ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

ADVANCED MANUFACTURING AND PROCESSING

Manufacturing in EU represents approximately 21% GDP, providing more than 30 million jobs in 230 000 enterprises, mostly SMEs. Despite growing globalisation and challenges from low-wage economies, manufacturing has a bright future in Europe in a sustainable, knowledge-based society. This perspective therefore requires continuing innovation in products and processes, with a need for consistent and effective research.

The research of the University of Bologna covers a wide range of issues:

- **Laser cutting and welding of thin films** for single and multi-layer films of thickness < 1 mm. Applications include MEMS and electronics, battery fabrication and product packaging, exploiting different wavelengths and pulse durations, from milliseconds down to femtoseconds.
- **Cutting and welding of bulk metals**, applied to a wide range of materials from alloy steel to alloys of Al, Cu, Ni, Ti and Mg using multi-kW, high brilliance industrial CW and "quasi-CW" laser sources.
- **Ablation & Micro-Machining** to achieve machining or modification of non-conventional materials such as semi-conductors, ceramics and glass or metals, under short and ultra-pulse exposure.
- **Surface heat treatment**: applications involving microstructural modification via localised surface heating. it is an optimum technique for obtaining selective, precisely defined regions of high surface hardness on geometrically complex steel and cast iron parts. It is also possible to select process parameters to obtain localized softening of material via microstructural modification.
- **Additive manufacturing for industrial mechanics**: redesign and fabrication of complex and high added value components for packaging machines and metal cutting complex tool.
- **Additive manufacturing in the field of biology** centred on the manufacturing of polymeric scaffolding for cellular regeneration, both in vivo and in vitro, via ultra-short pulse laser exposure, and around biomechanics applications based on the fabrication of Co-Cr prostheses for total ankle replacement.
- **Robotics**: replication of the human ability of manipulation, advanced vision systems, models for path optimization, haptic abilities, modelling and control for stability and performance, simulation environments, cooperative telemanipulation.
- **ICT for advanced production systems**: monitoring and control of industrial processes, diagnostic and supervision methods and algorithms for faults detection.
- **Process simulation** numerical simulation of manufacturing processes, in many fields of industrial application.

HIGHLIGHTS

Research and Innovation projects funded under Horizon2020:

REMODEL Robotic tEchnologies for the Manipulation of cOmplex DeformablE Linear

CLOUDIFACTURING Cloudification of Production Engineering for Predictive Digital Manufacturing

IOTWINS Distributed Digital Twins for industrial SMEs

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ELECTRONICS AND PHOTONIC MATERIALS

Novel materials for electronics and photonics are fundamental for progress in Information and Communication Technologies as well as Energy-transport and storage.

The researchers of the University of Bologna cover the whole chain of research and development necessary to establish novel electronic and photonic materials.

Research activities cover the synthesis of novel active materials, processing of materials and deposition, characterization, integration and simulation as well as application design:

- Development and characterization of thin film transistors for applications in flexible and printed electronics: AD and DC electric characterization, local nano-electronic characterization, mechanical stability, optoelectronic properties, modelling
- Design and development of flexible ionizing radiation detectors based on novel organic and inorganic semiconducting materials and thin-film devices. Study of the direct response and radiation hardness under X-ray, proton and gamma-ray radiation
- Si-based and perovskites thin films for photovoltaic applications. Electronic structure and defect studies by photovoltage spectroscopy, conductive force atomic microscopy
- III-Nitrides alloys and heterostructures for high-frequency electronics. The role of the defects on device properties by photocurrent and photovoltage spectroscopy, deep-level transient spectroscopy, Kelvin-probe microscopy
- Titanium oxide based photoelectrochemical devices: fabrication, doping, nanostructures and characterization
- Inorganic, carbonaceous and polymeric nanostructured electrode materials for electrochemical sensing and energy storage
- Synthesis and characterization of photochromic polymers for smart sensors
- Materials for textile electronics: integrated biosensors based on conducting polymers
- Organic semiconductors: simulation of structure and properties, experimental characterization
- Optical guiding structures: optical fibers and integrated waveguides(...) simulation and experimental characterization
- Materials for soft electronic actuators and electromechanic transducers

HIGHLIGHTS

- **Large-area flexible photonic sensor systems**: investigation of novel semiconducting thin films (organic, amorphous oxides, perovskites) for UV-vis, X-ray and γ-ray detectors
- **Ageing and diagnostics of insulator materials**: polymeric materials failure under high AC and DC voltage, charge accumulation and conduction mechanism
- **Organic-inorganic conjugates for augmented photonics**: design of organic chromophores to tune optoelectronic properties for applications as luminescent probes or light harvesting antenna

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INDUSTRIAL BIOTECHNOLOGY

From the characterization of the feedstocks to the development of the biotech process for the production of biobased base and fine chemicals, ingredients, building blocks, biopolymers for food, feed, nutraceutical, cosmetic and pharmaceutical applications.

Biomass characterization & treatment

- Pre-treatment of agri-food wastes, by-products and biomasses using biocatalysts for the extraction of added value bioactive molecules and/or of substrates for fermentation/ bioconversion processes
- Characterization of biological activities of the extracted added value molecules

Fermentation & bioconversion processes

- Isolation from extreme and conventional environments of prokaryotic and eukaryotic microorganisms able to produce the target molecules
- Development and optimization, via conventional or statistical approaches, of the process conditions (media formulation, process parameters) and operating conditions (batch, fed-batch, continuous) for the production of target compound

Downstream

- Development of downstream processing for the selective recovery of the target biobased molecules

HIGHLIGHTS

The University of Bologna is part of BIOCIRCE: the first European Master in Bioeconomy in the Circular economy providing a rich combination of theoretical perspectives on life science innovation with a practical focus on the dynamics of the bioeconomy and its value chains.

