1) Graphene/Ni(111), pristine, defected, N-doped:
- Synthesis by C2H4 dehydrogenation in UHV
- Characterization and reactivity towards CO

2) Graphene/Cu
- Synthesis by C60 SuMBD at 35eV
- Cage opening and formation of defected but homogeneous single layer graphene
1) **SiC/SiO₂ NWs** as promising biomimetic biomaterial for implantable prosthetic devices. Core/shell NWs may be suitable for tissue regeneration.

Cells adhesion and proliferation on NWs

A549 cells: viability after 24, 48 and 96 hours. Cells appear elongated and spread, as typical of healthy cells.

2) **X-Ray induced photodynamic therapy for deep solid tumours treatments**

H₂TPACPP-functionalised nanowires and radiation on A549 cells.

**Project funded by the Swiss foundation ITI**

**Project funded by US National Institute of Health**
I-ZEB project (Terzo Accordo–Quadro CNR-Regione Lombardia 2017-2018, n° 19366/RCC, 10/01/2017) IFP value of research project 186 keuro (funding 50%)

IFP activity: development of advanced semiconductor materials (thin films, textured coatings) for low power electronics with a focus on renewable energy.

Status of task: development of inorganic photocatalysts → bismuth vanadate coatings (BiVO₄) were produced by plasma sputtering deposition technology using a Ar/O₂ mixture.
Targets: V and Bi₂O₃. Substrates: Si, glass, Al, Ti, FTO. Coating thickness range 400 - 600 nm. Deposition temperature: RT, post-annealing at 400°C for 2 hours.
To identify a suitable stoichiometry of coatings the power supplied to Bi₂O₃ target was changed in the range 15-30 W. The correct stoichiometry was found at 20 W, EDS measurements (in collaboration with ICMATE Milano) showed an atomic % for Bi, V and O of 16.9, 16.7 and 66.3, respectively (≈1:1:4).

X-ray diffraction (XRD) shows a BiVO₄ monoclinic phase
SEM (ICMATE Milano Lab.) The coating shows a dense, uniform and smooth structure.
UV-Vis diffuse reflectance spectra: energy gap estimated 2.46 eV, according to the literature values.
Photograph of BiVO$_4$ coatings as a function of the power supplied to Bi$_2$O$_3$ target. The deposition area is 2 cm x 7 cm.

In progress $\rightarrow$ BiVO$_4$ photocurrent measurements
$\rightarrow$ BiVO$_4$/WO$_3$ heterojunction produced by plasma
$\rightarrow$ BiVO$_4$/WO$_3$ heterojunction characterization
**Greencoat project 2017** (industrial task Prot. 751, 20-4-2017), IFP value of research project 10 keuro.

IFP activity: Plasma deposition of top-coatings on metal substrates to increase the surface hardness and corrosion resistance.

*Status of task:* organosilicon monomers (SiOxCyHz) are good process precursors for the deposition of protective coatings both anti-corrosion and anti-scratch on metal substrates. By a Plasma Enhanced Chemical Vapour Deposition (PECVD) process, it is possible to produce on the metal surface an optically transparent layer of a few nanometers of thickness with the desired characteristics. For this research activity, an appropriate layer was produced using hexamethyldisiloxane as monomer with dilution in oxygen. The deposited coating on the metal surface showed a high chemical stability, properties of water repellency and surface hardness.

**Ellegi project 2017** (industrial task Prot. 1469, 26-07-2017), IFP value of research project 12 keuro.

IFP activity: Plasma deposition of hexamethyldisiloxane-based coatings to facilitate the sliding of plastic components on conveyor belts.

*Status of task:* for this research activity, an appropriate layer was produced using hexamethyldisiloxane as monomer with dilution in oxygen. The deposited coating on the surface of plastic components showed a good property of sliding.
Topic sterilization/decontamination of materials by plasma methods

The plasma can be used as an efficient tool to sterilize and decontaminate surfaces without damaging them, or can be used to produce surfaces with bactericidal activity.

• Task sterilization/decontamination → low or high pressure plasmas produce oxidative sterilization/decontamination at low temperature to be used for example for medical devices and surgical instruments. On this topic, IFP obtained a project (industrial task Kenosistec Prot. 63, 22-01-2018, value of the project ∼10 keuro)

IFP activity: study of low pressure plasma processes to sterilize and decontaminate inorganic compounds inoculated with different microorganisms.

