encompassing research of excellence and technology transfer

imdea **materials** institute

institute imdea materials

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1 institute profile
研究所简介

IMDEA Materials Institute, one of seven Madrid Institutes for Advanced Studies (IMDEA), is a public research centre founded in 2007 by Madrid's regional government. The goal of the Institute is to do research at the forefront of Materials Science and Engineering, attracting talent from all around the globe, and collaborating with companies in an effort to transfer fundamental and applied knowledge into valuable technology. IMDEA Materials Institute has an established international reputation in the areas of design, processing, characterisation, modelling and simulation of advanced materials for applications in different industrial sectors with particular emphasis in transport, energy and healthcare.

1.1. Mission and visión

mission

We do research of excellence in Materials Science, contributing to tackle the challenges of society and fostering the sustainable development of the region of Madrid.

vision

Our vision for the future is that IMDEA Materials becomes a leading research institute, internationally recognized for its excellence in materials science and its contributions to the transformation of society.

The mission and vision of the IMDEA Materials Institute is based in three main pillars:

science	talent	transfer
excellence in materials **science** and engineering research	**attraction of talented** researchers from all over the world to work in Madrid in an international and interdisciplinary environment	technology **transfer** to industry to increase competitiveness and maintain technological leadership

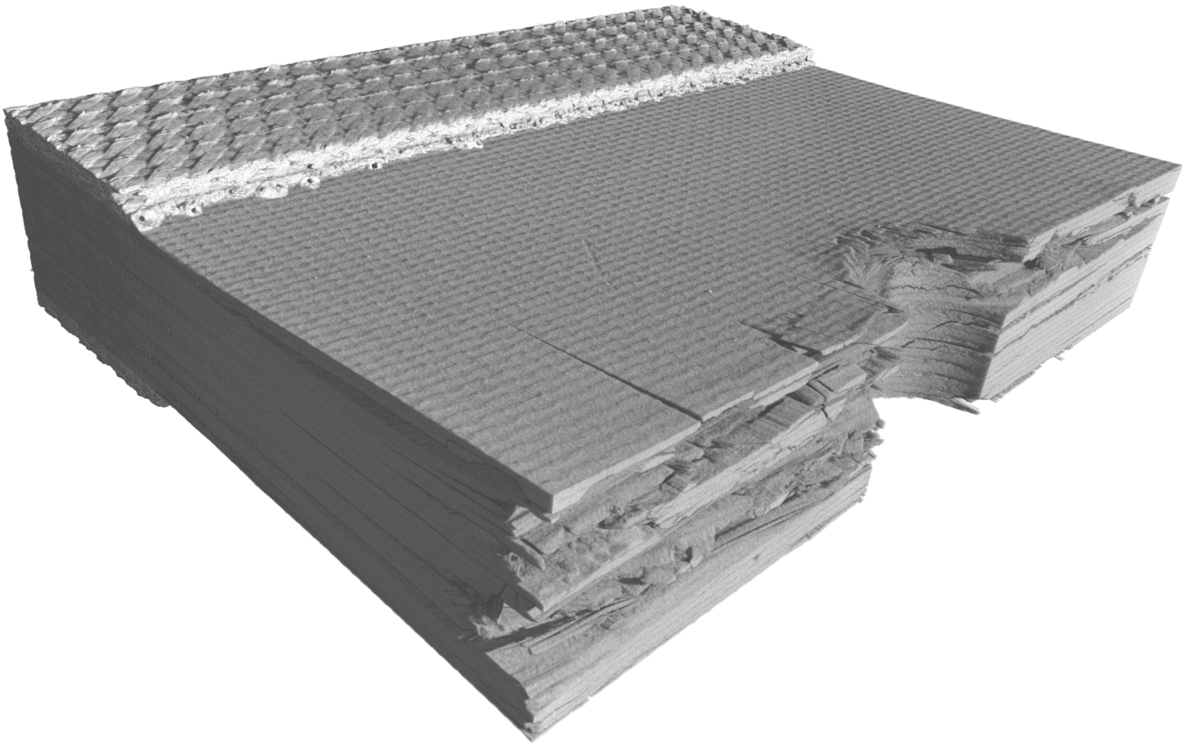
Figure 1.
IMDEA Materials Institute

1.2. Location

The building and laboratories of IMDEA Materials Institute are located at the Scientific and Technological Park of the Technical University of Madrid in Tecnogetafe, Madrid. The Institute has 2,640 m2 of research labs to manufacture, characterise and simulate advanced materials and nanomaterials, including their integration in lab scale prototypes and devices; and an auditorium (200 people) and networking space for international conferences and workshops.

1.3. Researchers

IMDEA Materials Institute research staff encompasses approximately 100 people, including 16 Staff Researchers, 2 Visiting Scientists, 20 Postdoctoral Research Associates, 40 PhD students and 20 master students from 16 different nationalities. Approximately 50% of the researchers have been born abroad while 60% of the PhDs were granted by foreign universities from the five continents, including Cambridge University, Max Plank for Iron Research, Delft University of Technology, University of California Berkeley, Dayton University, India Institute of Technology, China Central South University, Sichuan University, etc. This ability to attract talent from everywhere is rapidly contributing to establish IMDEA Materials Institute as an international reference in the materials science and engineering field.