The University of Bologna contributes to the international research progress developing innovative solutions:

- **PHENBIOX** spinoff develops and produces plant-derived high performance active ingredients for cosmetics, food and food supplements finished products. It provides customers with high-quality products with proven efficacy. They use their technology in order to both increase the speed of effect of the active ingredients and boost the effectiveness of their products.
- **WELLMICRO** spinoff offers a quick characterization of the intestinal microbiota in the service of nutrionist doctors, dieticians, gastroenterologists. The final output of the characterization is the Microbiopassport® that is a medical report easily interpreted thanks to graphic components; the Microbiopassport® describes the intestinal ecosystem in detail. Wellmicro staff adds indications and suggestions about eventual modulation of microbiota components using a therapeutical and nutritional approach.

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INDUSTRIAL SYMBIOSIS

Moving towards a more collaborative and integrated industrial ecosystem through an exchange of materials, water, energy stream, services and expertise.

Research at the University of Bologna covers a wide range of topics:

- Characterisation of the Italian and European industrial ecosystems such as the industrial district, EIP (Eco-industrial park) and APEA (Area produttiva ecologicamente attrezzata)
- Methodology and tools for the industrial symbiosis implementation
- Designing plants integration for energy efficiency
- Categorizing productive sectors and mapping industrial activities
- Supporting digital platforms through ICT and database tools for triggering data collection, stakeholders involvement and exchange opportunities
- Exploring the valorisation of the industrial waste as secondary raw material within the industrial ecosystem
- Exploring the opportunity to use by-products, debris and remains within the industrial ecosystem
- Designing potential synergies and matching among firms
- Developing new plants, processes and technologies for services, utilities and infrastructure sharing and process/products valorisation
- Assessing environmental and economic impact trough LCA and LCC studies for alternative and more sustainable scenarios
- Policy and legislative recommendations for promoting the application of a circular economy approach among companies
- Designing new and competitive business models based on a circular economy approach

HIGHLIGHTS

The University of Bologna has established an extensive network of collaborations with multi-utilities, public authorities, SME and industries; it is also **participating in the Symbiosis Users Network (SUN)** and it is **partner of the EIT Raw Materials and the EIT Climate-KIC**.

The University of Bologna contributes to the European progress in research and innovation **taking part to several funded projects**, such as: **TRIS** - *Transition Regions Towards Industrial Symbiosis as member of the Industrial Symbiosis Lab* - Emilia Romagna Region; **the FLAGSHIP EIT CLIMATE KIC**: **Re-industrialise**, **e-Circular**, **INSIGH**, **Surplus mall**; **the POR-FESR 2014-2020 - GREEN CHARCUTERIE** aimed at innovating the pig industry through the valorisation of vegetable by-products and the use of advanced process technologies for the sustainable production of meat and cured meat having a positive impact on health; **VALSOVIT** for the sustainable valorisation of the wine industry waste in the chemical, cosmetics and nutraceutical sectors; **SOSTINNOVI** on sustainability and Innovation in the Wine Supply Chain.

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MATERIALS CHARACTERIZATION

A knowledge driven use of materials requires a deep understanding of their characteristics, properties and function: the University of Bologna employs a wide range of state of the art characterization tools. The research of the University of Bologna handles different size scales to characterize a very different range of materials and provide researchers unprecedented insight into their properties for applications on different fields, spanning cultural heritage, medicine, chemistry, biology, ICT and engineering.

Employing electronic, electrochemical, photonic, spectroscopic, modelling, imaging, biomolecular as well as microscopy and mechanical techniques, the research of the University of Bologna covers characterization of:

- (Nano)materials for energy storage and energy conversion electrochemical systems (Li-ions and Li/O2 batteries, fuel cells, etc)
- Liquid crystals for ICT applications via mesoscale modelling techniques
- Photoactive molecular materials and bio-molecules by time resolve mulit-pulse non-linear spectroscopies on-silico
- Materials for cultural heritage and its preservation via combined spectroscopic, imaging and microscopy techniques
- Molecules of astrochemical and astrobiological interest in the ISM, as well as in extra-terrestrial atmospheres via vibro-rotational spectroscopy and modelling
- Supramolecular and nanomaterials for molecular and organic electronics, catalysis and nanotechnology: supramolecular organic systems, metal clusters, metal and inorganic nanoparticles, hybrid organic-inorganic nanoparticles, organometallic compounds
- Bioactive materials and nanomaterials for medical applications and drug delivery
- Composite materials and nanocomposites for high-tech applications
- Alloys for high-tech applications
- Inorganic nanocrystalline aggregates, non-crystallographic morphologies, biomorphs and bio-mimics
- Electronic and transport properties of materials (quantum dots, organic molecular materials, polymeric wires, etc) for optoelectronics
- New materials for energy storage in advanced batteries
- New materials for electrocatalyzed chemical processes
- Photoactive materials for water splitting
- New low band-gap materials and polymers for new flexible solar cells
- Biowastes (chemical–physical, structural and morphological properties)
- Bio-mimicking materials (polymers, biopolymers, etc)
- Biomaterials (proteins, genomic materials, etc) and their interactions via spectroscopic techniques

HIGHLIGHTS

The University of Bologna contributes to the European progress in research and innovation taking part to several European funded projects:

- H2020-**MAGNIFY**: From nano to macro: a ground-breaking actuation technology for robotic systems
- H2020-**ERC-STRATUS**:Structure and dynamics of biomolecules by two-dimensional ultraviolet
- FP7-**ERC-PROMETHEUS**:Pattern formation and mineral self-organization environments in highly alkaline natural
- FP7-**MINOTOR**: Liquid crystals characterization and properties
- FP7-**BIND**:Biaxial Nematic Devices

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MATERIALS FOR ENERGY

Materials are central and often critical to accelerate the evolution and future impact of new energy technologies. Whether dealing with energy conversion, harvesting or storage, the development of new materials with improved functionalities plays a pivotal role in efficiency, reliability, cost-effectiveness, and sustainability.