Status of task: plasma processes are in progress on Bacillus stearothermophilus, Staphylococcus aureus and Candida.

• Task surfaces with bactericidal activity → studying the natural bactericidal activity (due to nano-texture) of the surface of some insects, the plasma has been used to treat the surface of different materials in order to mimic this nano-texture. Plasma treated surface inoculated with E. Coli and B. Cereus microorganisms confirmed the bactericidal mechanism.
AP10 Advanced Materials and Nanotechnology

Istituto per le Applicazioni del Calcolo “M. Picone” - CNR

COPMAT
full-scale Computational design of Porous mesoscale MATerials

2018-2022
Diffusion problems from a polymeric platform for drug delivery

A coupled two-layer model for drug releasing systems

Drug release from a composite spherical nano-capsule
**Objective:**

- SOFCs are based on *ceramic materials* and operate at high temperatures between 800-1000°C.
- The challenges in this sector are regarding the reduction of the operation temperature and the direct utilization of hydrocarbons.
- This will allow to decrease degradation and make the device cost-effective by system simplification (reduced fuel processing) and use of cheap ferritic steel interconnectors.

**Approach:**

- The approach is to develop ceramic electrolytes for intermediate temperature operation based on ceria and gallates, use a multifunctional electrocatalytic layer at the anode to favour internal fuel processing and tailor the composition of the perovskite cathodes to speed-up the oxygen reduction process.

**Scientific Impact/Results:**

- The new materials and cell architectures have been validated for the direct oxidation of hydrocarbons such as methane, ethanol, bio-gas, propane, reformed diesel etc. in systems up to 2 kW power.

- Tecnologie ad alta Efficienza per la Sostenibilità Energetica ed ambientale On-board (TESEO) Progetto PON2_00153_2939517.
- Intermediate temperature solid oxide fuel cells fed by bio-fuels (BIOITSOFC) prot. 2010KHLKFC. (PRIN)
Catalysts for the cathode of PEMFC/DMFC:

- Pt/C, PtMe/C (Me: Ni, Co, Fe)

Catalysts for the anode of PEMFC/DMFC:

- Pt/C, PtRu/C

C (Ketjenblack, Vulcan, Acetylenblack, carbon nanofibers/nanotubes...)

Synthesis procedure: sulphite complex route

Characterized by:

- Employment of sulphites as complexing agents
- Low crystallite sizes (2-4 nm)
- Great metallic dispersion (even at high loadings, i.e. 80 wt.%)


Improved Lifetime of Automotive Application Fuel Cells with ultra low Pt-loading.
Next generation water electrolysers must achieve a good dynamic behaviour (rapid start-up, fast response, wider load and temperature ranges) to provide proper grid-balancing services and thus address the increase of intermittent renewables interfaced to the grid.

Enhanced performance and cost-effective materials for long-term operation of PEM water electrolysers in combination with renewable power sources are developed at ITAE. The aim is to contribute to the road-map addressing the achievement of a wide scale decentralised hydrogen production infrastructure.
**AIM:** The main focus is the development of new materials for Solid State $\text{H}_2$ storage, having low cost, simple synthesis, no sensitivity to air, $\text{H}_2$ storage value comparable to commercial material in non drastic T and P conditions.

### Materials

- Polymers
- Composite materials based on metal oxides grown onto polymer matrix
- Metallic Alanates covered with polymers
- Study on natural volcanic materials
- Activated carbons from natural wastes (banana peels, etc.)

Volumetric analyses revealed a good $\text{H}_2$ sorption (~3wt%) value in particular at non drastic conditions (40bar 50° C).
**Advanced Materials for electrochemical devices and purification systems**

1. Membranes for electrochemical systems (PEFC, AMFC, EHC, VRFB, Super-Cap)
   - **PEFC:** Nafion composite (ZrO₂, YSZ, TiO₂)
     - s-PEEK; s-PSF
     - Biopolymers (chitosan, Nanocellulose)
   - **AMFC:** Polysulphone PSF-Q
     - Anionic conductivity(Cl⁻): 3mS/cm
   - **VRFB:** s-PEEK composite with SiO-NH₂
     - Charge/discharge efficiency of 96% against 85% for N115
     - Selectivity to ions V⁴⁺ di 49·10⁶ S·s·cm⁻³ against 6·10⁶ S·s·cm⁻³
   - **Super-Cap:** s-PEEK
     - Specific capacity (123F/g) higher than reference porous separator
     - Stability of 20000 cycles at 2A/g