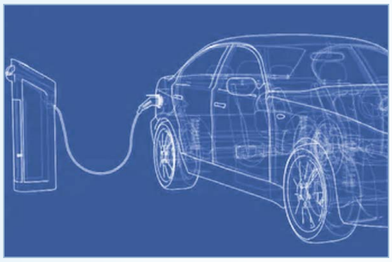
1.4. Research

talent science transfer

The Institute is currently organised into sixteen **research groups** focused on different areas in the field of Materials Science and Engineering. Each of these groups is led by one staff researcher, who is in charge of coordinating and supervising a research team of post and predoctoral reseachers. The research groups, as key units of the Institute, develop research projects and collaborations to drive the frontier of science of their field forward and transfer knowledge into valuable technology.

As a result of a high degree of internal collaboration, each research group at the IMDEA Materials Institute participates in several of our **research programmes**. Driven by the talent of the researchers, the research programmes combine cutting-edge fundamental oriented research in topics at the frontiers of knowledge with applied research encompassing the midterm interest of our industrial partners to provide long-term technological leadership.

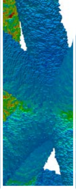
Advanced Materials for Multifunctional Applications



- Synthesis and integration of nanomaterials and polymer-based multifunctional nanocomposites
- New materials and strategies for electrochemical energy storage and conversion
- Computational and data-driven materials discovery

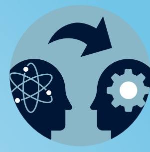
The Next Generation of Composite Materials

- Processing of high performance composites and nanocomposites. Recycling structural composites
- New frontiers of structural performance (impact, high temperature, mechanical...)
- Virtual testing and virtual processing of structural composites. Sensoring and Industry 4.0
- Multifunctional capabilities (fire resistance, electrical, thermal, sensing, energy management, health monitoring...)

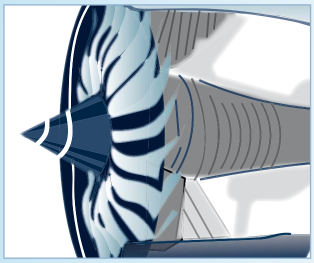



talent


science


transfer

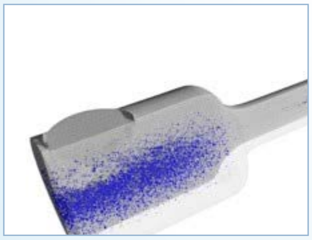
Novel Alloy Design, Processing and Development



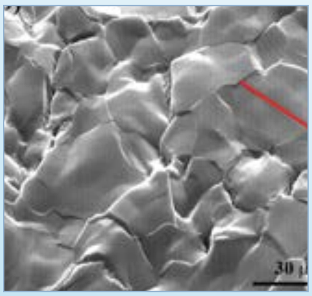
- Structural alloys: light alloys, high temperature alloys and high strength steels
- Characterisation of microstructure and mechanical behaviour
- Advanced manufacturing: solidification and casting, physical simulation of metallurgical processes (rolling, forging, extrusion…)
- Powder metallurgy and additive manufacturing: powder design and fabrication, process optimisation
- Virtual processing and virtual testing of metallic alloys

Multiscale Characterisation of Materials and Processes

- **3D characterisation of materials**
  (X-ray tomography and diffraction, SEM, TEM…)

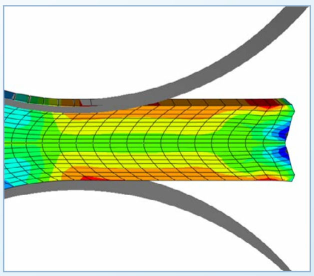


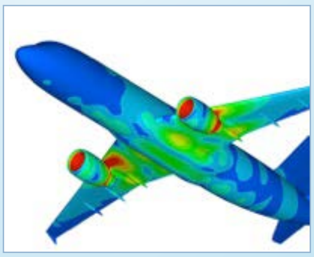
- **4D characterisation:**
  In-situ characterisation of deformation and processes across multiple length scales (750ºC)

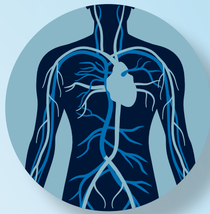


Integrated Computational Materials Engineering

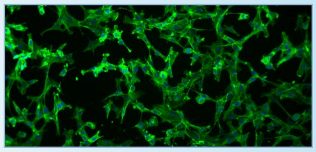
- Virtual materials design, including virtual processing and virtual testing
- Materials modelling at different length and time scales
- Multiscale materials modelling





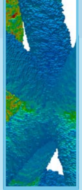


Materials for Health Care



- Additive manufacturing of biodegradable scaffolds (metallic, polymeric and composites) for tissue engineering (bone, cartilage, skin)
- Biofunctionalization and surface modification on materials with molecules (proteins, peptides, grow factors, drugs) to improve the performance of materials for biological applications and medical devices
- Mechanotransduction: effect of mechanical and electrical stimuli on biological actions
- Manufacturing and application of nanoparticles for drug delivery, disease treatment and antimicrobial activity
- Characterisation of cytocompatibility and biological functionality *in vitro*