Research at the University of Bologna covers a wide range of issues:

- Design and characterization (electrochemical, physico-chemical) of new (nano)materials (porous and nanostructured materials, transition metal oxides, electronic conductive polymers, organic electrolytes and ionic liquids) for efficient energy transport, storage and conversion electrochemical systems (Li-ions and Li/O2 batteries, fuel cells, etc.)
- New materials for next-generation lithium metal and lithium-ion batteries
- Design of new blends for efficient charge separation and charge transport in photovoltaics
- Materials for new electrodes in efficient energy systems: photocathods/ photoanodes in photovoltaics, etc.
- Design of nanomaterials and catalysts for CO2 photoreduction, capture, hydrogen generation and storage
- Materials for (solar, (thermo)mechanical, thermal) energy harvesting
- Innovative materials (bio inspired, nano, super-molecular, polymeric, hybrid perovskites thin films) and devices for high efficiency, low cost and sustainable energy (solar, light, wave, etc.) conversion
- Materials (Nanofibers, adapted Thermo Chemical Materials, Metal Foams and Functional Surface Technologies) for Thermal Energy Storage
- Design and development of (nano)materials and (nano)composites for energy saving, low consumption, insulation and low carbon buildings
- Materials for low and high energy superconductivity
- Design of materials for thermonuclear fusion power stations
- Materials for sustainable, energy efficient chemical separation processes
- Materials for high-voltage supercapacitors
- Novel thermoplastic polymer composite materials to enhance performance of essential components of smart grid infrastructure
- Catalysts for the transformation of biomasses into chemicals and fuels, both in the liquid and in the gas phase

HIGHLIGHTS

European Projects

HyFlow - *Development of a sustainable hybrid storage system based on high power vanadium redoxflow battery and supercapacitor – technology,* H2020-LC-BAT-2020

NANOMEMC2 - *NanoMaterials Enhanced Membranes for Carbon Capture*. H2020 - SC3

LEAPS - *Light effected autonomous molecular pumps: Towards active transporters and actuating materials*, H2020-ERC Adv.

GRIDABLE - *Plastic nanocomposite insulation material enabling reliable integration of renewables and DC storage technologies in the AC energy grid*, H2020 LEIT NMP.

PhotoSi - *Silicon nanocrystals coated by photoactive molecules: a new class of organic-inorganic hybrid materials for solar energy conversion*, FP7-ERC starting grant.

PolyWEC - *New mechanisms and concepts for exploiting electroactive Polymers for Wave Energy Conversion*, FP7-Energy.

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MATERIALS FOR HEALTH

In the healthcare field, fundamental research on materials and technologies is strongly linked to the clinics, with the ultimate goal of improving human health. Biomaterials play a key role in the development of medical devices, prostheses, implants for tissue repair and replacement, drug delivery systems and diagnostic platforms.

The world-leading research of the University of Bologna on materials for health is carried out in several areas, driven in a multidisciplinary way, including theoretical modelling, novel synthesis processes, and advanced characterization techniques. –The research vision includes projects addressing specific clinical needs, and exploiting collaboration among clinicians, biologists, biochemists, physicists, chemists and engineers. The research of the University of Bologna covers a wide range of issues:

- A main application area is covered by tissue engineering: development of 'soft' materials as scaffolds for neural conduits, dermal grafts, cardiovascular patches, etc.; 'hard' materials as scaffolds for bone and osteochondral regeneration; strategies affording prevascularized cell-based constructs for myocardial tissue engineering are also developed
- Hybrid biomimetic scaffolds
- Functionalized biomimetic micro- and nano-crystals of calcium phosphates for bone tissue repair. Calcium phosphate bone cements as orthopedic implant materials
- Natural polymers-based scaffolds (collagen, gelatin, chitosan, alginate, etc.)
- Materials and strategies for wound healing
- Investigation of the mechanobiology of cancer cell–ECM interaction through 3D scaffolds
- Materials for pharmaceuticals and personal care
- Drug delivery systems. Controlled drug delivery. Local drug delivery
- Imaging and diagnosis of living systems
- Engineering surfaces of implants (titanium etc.) to avoid biofilm infections. Inherently bactericidal surfaces. Anti-infective and anti-microbial materials
- Biomimetic coatings, surface functionalization of biomaterials
- Smart materials: shape memory polymeric biomaterials. Stimuli responsive biomaterials. Thermo-responsive hydrogels
- Macromolecular hydrogels. Peptide-based hydrogels
- Electrospinning and electrospraying for nanofibers and nanoparticles fabrication
- Electroactive polymers (EAPs) for artificial muscles: conducting polymers, dielectric elastomers, piezoelectric polymers
- Materials and devices for orthopedic, trauma and dental implants inducing proper osteointegration (titanium, polymeric materials, micro-nanostructured materials, functionalized materials)
- Materials for implants in the brain and in spinal cord injuries
- Bioinspired surfaces for bio-diagnostics and drug discovery devices
- Magnetic scaffolds for tissue regeneration
- Polymeric biomaterials for 3D printing and 3D bioprinting of scaffolds for organ engineering

HIGHLIGHTS

Biomimetic Materials and scaffolds for tissue engineering: functional polymeric biomaterials from electrospinning: nanofibres for tissue engineering and drug delivery.
Electroactive polymers for artificial muscles: conducting polymers, dielectric elastomers, piezoelectric polymers.
Development of materials for **orthopaedics and dental implants**.

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MATERIALS FOR TRANSPORTS

Materials can enable industrial and commercial success of new products and processes, introducing new functionalities, improving properties and adding value.