2. Membranes for pH and metals optical sensors
   - Composite Nafion and s-PEEK with porphyrins

3. Membranes for waste water purification systems
   - PSF
   - PVDF
   - PP
   - PEEK

4. Membranes for Liquid Desiccant and dehumidification systems
   - Asymmetric membranes based on: PP, PVDF, PSF, PVA
Vanadium Redox Flow Battery (VRFB) Activity
Materials and Stack Design Optimization to improve electrochemical parameters and reduce technology costs

- Electrode materials synthesis by electrospinning technique
- Electrochemical characterizations from single cell up to kW stack
- Stack design and development
- Electrochemical model development
- Cell and stack fluid dynamic studies

1 kW VRFB Stack

Electrospinning equipment for material synthesys

CoFe₂O₄ / CNF
CNF form PVP

1200 W @ 100 mAcms⁻²
Nanomaterials for metal-air batteries

Based on the electrochemical reaction of a metal (Fe, negative electrode) with oxygen from atmospheric air (positive electrode):

\[
O_2 + 2Fe + 2H_2O \xrightarrow{\text{discharge}} 2Fe(OH)_2
\]

\[
3Fe(OH)_2 + \frac{1}{2}O_2 \xrightarrow{\text{charge}} Fe_3O_4 + 3H_2O
\]

- Materials for the positive electrode (air):
  - **Noble metal catalysts:** Pd/C (sulphite complex route)
  - **Cost-effective materials:** Perovskites (La\(_{0.6}\)Sr\(_{0.4}\)Fe\(_{0.8}\)Co\(_{0.2}\)O\(_3\))

- Materials for the negative electrode (Fe):
  - Fe\(_2\)O\(_3\)/C + sulphide additives (synthesized by several methods: colloidal routes, both organic and inorganic, salt fusion method).

- Alternative supports (more resistant to corrosion):
  - Carbon nanofibers (CNFs)
  - Ti-suboxide

EU Project
1. Development of Electrode materials
   - Mesoporous carbon
   - Carbon xerogels
   - Graphene
   - Manganese oxides

   Well developed porosity
   High charge/discharge rate
   Appreciable cycling stability

2. Development of Electrolytes
   - Neutral aqueous
   - Solid Polymer
   - Inexpensive
   - Easily handling
   - Environmental friends but.....
   - Low operating voltages

How working voltage window can be increased?

3. Development of Electrodes
   - Casting/Coating technology

4. Configuration of supercapacitors

5. Prototype of Supercapacitors

- 1.5 F
  - 5.5 V
- 12 F
  - 5 V
- 50 F
  - 1.5 V
- 20 F
  - 3 V
Development and Validation of an Innovative Solar Compact Selective-Water-Sorbent-Based Heating System — SWS-HEATING

Aim:
The SWS-Heating project will develop an innovative seasonal thermal energy storage unit based on a novel composite sorbent material and creative multi-modular configuration.

Composite sorbent concept

Vermiculite-LiCl synthesized

Morphological, structural and thermal characterization of ad/desorbed material

Next steps:
- Synthesis optimization
- Cycling stability analysis
- Scale-up of the production
- Full-scale sorption storage testing

The SWS-Heating project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement N° 764025.
Pyrolysis of local residual biomass to produce activated carbon (bio-char) with a high surface area and remarkable CO₂ adsorption properties

Beached seaweed (Posidonia Oceanica)

**Elemental Analysis (wt%)**

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>H</th>
<th>N</th>
<th>O</th>
<th>O/C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass</td>
<td>40.3</td>
<td>5.7</td>
<td>1.1</td>
<td>25.6</td>
<td>0.64</td>
</tr>
<tr>
<td>Activated Bio-Char</td>
<td>92.7</td>
<td>2.1</td>
<td>0.6</td>
<td>4.6</td>
<td>0.05</td>
</tr>
</tbody>
</table>

**Bio-char Adsorption-Desorption measurements**

- Surface Area m²/g: 2938
- Adsorbed CO₂ mmol/g: 4.8
- Pore volume cm³/g: 0.91
- Horvath Kawazoe Median pore width nm: 1.16
**Nanohybrid materials for the production of DME via CO₂ hydrogenation**

- **CO₂ sequestration & recycling**
- **CO₂ hydrogenation**
- **Dimethylether (DME)**