2 research programmes
研究课题

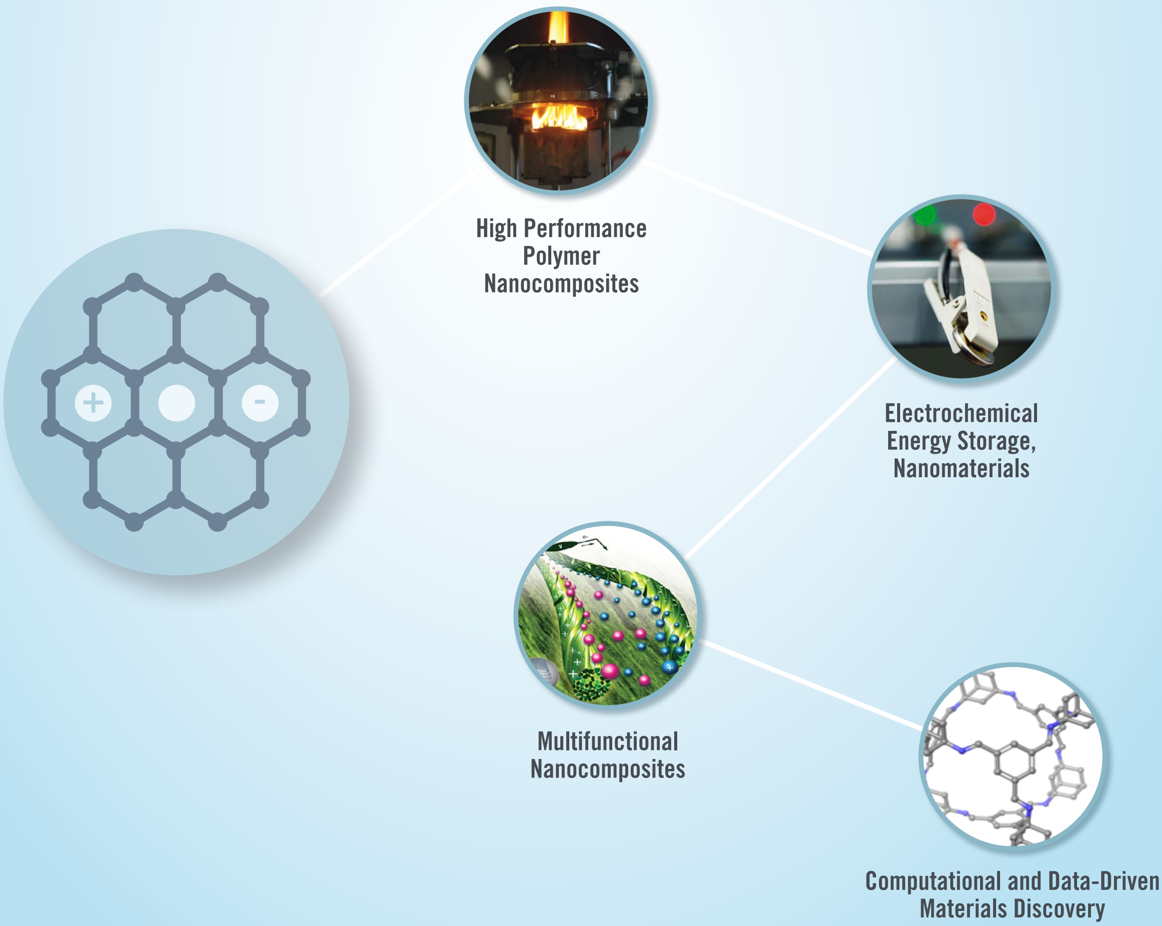


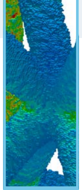
programme

Advanced Materials for Multifunctional Applications

Goal and vision

This programme combines expertise in design and synthesis of nano and molecular building blocks with their integration into macroscopic materials and devices. The guiding objective is to simultaneously realise various functions, including fire safety, fire safety energy materials, multifunctional smart materials, high performance and tailored lightweight composites, mechanical properties and efficient energy management, amongst other properties. 33 researchers in the programme combine expertise spanning from *in silico* molecular design to fabrication of large energy storing devices.





Main research lines

Synthesis and integration of nanomaterials (nanotubes, nanowires, nanofibers and hybrids)

- Synthesis and study of high-performance fibers based on carbon nanotubes.
- Synthesis of nanocarbon/semiconductor hybrids for photo and electrocatalysis, interaction of nanocarbons with liquid molecules, polyelectrolytes and inorganic salts.
- Sensors: chemical, piezoresistive, piezoelectric, triboelectric.
- Hierarchical materials: materials design from the nanoscale to the macroscale, nano-reinforced materials, composite materials with enhanced electrical and thermal conductivity, and fire safety.
- Fire-safe energy materials.
- Phase-change materials for energy storage.

Synthesis and properties of polymer-based multifunctional nanocomposites

- Fire retardant materials via nano-design: multifunctional nanomaterials to increase fire retardancy, e.g. MOF related nanoparticles and lightweight nanocomposites, etc.
- Fire retardant materials via molecular-design: flame retardant polymer electrolytes, novel environment-friendly flame retardants, etc.
- Sustainable materials: biobased supramolecular polymers and bio-based polymers, etc.

Solar energy conversion schemes

- Advanced dye-sensitised solar cells: Pt-free counter-electrodes, new electrolytes, etc.
- Fabrication of flexible solar cells with non-conventional substrates.

Thin-film lighting technologies

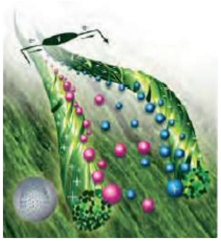
- Development of perovskite-based lighting devices with a focus on new NPs and device architectures.
- Fabrication of efficient and stable white lighting devices based on new organic and organometallic emitters.
- Dual functional devices: Design of novel device architectures and components.

Electrochemical energy storage

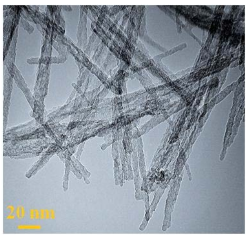
- Tailored designing of nanostructured electrode materials for electrochemical energy storage.
- Engineering of electrode-electrolyte interfaces for high-performance batteries and capacitors
- Spectroscopic and microscopic (in-situ and ex-situ) investigation of ion storage mechanism in energy storage devices.
- Fabrication of flexible battery electrodes for transport and other structural applications.
- Fire safety design and investigation on electrochemical energy storage devices.
- Dry processing of high capacity anodes for Li-ion batteries.
- Synthesis of nanostructured Si anodes for Li-ion batteries.