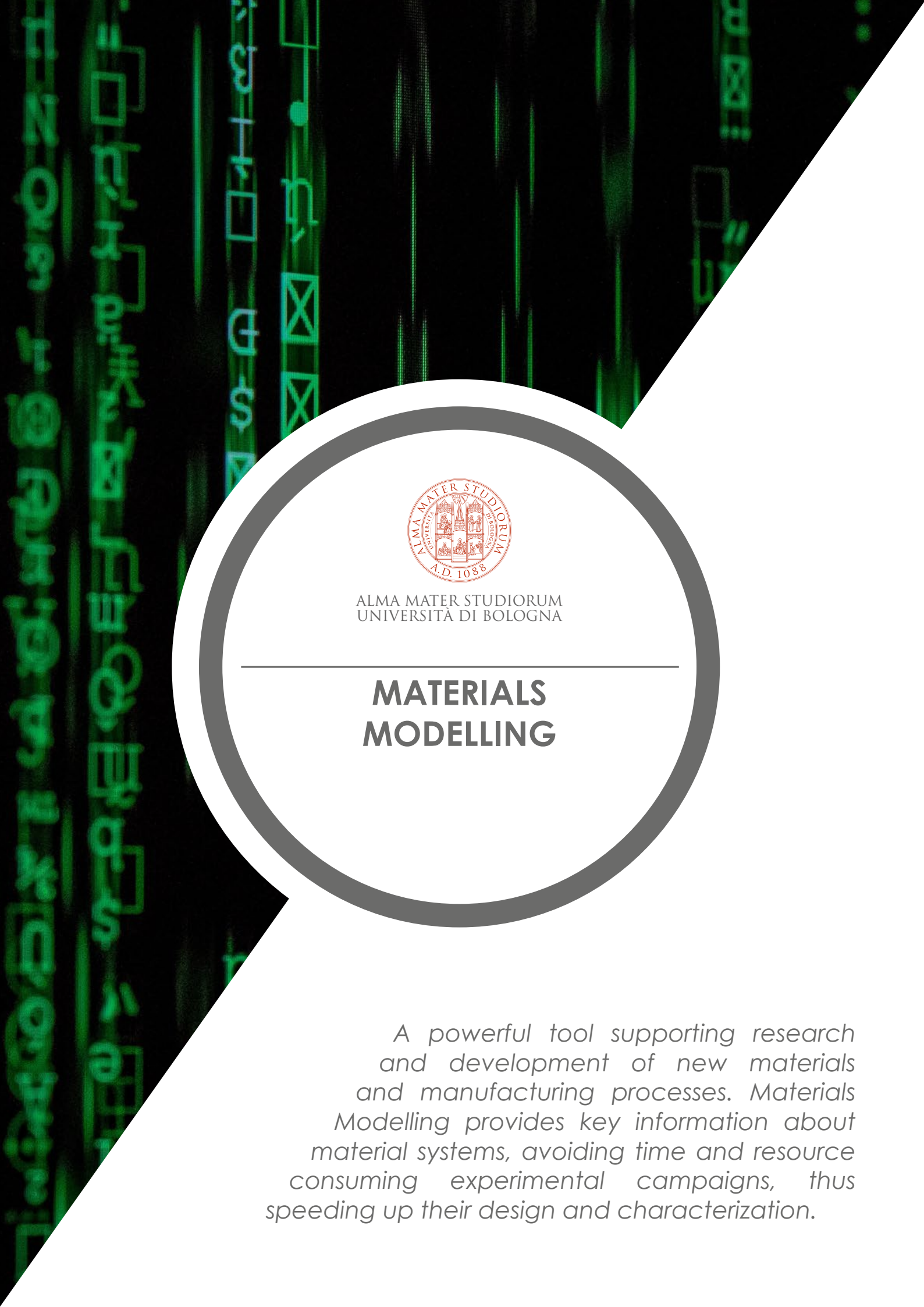
The engineered production of materials for transport systems thus represents an invisible revolution; that might allow the development of products and infrastructures under a really sustainable systemic approach.

The research at the University of Bologna on materials for transport applications profits from a wide range of scientific expertise, such as chemistry, physics, biology and engineering, as well as from all available technologies and multidisciplinary approaches, and a strong collaboration with industry and end users.
The University of Bologna provides a wide range of expertise on materials for application in transport systems:

- **Metals and metal matrix composites**: optimization of manufacturing cycles for tailored final proprieties, superplasticity, friction and wear behaviour heat treatment optimization microstructural and mechanical characterization of light alloys (Al, Ti, Mg, MMC); production and characterization of Al based nanocomposites
- **Polymer-matrix composite materials and metal**: design with FEM simulations, characterization of materials after thermal, hygroscopic or UV rays degradation, analysis of the crashworthiness properties of components using FEM simulations and experimental tests, development and optimization of technologies for the production of components with conventional and innovative composite materials, or innovative biocompatible ones; simulation of processes with FEA software
- **Metallic materials (conventional, lightweight and ultra-lightweight alloys)**: tolerance to the detriment of aeronautical structures, Laser Shock Peening Process, analysis and optimization of processes of plastic deformation, development of systems for solid state welding of light alloys and ultra-light
- **New advanced graphene based polymer matrices**: for carbon fiber composites production, with improved properties
- **Materials for energy storage/conversion devices**: electrochemistry particularly inorganic, carbonaceous and polymer electrodes and ionic liquids for lithium batteries, supercapacitors and fuel cells, synthesis, characterization and assembly
- **Development and characterization of lithium-ion batteries for PHEV** (plug-in hybrid electric vehicles), development, characterization and assembly of Li-air battery for EV
- **Pavement Engineering**: recycling and alternative materials in pavements

HIGHLIGHTS

- H2020 **CARIM** - *Commercialization of a full carbon wheel manufactured with an automated high-volume process for the automotive market*
- FP7 **THERMACO** - *Smart Thermal conductive Al MMC's by casting*



