio e/o ferro per uso in celle solari a colorante organico.*
- **[102016000002346]** *Trasduttore integrabile per applicazioni aptiche.*
- **[102016000008310]** *Materiali compositi a base di fibre C con matrice ultrarefrattaria ad alta tenacità e resistenza all'ablazione.*
- **[102016000023614]** *Filtro solare fisico costituito da idrossiapatite sostituita in una matrice organica.*
- **[102017000022625]** *Filtro per lo scambio di calore e umidità per applicazione in campo medicale e procedimento per la sua produzione.*

Technological Transfer: our success stories

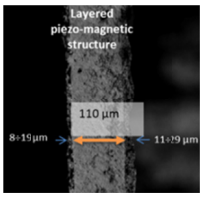
Creation of new enterprises through know-how transfer and licensing of patents

Finceramica S.p.A - www.finceramica.it

*Finceramica was founded in **1992**; the company is world leader in cranial reconstruction and one of the outstanding European producer for bone and cartilage substitutes.*

IPECC Srl

IPECC was founded in 2005 to provide engineering R&D services for piezo technology: manufacturers of inkjet printers, vibration control mechanisms, medical new device technologies and energy harvesting devices.



GREENBONE Ortho S.r.l. - www.greenbone.it

***Greenbone** was founded in **2014**, to develop highly innovative wood-derived bone implants: the unique regenerative solution for the cure of large comminuted or non-union fractures and other nasty skeleton damages.*
Second round of investment closed in June 2017 for 8.4 Million Euro

Dissemination (2012 - 2017)

CERMODEL 2017 International Congress
Modelling and Simulation Meet Innovation in Ceramics Technology
***Trento,* July 26 - 28, 2017**
Co-organizer: ISTEC-CNR & Trento University

CERMODEL 2015 International Congress
Modelling and Simulation Meet Innovation in Ceramics Technology
***Trento,* July 1 – 3, 2015**
Co-organizer: ISTEC-CNR & Trento University

International Workshop *"Mosaic: Archaeometry, Technology and Conservation"* held in *Faenza* from 2008.
10th Edition "MUSIWACAER" will be organized in *Impruneta (Florence)* in November 21 – 24, 2017.
Co-organizer: ISTEC-CNR & Musiwa: International Association for Art, Culture and Peoples

CEn 2017 International Congress
1st and 2nd *International Forum on Ceramics and Inorganic Materials*
***Faenza,* June 7 - 9, 2017**
Organized by ISTEC

MiMe 2013 International Congress
1st Edition - *Materials in Medicine*
***Faenza,* October 8 - 11, 2013**
Organized by ISTEC

ISTEC Staff

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DONDI Michele
GALASSI Carmen
GALIZIA Pietro
GARDINI Davide
GONDOLINI Angela
GUALTIERI Sabrina
HOSTASA Jan
IAFISCO Michele
LANDI Elena
MACCHIAROLA Michele
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MERCADELLI Elisa
MICCIO Francesco
MONTESI Monica
MONTEVERDE Frederic
NATALI MURRI Annalisa
ORTELLI Simona
PANSERI Silvia
PAPA Elettra
RAIMONDO Maria Rosa
RUFFINI Andrea
SANDRI Monica
SANGIORGI Nicola
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SCITI Diletta
SILVESTRONI Laura
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SPRIO Simone
VERONESI Federico
ZANELLI Chiara
ZOLI Luca

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CAMPODONI Elisabetta
DEGLI ESPOSTI Lorenzo
DOZIO Samuele
FAILLA Simone
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SANGIORGI Alex
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CIANI Barbara
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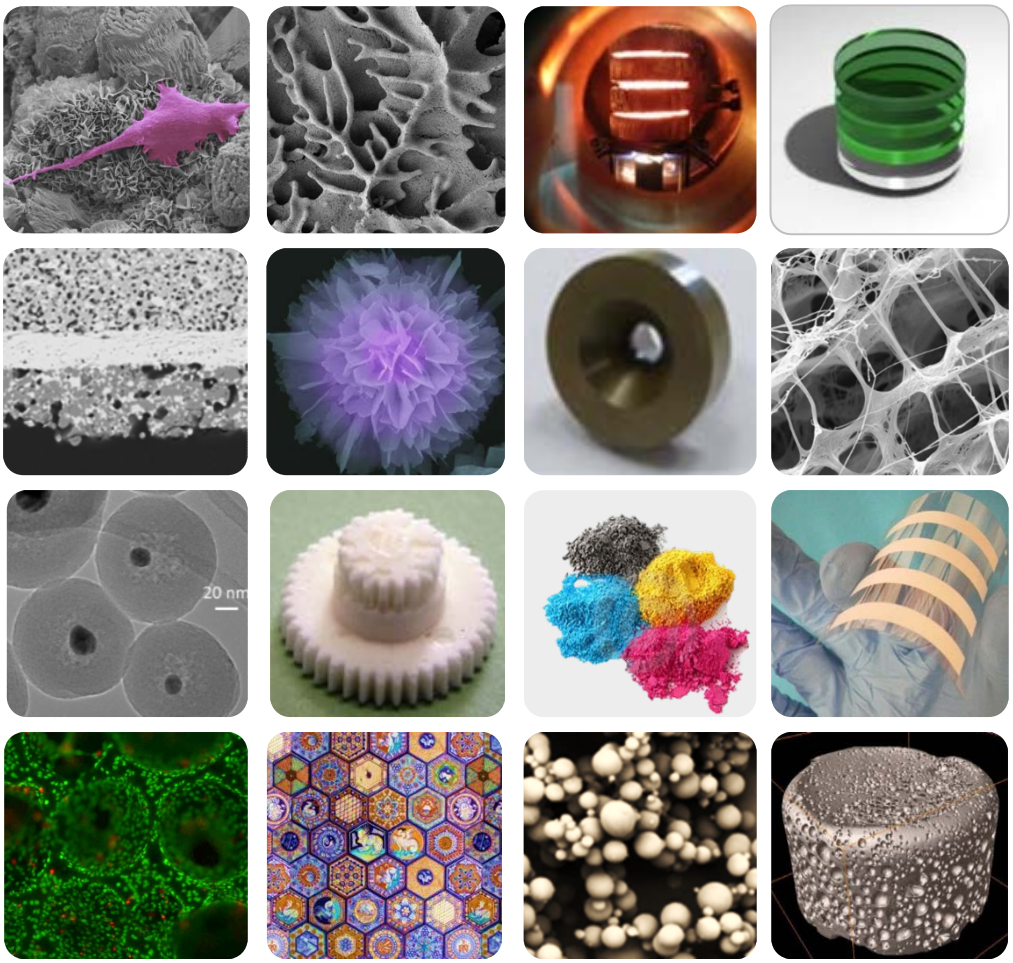
MANZARI Anika
MENGOZZI Laura
MONTALEONE Francesco
RIZZUTO Simonetta
ZAMA Barbara


Ph.L.Mengozzi



Medium te mundi posui, ut circumspiceres inde commodius quicquid est in mundo. Nec te caelestem neque terrenum, neque mortalem, neque immortalem fecimus, ut tui ipsius quasi arbitrarius honorariusque plastes et FICTOR, in quam malueris tute formam effingas.....

PICO DELLA MIRANDOLA ~ Oratio de hominis dignitate

Ti ho posto al centro del mondo affinché tu possa contemplare meglio ciò che esso contiene. Non ti ho fatto né celeste né terrestre, né mortale né immortale, affinché da te stesso, liberamente, in guisa di buon pittore o provetto *CERAMISTA* tu plasmi la tua immagine....

National Research Council of Italy
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