Computational and data-driven materials discovery

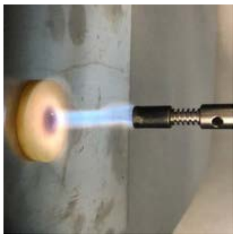
- Discovery of synthetic porous materials for energy-related separations and storage applications (e.g. CO_2 capture, methane and hydrogen storage).
- Design of ionic liquids and polymers.
- Development of modified natural porous materials for selective separation and degradation of organic molecules in food and feed industries.



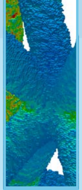
Concept of CNT fiber as current collectors/active materials for energy management devices.



Defect engineered electrodes.



Fire-safety multifunctional materials.

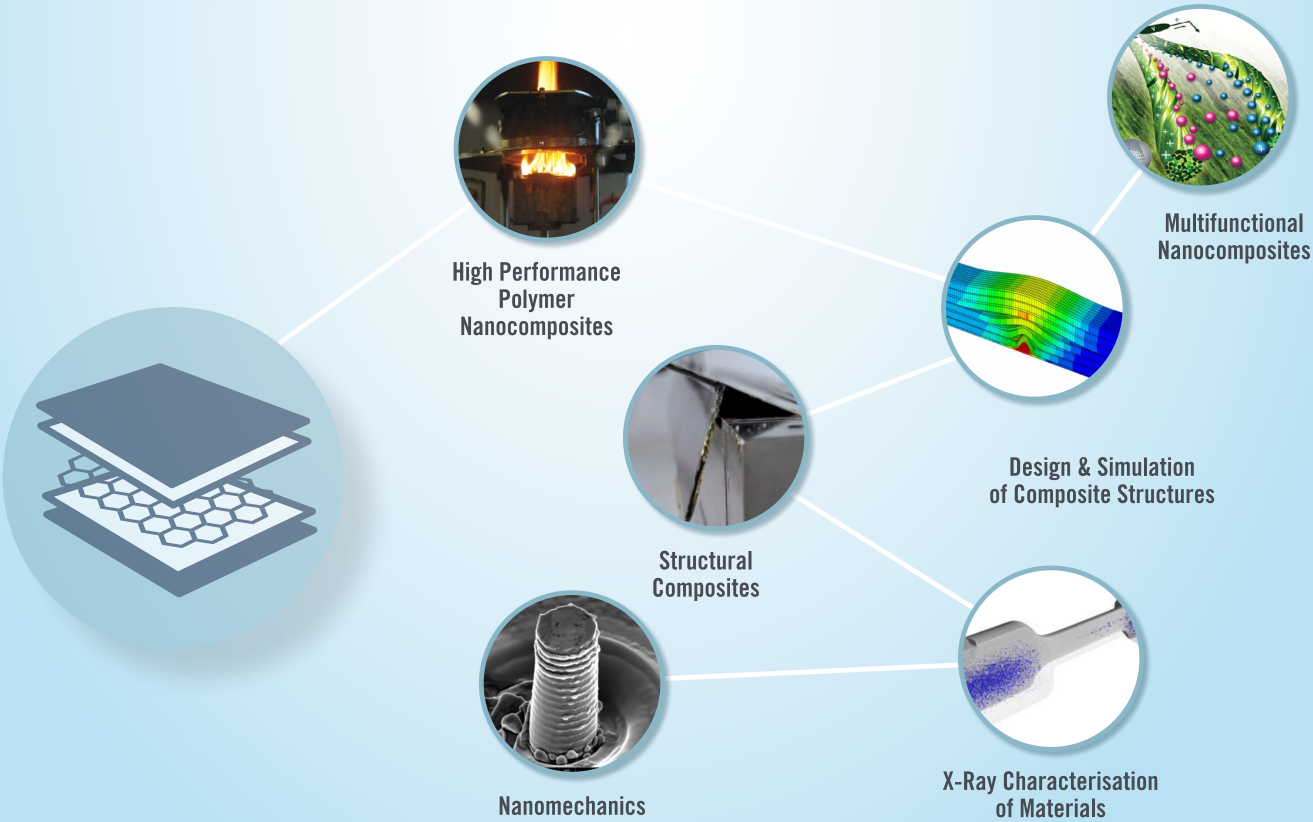


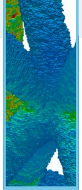
programme

The Next Generation of Composite Materials

Goal and vision

The Next Generation of Composite Materials Programme aims at developing solutions for high performance structural composites with enhanced multifunctional capabilities such as thermal, electrical and fire resistance. The programme is focused on key aspects of materials science and engineering including manufacturing, optimisation of material performance (damage tolerance and impact resistance), material characterisation at different length scales (nanoindentation, X-ray tomography) and development of modelling tools for both virtual processing and virtual testing. Manufacturing of composites by injection/infusion/pultrusion or prepreg consolidation is assisted by advanced sensors that support the use of smart manufacturing techniques toward process optimisation. Multiscale physically-based simulation tools are envisaged to predict the mechanical performance of structural composites as a function of their structure allowing a significant reduction of costly experimental campaigns.





Main research lines

Processing of high performance composites

- Optimisation of out-of-autoclave processing (injection/infusion/pultrusion or prepreg consolidation) and other manufacturing strategies including non-conventional curing strategies.