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MATERIALS MODELLING

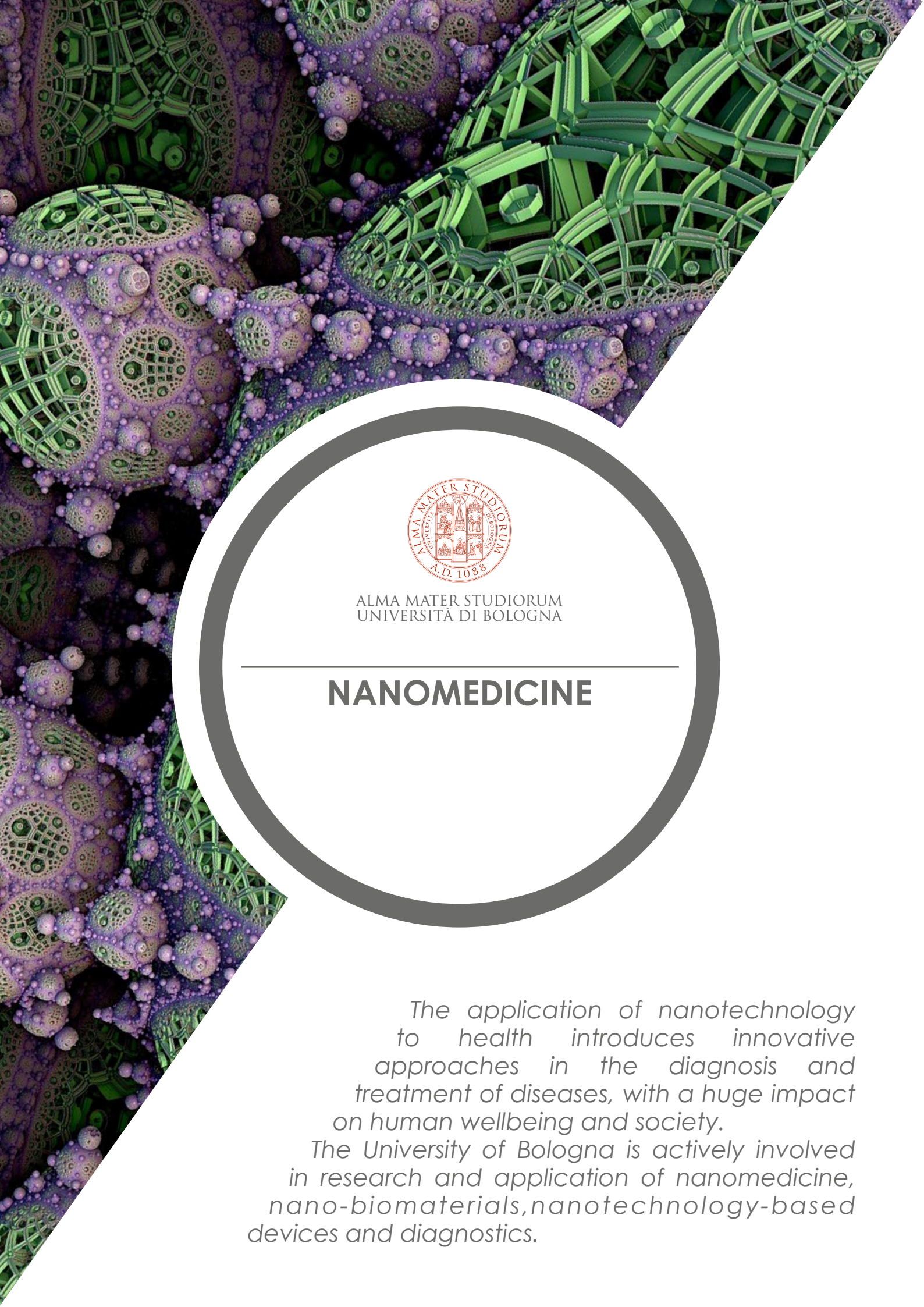
A powerful tool supporting research and development of new materials and manufacturing processes. Materials Modelling provides key information about material systems, avoiding time and resource consuming experimental campaigns, thus speeding up their design and characterization.

The research on Materials Modelling of the University of Bologna bases on a multidisciplinary approach crossing different areas and scales, from science and engineering, computational fluid dynamics, combustion, mechanical analysis, plasma physics, to computational chemistry, structural analysis and electromagnetism. The research on Materials Modelling of the University of Bologna covers several issues:

- Transport processes in polymeric, materials and membranes
- Electromagnetic characterization of materials
- Soil-structure interaction and structural analysis of historical and archaeological constructions
- Electronic models for spectroscopic characterization of molecules of biological, medical, pharmacological and astrochemical relevance
- Molecular and coarse-grained models for liquid crystals, polymers, membranes, proteins and other soft materials in the bulk or nanoconfined
- Modelling electronic processes and chemical reactions of light-induced events in complex molecular, nano-structured and biomaterial systems
- Atomistic modelling of nano-systems, self-assembled and soft molecular materials, including electronic processes and interaction with external stimula
- Orthopaedic biomechanics
- Plasma processing and synthesis of materials
- Modelling for set-up and verification of technological processes (e.g. plastic deformations, extrusion, casting, structural analysis) and material testing
- Modelling of internal combustion engines and real-time process control
- Modelling catalysed processes in organic chemistry and within bio-systems

HIGHLIGHTS

The University of Bologna is an active partner of the **European Materials Modelling Council (EMMC)**, aimed to bring materials modelling closer to the demands of industry and to **elaborate the Materials Modelling Roadmap as recommendation for the EC strategies.** The University of Bologna is also involved in several research projects financed at European level, contributing with Materials Modelling expertise:
H2020-**SimDOME**: Digital Ontology-based Modelling Environment for Simulation of materials.
H2020-**OntoCommons**: Ontology-driven data documentation for Industry Commons.
H2020 - **OntoTRANS**: Ontology driven Open Translation Environment.
H2020 - **DOME4.0**: Digital Open Marketplace Ecosystem 4.0.
H2020-**NANODOME**: Nanomaterials via Gas-Phase Synthesis: A Design-Oriented Modelling and Engineering Approach.
H2020-**EXTMOS**: EXTended Model of Organic Semiconductors.
H2020-**EMMC-CSA**: European Materials Modelling Council.
H2020-**INSPIRED**: INdustrial Scale Production of Innovative nanomateRials for printEd Device.
FP7-**ERC-STRATUS**: Structure and dynamics of biomolecules by two-dimensional ultraviolet spectroscopy.