**Hybrid nanocatalysts for high-pressure process**

- **Photosynthesis // biomass**
- **Power plants**
- **Fossil Fuels**

**Renewable energy**

- **CO₂ hydrogenation**
- **Hydrogen H₂**

**Transportation**
- cooking;
- heating;
-...

**Household purposes**
- fuel cells;
- gas turbines;
-...

**Energy production**
- cooking;
- heating;
-...
Structured catalysts with enhanced transport and surface to volume ratio properties for the development of intensified reactors for catalytic conversion of CO₂ into usable fuels and chemicals (methanation case)

- Catalyst loading: 0.5 g/cm³ (60% of packed bed)
- Well uniform and high-resistance coated layers
- Adhesion tests results, pointed out good resistance of the coated layers, with negligible weight loss (0.3-0.5%) after two sonication baths.

<table>
<thead>
<tr>
<th>Channel Inner Size (d_p) (mm)</th>
<th>Wall thickness (t) (mm)</th>
<th>Bed density (kg/m³)</th>
<th>Bed porosity (%)</th>
<th>Open frontal area (\varepsilon)</th>
<th>Geometric surface area GSA (cm²/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.83</td>
<td>0.32</td>
<td>771</td>
<td>72.5</td>
<td>0.52</td>
<td>25.29</td>
</tr>
</tbody>
</table>

- MO-B catalyst allowed saving about 40-50% of catalyst employed in packed-bed system. High surface-to-volume ratio and good interphase mass transfer were able to ensure high methanation activity with low amount of catalytic phase.

- \(\text{CH}_4\) productivity increased by increasing space velocity, reaching the maximum at 400°C and 50,000 h⁻¹: \(10.7\, \text{L}_{\text{CH}_4}/\text{g} \cdot \text{h}\).

Future perspective

- Advanced materials for catalytic conversion of CO₂ into usable fuels and chemicals are needed to scaling down the conventional processes for small-scale application and integration with distributed renewable energy production.

- New environmental friendly and competitive cost solutions for power plants and carbon-intensive industry, new markets and job creation for innovative industrial sectors.
2.1 Advanced materials for industrial processes

- Development of sustainable methods for machining Ti alloys and Inconel materials for aeronautic and aerospace applications: replacement of conventional lubrorefrigerants, with reduction of environmental impact.
- Wear and friction properties of materials for mechanical applications (main focus on brake systems): redesign of pads materials, for environmental impact reduction.
- Metal oxide nanomaterials for gas sensing: early detection and monitoring of poisonous and hazardous chemicals, allow advancing on environmental security and healthcare.

2.2 Enhanced materials and nanotechnologies for energy and environment

Oxidic nanostructures embedded into a polymer for flexible, versatile coatings of easy fabrication and low environmental impact for application in renewable/alternative energy technologies: use of wasted mechanical energy, energy consumption and carbon emissions reduction.

2.3 Advanced materials and nanotechnologies for bio-medical use

Nanocomposite materials (oxide-polymer) for biomedical applications, endowed with reduced rigidity compared to metals and ceramics, with enhanced osseointegration properties with respect to polymers: cost reduction compared to commercially available materials.
AP10 Advanced Materials and Nanotechnology

Low-Dimensional materials: quantum and 2D

✧ advanced synthesis
✧ nanoscale characterization
✧ material modelling

control over the fundamental quantum-mechanical properties of materials

✧ 2D MoS$_2$: promising candidate for transistors, memory devices, photodetectors, solar cells, electrocatalysts for HER, lithium ion batteries.

Synthesized by **Ion Jet Deposition (IJD)**

![Ion Jet Deposition Image](image1)

Advanced synthesis in vacuum: no need for post-deposition treatments

Synthesized by **Chemical Vapor Deposition (CVD)**

![Chemical Vapor Deposition Image](image2)

HR-TEM of MoS$_2$ flakes: bilayer, monolayer
Graphene nanoribbons and C-based nanostructures: suitably designed precursor molecules determine different structures and different electronic properties.

Epitaxial semiconductor Quantum Dots: 0-dymensional systems integrated into a semiconductor platform for the realization of electro-optical devices as QD lasers, QD single photon emitters, QD sensors.