Recycling of structural composites

- Green (recyclable) epoxies. Electric current-assisted curing for bondings and repairs. Effect of ageing on composite performance. Recycling and reuse of carbon fibre.

New frontiers of structural performance

- Mechanical behaviour under low and high velocity impacts. Composites with non-conventional lay-up configuration. Hybrid composites.

Composites with multifunctional capabilities

- Fire resistance. Electrical and thermal conductivity. Energy management. Barrier properties. Non-destructive evaluation and health monitoring. Sensors and smart materials.

Micromechanics of composites

- In-situ measurement of matrix, fibre and interface properties. Micromechanical based failure criteria. Computational-design of composites with optimised properties (non circular fibres, thin plies, novel fibre architectures, etc.).

Virtual testing of composites

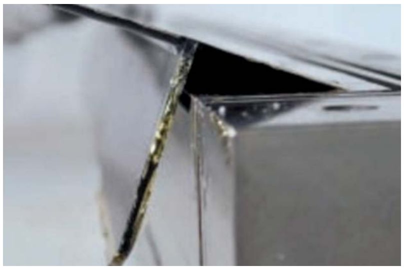
- Multiscale strategies for design and optimisation of composite materials and structures. Behaviour of composite materials and structures under high velocity impact (ice, metallic fragment or blade). Crash-worthiness and failure of composite structures. Effects of defects.

Virtual processing of composites

- Manufacturing process simulation. Multiphysics models for manufacturing including forming, injection/infusion process as well as curing. Characterisation of processing parameters.

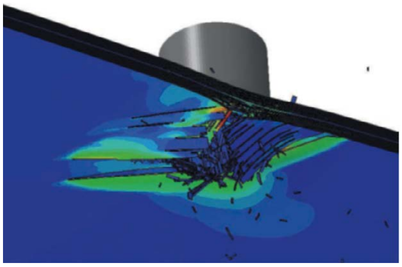
Digital technologies for structural composites

- Methods of artificial intelligence for optimization of composite manufacturing and structural performance. Sensors and process controls. Digital twins and hybrids.



Manufacturing of structural composites.

Multifunctional composites (e.g. lightning impact).



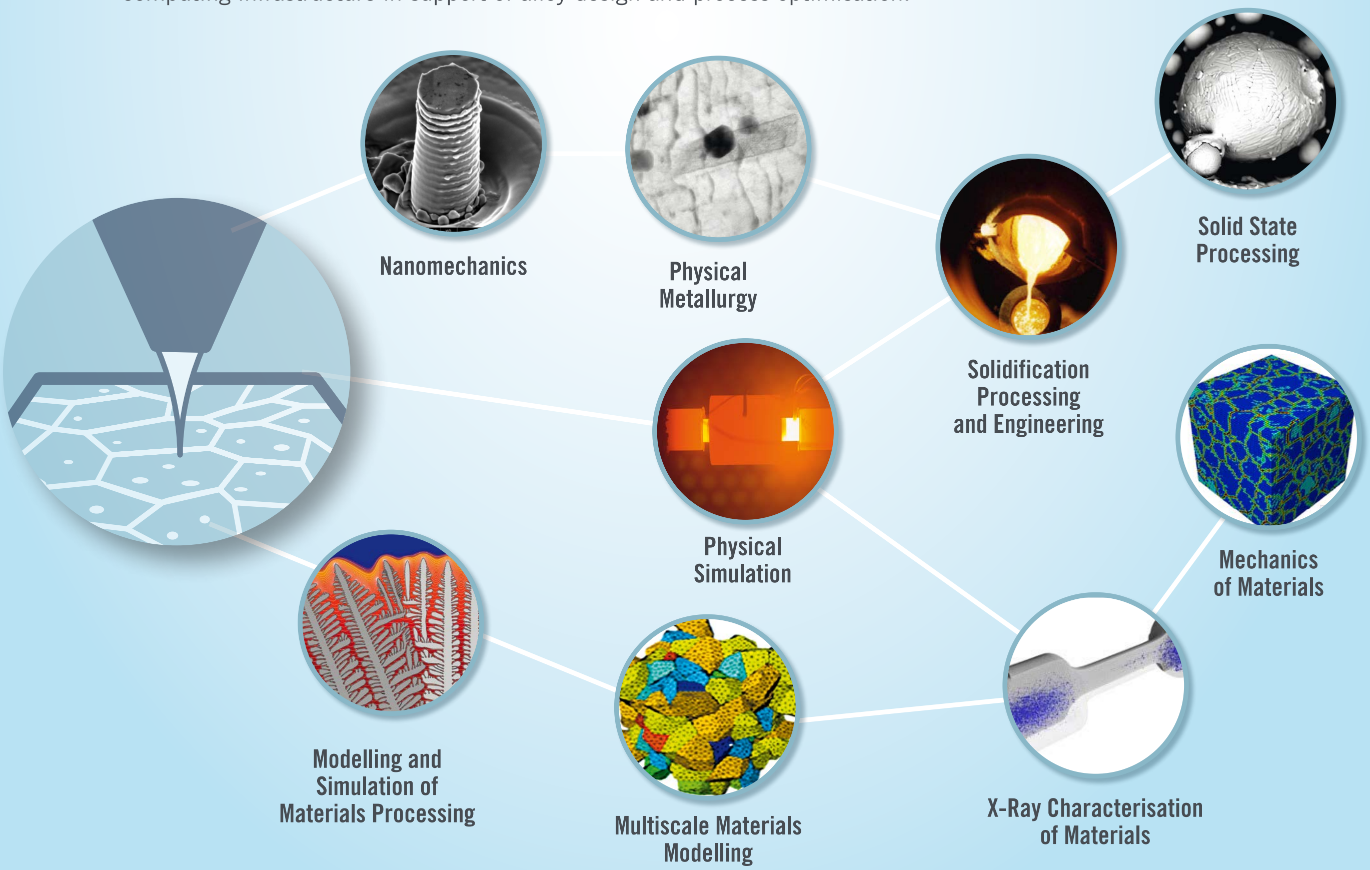
Multiscale virtual testing and processing.