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NANOMEDICINE

The application of nanotechnology to health introduces innovative approaches in the diagnosis and treatment of diseases, with a huge impact on human wellbeing and society.

The University of Bologna is actively involved in research and application of nanomedicine, nano-biomaterials, nanotechnology-based devices and diagnostics.

The deep knowledge in chemistry, physics, biology, medicine and engineering, is exploited through an interdisciplinary collaborative effort. University of Bologna is an active partner of the European Technology Platform on Nanomedicine.
The Research of the University of Bologna covers a wide range of issues:

- Nanotechnology-based diagnostics
- Functional imaging: hard and soft nanoparticles for image-guided surgery in nanomedicine; nanoparticles for targeted tumor imaging; ultra-bright and stimuli-responsive fluorescent nanoparticles for bioimaging. Electrochemical imaging
- Understanding protein–nanoparticle interactions
- DNA Nanotechnology: DNA and nucleic acids as building material for nanostructures by design
- Atomic Force Microscopy and related techniques to study biological macromolecules and their interaction with materials. Characterization of nucleic acids and of proteins, also using the 'single molecule force spectroscopy' to study of the mechanochemical behavior of molecules
- Nanobiotech-enabled biosensing platform
- Nanomaterials for tissue and organ regeneration
- Development of magnetic nanoparticles to functionalize scaffolds
- Gold nanorods and magnesium nanoparticles embedded into synthetic and natural biopolymers: non-toxic nano-heaters for cancer therapy
- Theranostic applications in Nanomedicine
- Design and development of nanoparticles and nanofibers for targeted drug delivery and drug release systems. Multi-drug-loaded materials to inhibit neuroinflammation and prevent neurodegeneration
- Dendrimers as scaffolds for constructing functional nanoscale devices
- Computational bionanotechnology: iInteraction of biomolecules with carbon nanoparticles; modelling cellular membrane permeation; reverse docking techniques to analyze systematically interaction between nanoparticles and proteome
- Nanofibers and nanoparticles fabrication through electrospinning and electrospraying

HIGHLIGHTS

Multifunctional Nanoparticles. Dye-doped silica nanoparticles as luminescent organized systems for nanomedicine. Biodegradable functionalized polymeric nanoparticles for targeted drug release. Surface functionalized nanoparticles to design 'nanobioreactors' with applications for magnetic fluid hyperthermia, targeted drug delivery and phototermal ablation.

Nanohybrids for photodynamic applications. The combination of a photosensitizing nanohybrid and focused irradiation, generating reactive oxygen species, has the potential to act specifically at the desired site of action, lowering the collateral damage to healthy cells.

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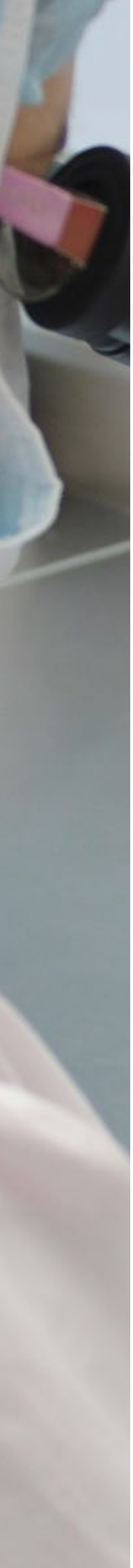
NANOSTRUCTURE ANALYSIS

A knowledge driven design of nanomaterials requires a profound understanding of the underlying atomic and electronic structures. The University of Bologna employs state of the art scanning microscopies and spectroscopic techniques to reveal such details at the atomic to nanometer level and provide researchers unprecedented insight into the structure of their materials.



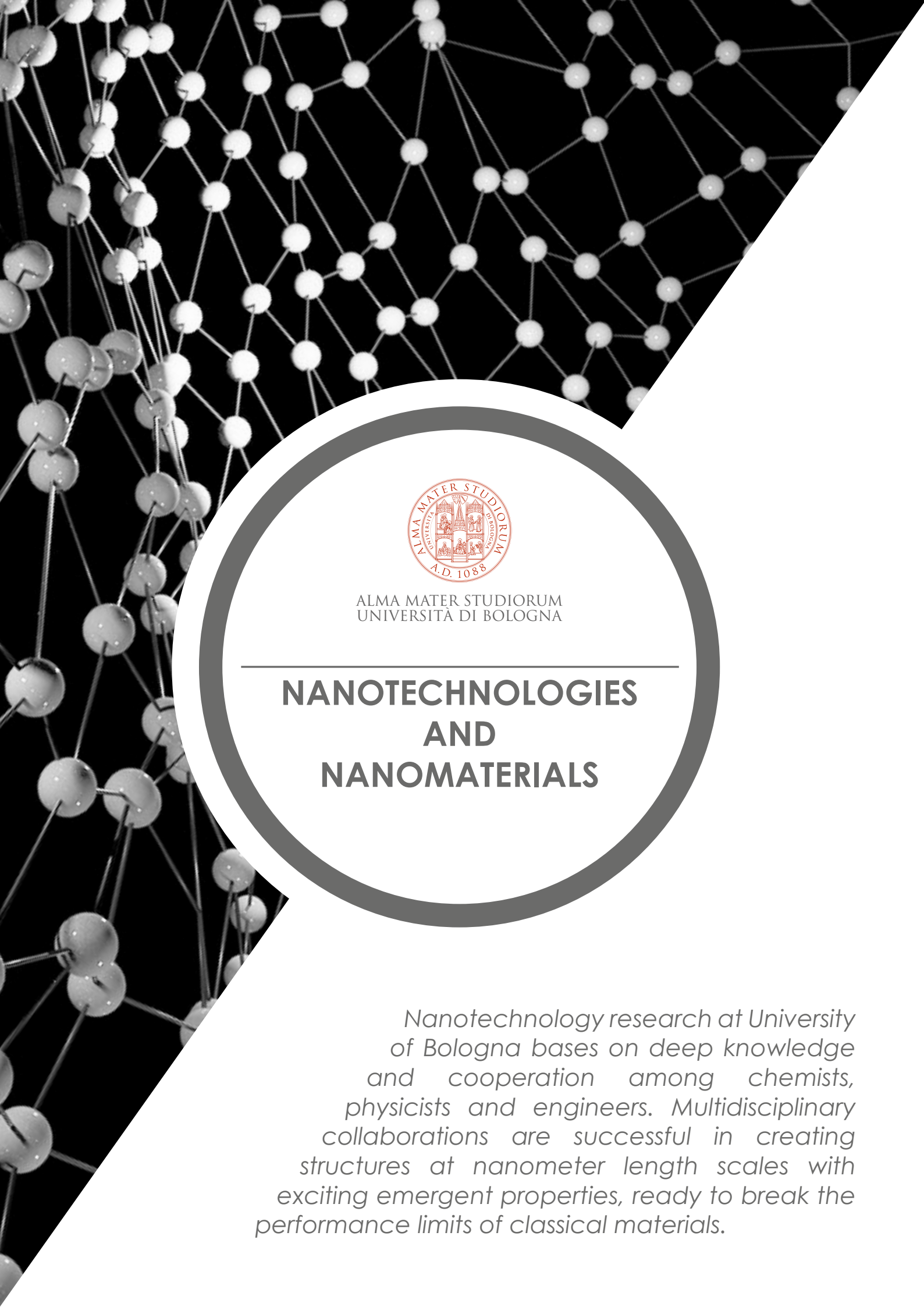
The research of the University of Bologna selects the most efficient analysis technique for a given nanomaterial sample:

- Atomic force microscopy to investigate nanostructures on surfaces. Different techniques to assess functional properties of nanostructures based on mechanical, electrostatic, conductive, piezoelectric or electrochemical probes
- Scanning electron microscopy to reveal the structure of fibrous or porous samples
- Light scattering to determine the size of dispersed nanoparticles
- X-ray scattering techniques to determine particle size distributions and crystallinity in nanostructured samples
- Time resolved spectroscopic techniques to investigate optical properties and energy transfer in nanostructured materials
- Nanoindentation experiments to assess mechanical properties at the nanoscale
- Determination of the local chemical composition of nanostructures by FTIR and EDS-SEM
- Confocal optical microscopy to reveal 3D structures and optical properties in nanostructured samples
- Scanning electrochemical microscopy (SECM) to investigate the functionality and the reactivity of the nano-objects

The University of Bologna has a strong experience in several advanced techniques: **Scanning Electrochemical microscopy:** ultramicro-/nanoelectrode probes to image the functionality and reactivity of nano-objects. Among other applications, this technique allow to assess charge transfer phenomena at single entity level; local conductivity; electro-catalytical/catalytical efficiency of the nanostructures; local reactions; the effect of the interaction of nanoobjects with living cells.

Functional nanoelectronic characterizations: scanning probe microscopies with electrostatic interactions, to achieve multimodal acquisition of structural and electronic properties at the nanoscale (i.e. allowing the investigation of failure mechanisms in flexible nanoelectronic devices).

Synchrotron Radiation and Free Electron Lasers for Fine Analysis: X-ray spectroscopy and scattering methods for fine characterization of the atomic and electronic structure of advanced materials and nanostructures. Studies of fundamental interaction mechanisms and methods on the ultra fast (femtosecond) time scale.



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NANOTECHNOLOGIES AND NANOMATERIALS

Nanotechnology research at University of Bologna bases on deep knowledge and cooperation among chemists, physicists and engineers. Multidisciplinary collaborations are successful in creating structures at nanometer length scales with exciting emergent properties, ready to break the performance limits of classical materials.

The focus of Nanotechnology and Nanomaterials research of the University of Bologna regards:

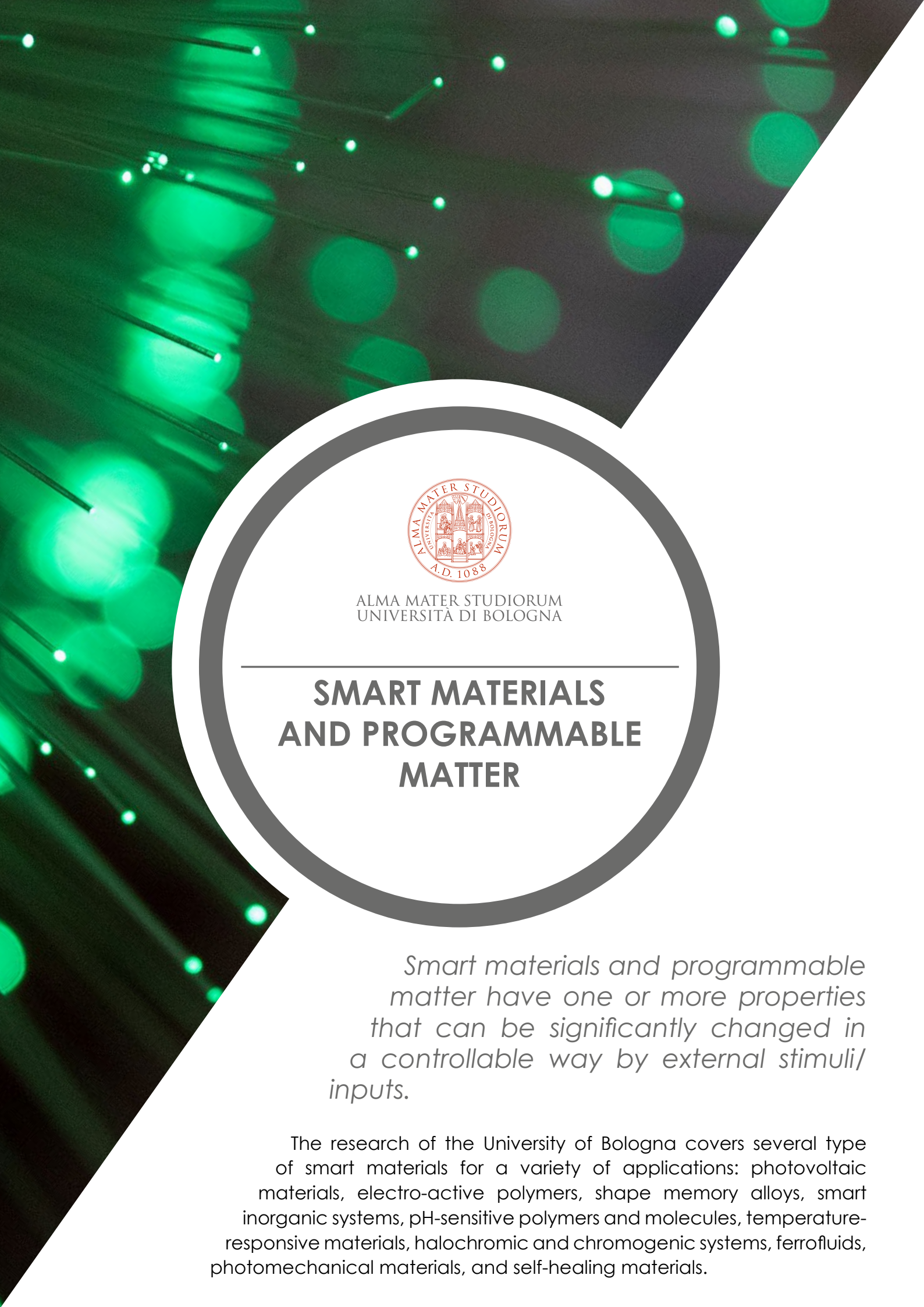
- Development of methods to synthesize metallic, oxide, semiconducting or polymer nanoparticles with diverse functionalities and fields of application
- Multifunctional nanocomposites for targeted drug release
- Realization of nanostructured surface coatings and thin-films
- Design and synthesis of supra-molecular structures that self-assemble into nanoscale molecular devices and machines
- Assembly of nanomaterials into hierarchical structures with active electrical or luminescent properties
- Chemical modification of nanostructured materials. Control of surface properties to achieve a homogeneous dispersion of nanomaterial in polymer
- Semiconductor quantum dots to enhance optical properties in novel sensor or solar cell architectures
- Design and fabrication of nanostructured surfaces and interfaces for energy applications
- Development of nanofillers to enhance properties of composite materials for packaging applications
- Development of biopolymer based nanomaterials to foster a more sustainable approach to nanotechnology
- Fabrication and investigation of nano-materials for electrochemical processes develoment of nanoparticle supported catalysts for chemical transformations
- Fabrication, modification and application of carbon based nanostructures synthetic DNA nanostructures

HIGHLIGHTS

Nanofibres through Electrospinning combine high-throughput fabrication and unprecedented material properties. Nanofibre mats are employed as scaffolds in regenerative medicine, as permeable membranes, or to enhance mechanical properties of construction materials.

Photonic nanoparticles combine highly specific optical properties with stability, biocompatibility and biological uptake. They are employed as future diagnostic tools or specific non-toxic vectors enabling better medical diagnostics and less invasive treatments.

Nanomaterials for Information and Communication Technologies allow the transition of traditional microelectronics into flexible, distributed electronics. Examples are stretchable bioelectrodes, flexible supercapacitors or highly sensitive electrochemical sensors.



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SMART MATERIALS AND PROGRAMMABLE MATTER

Smart materials and programmable matter have one or more properties that can be significantly changed in a controllable way by external stimuli/ inputs.

The research of the University of Bologna covers several type of smart materials for a variety of applications: photovoltaic materials, electro-active polymers, shape memory alloys, smart inorganic systems, pH-sensitive polymers and molecules, temperature-responsive materials, halochromic and chromogenic systems, ferrofluids, photomechanical materials, and self-healing materials.

The research of the University of Bologna covers a wide range of issues:

- Smart two-dimensional material-based time modulated array for RFID applications
- Development of adhesive durability materials for root canal using self-adhesive resin cements
- Smart barriers for Sustainable Food Packaging Applications
- Hybrid nanocomposites based on electroactive hydrogels and cellulose nanocrystals for high-sensitivity electro-mechanical underwater actuation
- Anti-listerial coatings entrapping living bacteria

HIGHLIGHTS

On a daily basis, the researchers of the University of Bologna design, produce and characterize materials that qualitatively and quantitatively respond to stress, temperature, moisture, pH, electric or magnetic fields, light, or chemical compounds. Applications include sensors and actuators, shape memory materials, Nature-inspired systems, and artificial barriers to chemicals or physical agents. Techniques in use include AFM, SEM, DLS, X-ray, time-resolved spectroscopies, FTIR, confocal microscopy, and SECM.

The University of Bologna actively contributes to research and innovation on smart materials also through several projects funded under the European Union's Framework Programmes **Horizon 2020** and **FP7**:

- **SiNBioSys** - *Luminescent silicon nanocrystals as bioimaging systems* (Horizon2020 – ERC): to develop a highly-robust and biocompatible hybrid material, which exhibits colour tunability across the visible and near-infrared region, and an extraordinary brightness of the material coupled to a long-lived luminescence which enables time-gated detection
- **LEAPS** - *Light effected autonomous molecular pumps: Towards active transporters and actuating materials* (Horizon2020 – ERC): to develop the first synthetic photochemical supramolecular pumps and to apply them for performing nanoscale transport functions and macroscopic actuation
- **HYSENS** - *Hybrid Molecule/Nanocrystal Assemblies for Photonic and Electronic Sensing Applications* (FP7-NMP): to harness the complementary properties of organic functional materials and inorganic nanocrystals to fabricate novel hybrid materials
- **i-FLEXIS** - *Integrated flexible photonic sensor system for a large spectrum of applications*: from health to security i-FLEXIS . FP7-ICT): to develop an innovative, reliable and low-cost integrated X-ray sensor system based on heterogeneous inorganic, organic and hybrid components