Molecular Beam Epitaxy of InGaAs-based nanoislands:

optical emission at telecom wavelength: lasers / single-photon emitters
High band-gap semiconductor for high power electronics UV detection and quantum photonics

Ga2O3 as an emerging material for power devices
Development of e-Ga2O3 epitaxy by Vapor Phase Epitaxy
Material characterization (structural, optical, electrical)
Device prototyping (realized: UV-photodetector)

3C-SiC as an emerging material for quantum photonics
Single photon emission
Optical resonant microstructures

mm-long rolled-up semiconductor µicrotubes with nm-thin walls

Applications as µfluidics channels for sensing, photonic integrated compononents, catalytic µicrotubular engines
**Metal oxide nanostructures**

- **ZnS(en)$_{0.5}$ hybrid**
- **Porous ZnO platelets**

Mesoporous ZnO nanobelts and by thermal decomposition of ZnS(en)$_{0.5}$ precursors

- **Gas sensing**
- **Solar cells**

- **ZnO nanorods on a carbon fiber by wet chemistry**

**CdZnTe-based X- and gamma-ray detectors**

CdZnTe is the best material for room temperature operating, spectroscopic x- and gamma-ray detectors

- **XDRONE**
  - Localization of nuclear materials
  - 32000 pixels imaging detector

- **ZnO tetrapods by vapor phase**

**ZnO nanorods**

**ZnOnanorods-based piezosensor**

Linear array detectors for X-ray scanners
Advanced catalysts and materials for sustainable chemistry and energy

Development of novel and advanced materials/catalysts for process intensification and/or new alternative processes compared to traditional ones.

- Formulation of new materials with chemical and physical properties and functionalities tailored for specific applications
- Lowering costs and enhancing performances of currently used materials
- Development of properties of resistance to severe operating conditions
- Toxicity mitigation of common materials
AP10 Advanced Materials and Nanotechnology

Advanced catalysts and materials for sustainable chemistry and energy

From combustion pollutants and raw materials and precursor to engineered materials

- Sensitive and conductive thin films (VOC detection)
- Photoactive materials (PLE enhancers, selective photo catalysts)
- Advanced Materials development
- Biocompatible and bioinspired materials
- Water remediation (heavy metal capture)
- CO₂ capture and storage
- MOF/graphene hybrids
- Flame-formed TiO₂ nanoparticles
- Surface - tailored (also magnetic) carbon-based nanoparticles
- Eumelanin-based conductive layers

- Inorganic coating (flame synthesis)
- Organic coating (wet chemistry)
Advanced catalysts and materials for sustainable chemistry and energy

Heterogeneous Catalysis for Energy & Environment

- Improved sulphur tolerance
- Power to Gas/ CO₂ valorization
- Natural Gas and Bio-Gas Conversion
- Catalytic Combustion
- Catalysts & process development
- Upgrading & Purification
- Catalysts for Chemical Looping/Solar Splitting
- Pollution control (NOx, VOC, soot, Hg)
- Radiant catalytic combustors
AP10 Advanced Materials and Nanotechnology
Magnetic materials and multiferroics

RE-FREE PERMANENT MAGNETS
FOR HYBRID AND ELECTRIC
MOTORS AND WIND POWER TURBINES

BULK MATERIALS, THIN FILMS
AND NANOSTRUCTURES FOR
SENSORS AND MEMORIES

MAGNETOCALORIC MATERIALS FOR
RT MAGNETIC REFRIGERATION

Energy efficiency
Emission reduction

Materials based on
non-critical elements

MAGNETIC
NANOPARTICLES AND
NANOCOMPOSITES FOR
BIOMEDICINE

Multiresponsive systems
New functionalities

MULTIFUNCTIONAL MATERIALS (e.g.
MAGNETIC SHAPE MEMORY,
MULTIFERROIC, MAGNETOPLASMONIC)
FOR SENSORS, ACTUATORS, SMART
APPLICATIONS
Organics

Semiconducting properties

Electronic and optoelectronic devices

Inorganic surface functionalization

Multifunctional materials, Biocompatible inorganics, Theranostics

Acenes, phenacenes, perilenes thin film by Supersonic Molecular beams (SuMBD).

OFET, OTFT, LET

Nanowires direct functionalization by H₂TPP(F) SuMBD.

Multifunctional materials for X-ray/NIR PDT and imaging
Aminoacid Glutamate self-assembly on Ag(100) surface. Biosensing, biomedicals.