programme

Novel Alloy Design, Processing and Development

Goal and vision

This programme, integrated by experts in physical simulation, solidification and casting, physical metallurgy, solid state processing and computational materials engineering, aims to explore the processing-structure-property relationships in metallic alloys, with special emphasis on the role of microstructure on the mechanical response at all length scales. This interdisciplinary pool of researchers is formed by physicists, chemists, and engineers (materials, mechanical and aeronautical) carrying out fundamental research and also working in close collaboration with companies in the transport, aerospace, energy and biomedical sectors. Research facilities include state-of-the-art equipment for processing at a laboratory scale (casting, wrought processing, physical simulation of metallurgical processes, atomization, additive manufacturing by selective laser melting, etc), microstructural characterisation (electron microscopy, X-ray diffraction, nanotomography) and mechanical property testing at a wide range of temperatures and strain rates, as well as a range multiscale simulation tools and high-performance computing infrastructure in support of alloy design and process optimisation.



Main research lines

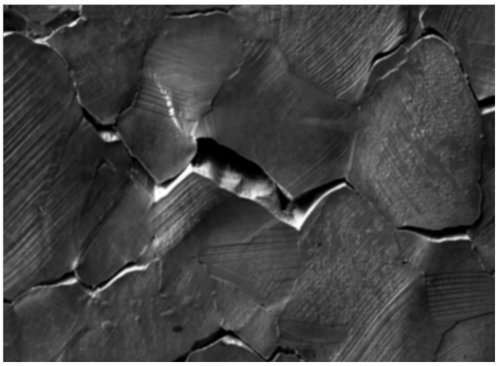
- **Characterisation** of microstructure and mechanical behaviour.

- **Advanced manufacturing:**
  - Solidification and casting. Centrifugal, suction casting and reactive infiltration.
  - Development of high-throughput methods by physical simulation of metallurgical processes (rolling, forging, extrusion, welding).

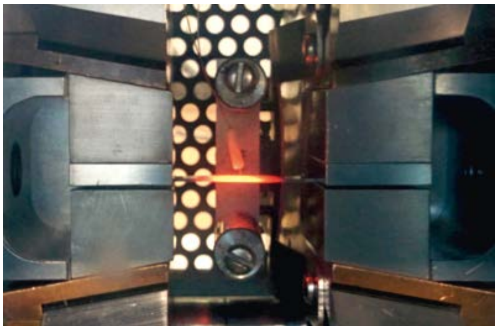
- **Powder metallurgy and additive manufacturing:**
  - Powder design, fabrication and characterizing.
  - Process optimization.

- **Virtual processing:**
  Multi-scale modeling of solidification and phase transformations in metallurgical processing of metals and alloys.

- **Virtual testing:**
  Multi-scale modelling of the mechanical behaviour of metallic polycrystals as function of their microstructure.



In-situ characterisation.



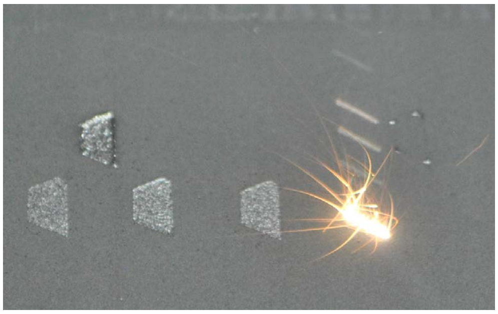
Thermo-mechanical processes in Gleeble thermo-mechanical simulator.

Materials of Interest

- **Metallic alloys for high temperature structural applications.** Ni/Co-based superalloys, High Entropy Alloys, NiAl, TiAl and FeAl alloys for aeroengine components.

- **Lightweight alloys and their composites.** For biomedical applications (Ti, Mg), electrical applications (Al alloys) or transport (Ti, Mg and nanocomposites).

- **High strength steels**. Quenched and partitioned steels with superior mechanical properties.