Hybrid materials

Organometal halide perovskites $\rightarrow$ Energetics and optoelectronics

$\text{CH}_3\text{NH}_3\text{PbI}_{3-x}\text{Cl}_x$ $\rightarrow$ $\text{CH}_3\text{NH}_3\text{PbI}_{3-x}\text{Br}_x$

Organometal halide perovskites by vacuum flash evaporation. PV cells, LED, photodetectors.
WHAT ARE NANOFLUIDS?

- COLLOIDAL SUSPENSIONS OF NANOPARTICLES IN COMMON FLUIDS
  - BASE FLUIDS: water, oil, ethylene glycol, refrigerants
  - NANOPARTICLES: oxides (ceramics), metals, carbon nanotubes

MAIN ACTIVITIES

- THERMOPHYSICAL PROPERTIES MEASUREMENTS
  - colloidal suspension stability
  - transport properties ($\lambda$, $\mu$, $\alpha$)
- TRIBOLOGICAL PROPERTIES MEASUREMENTS
  - evaluation of anti-friction and anti-wear properties
- PERFORMANCE EVALUATION IN ENERGY SYSTEMS

POTENTIAL APPLICATIONS

- COOLING SOLAR COLLECTORS
  - flat plate
  - direct absorption (DAC)
  - evacuated tubular

- HEAT PIPES
  - heat pipe for CPU cooling
  - screen mesh heat pipe
  - flat plate heat pipe

- HVAC&R DEVICES
  - domestic refrigerators
  - residential air conditioning units
  - compressor lubrication

- PEM FUEL CELL COOLING SYSTEMS
  - domestic refrigerators
  - residential air conditioning units
  - compressor lubrication
HETEROGENEOUS PHOTOCATALYSIS

CHEMICAL REACTIONS CATALYZED BY LIGHT AND (NANOCRYSTALLINE) SOLID PHOTOCATALYSTS

- Oxidation and reduction processes of organic and inorganic species in air and water
- Needs of specific instruments for the study of photocatalytic materials performance

MAIN ACTIVITIES

DEVELOPMENT OF SPECIALIZED ANALYTICAL SYSTEMS FOR PHOTOCATALYTIC ACTIVITY MEASUREMENTS

- Advanced measurement of photocatalytic air depollution with a state-of-the-art, specifically developed analytical system
- Activity studies of nanostructured photocatalysts in air and water for special photocatalytic materials development
- Study of water-based photocatalytic oxidation processes of natural products

POSSIBLE APPLICATIONS

DEVELOPMENT OF HIGH EFFICIENCY PHOTOCATALYSTS OPERATING IN UV AND VISIBLE LIGHT

- Air and water depollution by special photocatalytic materials
- Photocatalysis-based advanced oxidation processes (AOP) for waste water treatments
- Water-based and solar driven chemical processes for sustainable chemistry

Contact: alberto.strini@itc.cnr.it
Plasmonic substrates for rapid surface enhanced Raman detection of proteins, hormones, DNAs, disease biomarkers in trace amounts in biological fluids. [Coordinator: P. Matteini; Ref: Sci. Rep. 8 1033 (2018)]

Photonic components, such as:
• Whispering gallery mode resonators as transducers for the detection of analytes of biomed interest [Coordinator: S. Pelli]
or broadband ultrasound [Coordinator: S. Soria]
• Optical fiber nanotips for intracellular sensing and monitoring of the effect of new drugs [Coordinator: S. Pelli, Ref: US PATENT pending]
Hybrid particles for intracellular delivery of DNA probes, such as so-called molecular beacons, which acts as theranostic agents capable to sense and to silence m-RNA [Coordinator: A. Giannetti; Ref: J. Contr. Release, 280, 76 (2018); Biosens Bioelectron, 88, 15, (2017)]

Bionic contrast agents for photo-acoustics/thermics in association with biomolecular ligands or cellular vehicles, i.e. autologous cells that constitutively migrate to a tumor microenvironment [Coordinator: F. Ratto; Ref: Adv. Funct. Mater. 26, 7178 (2016)]

Optically responsive patches for welding of connective tissue and controlled drug release [Coordinator: P. Matteini; Ref: PATENT US2015086608]
Graphene oxide/alginate hydrogel for articular cartilage regeneration

Histological sections representing cartilage matrix deposition of human mesenchymal stem cells cultured within the materials

Cell adhesion over scaffolds functionalized with graphene’s derived nanomaterials for bone regeneration

AFM images of biomimetic substrates functionalized with graphene’s derived nanomaterials