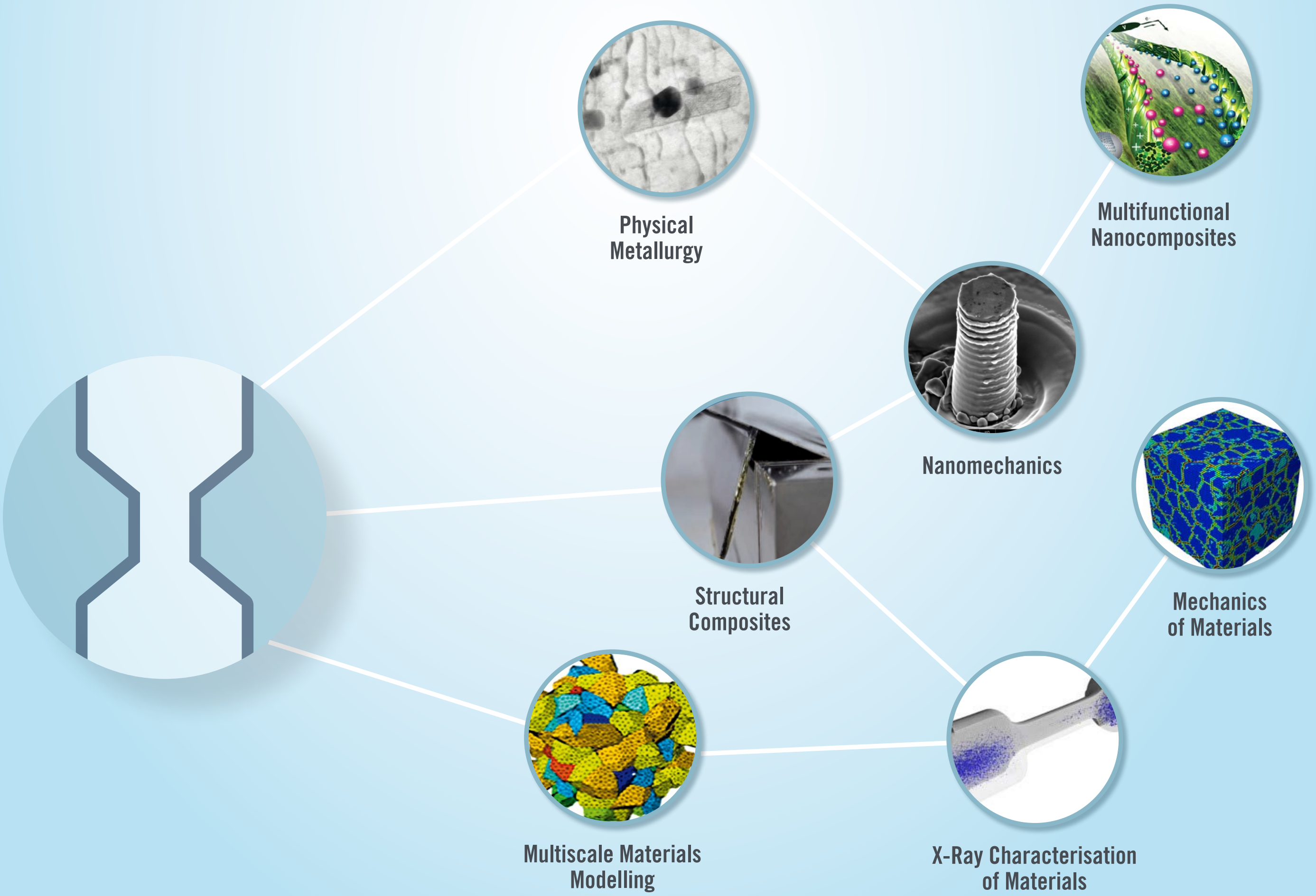
Advanced manufacturing.

programme

Multiscale Characterisation of Materials and Processes

Goal and vision

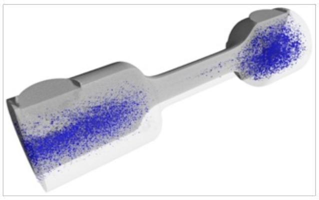
Progress in the development of new materials and processing methods can only come from a thorough understanding of microstructure evolution, either during processing or during service operation. Since the microstructural features that determine the material behaviour usually span several length scales (for instance, from the macroscopic defect distribution to the nanometer scale precipitates in the case of metallic alloys), this understanding can only come from advanced 4D characterisation techniques, capable of determining the evolution of the 3-dimensional microstructure over time at different length scales (hence the name 4D). This is precisely the objective of this programme, i.e., to understand microstructure/defect evolution in advanced materials during processing and service using advanced characterisation techniques.



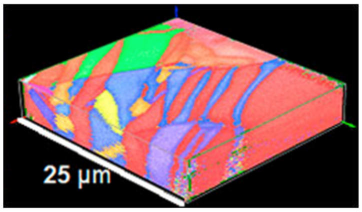
Main research lines

3D characterisation, including microstructural, chemical and crystallographic information across several length scales and using different techniques:

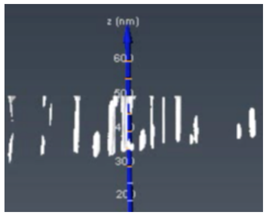
- X-Ray Tomography (XCT) and Diffraction (XRD).
- FIB-FEGSEM, including 3D-EDS, 3D-EDS and 3D-EBSD.
- TEM, including 3D-STEM and 3D-EDS.
- Correlative tomography studies, i.e., combining insights from different techniques.



XCT: Porosity in die-cast Mg alloys



3D-EBSD: Twin structure in a Mg alloy



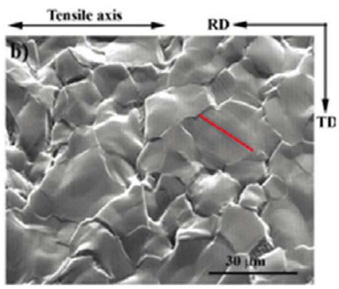
3D-TEM of Mg-Zn precipitates

4D characterisation: in-situ multiscale characterisation of processes:

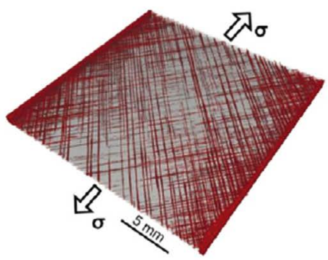
- **In-situ mechanical testing** across several length scales:
  - Tension, compression, fatigue, creep…of advanced metallic alloys and composites in the SEM and XCT.
  - Micro- and nanomechanical testing (nanoindentation, micropillar compression, microtensile testing…), including elevated temperature testing.
- **In-situ characterisation of forming processes by XCT:**
  - Infiltration and resin flow studies in composites.
  - Solidification studies.

From mm....

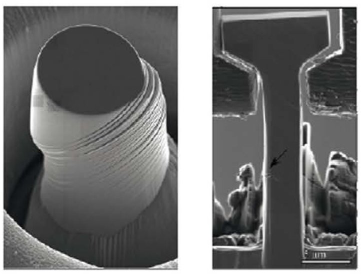
...to nm



Deformation of polycrystals in SEM

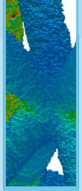


Composite failure in XCT



Micropillar compression / microtensile testing in SEM/TEM

Cross-correlation between experiments and multiscale simulations (ICME)



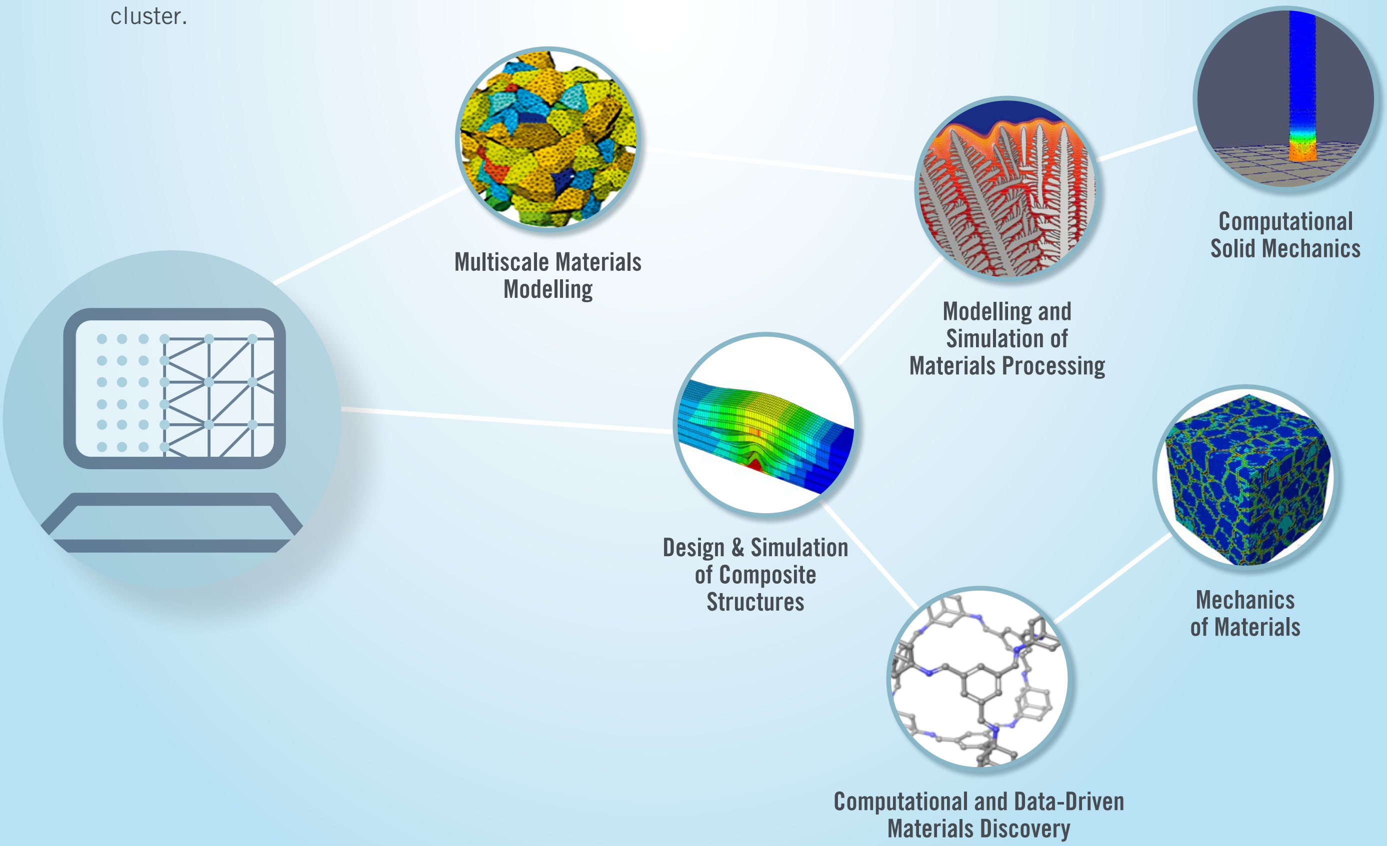
programme

Integrated Computational Materials Engineering

Goal and vision

The research programme on Integrated Computational Materials Engineering (ICME) is aimed at integrating all the available simulation tools into multiscale modelling strategies capable of simulating processing, microstructure, properties and performance of engineering materials, so new materials can be designed, tested and optimized before they are actually manufactured in the laboratory. The focus of the programme is on materials engineering, i.e. understanding how the microstructure of materials develops during processing (virtual processing), the relationship between microstructure and properties (virtual testing) and how to optimise materials for a given application (virtual design). Moreover, experiments are also an integral part of the research programme for the calibration and validation of the models at different length and time scales.

The expertise of the researchers in the programme covers a wide range of simulation techniques at different scales (electronic, atomistic, mesocopic and continuum) and is supported by a high performance computer cluster.



Main research lines

Virtual materials design, including virtual processing and virtual testing

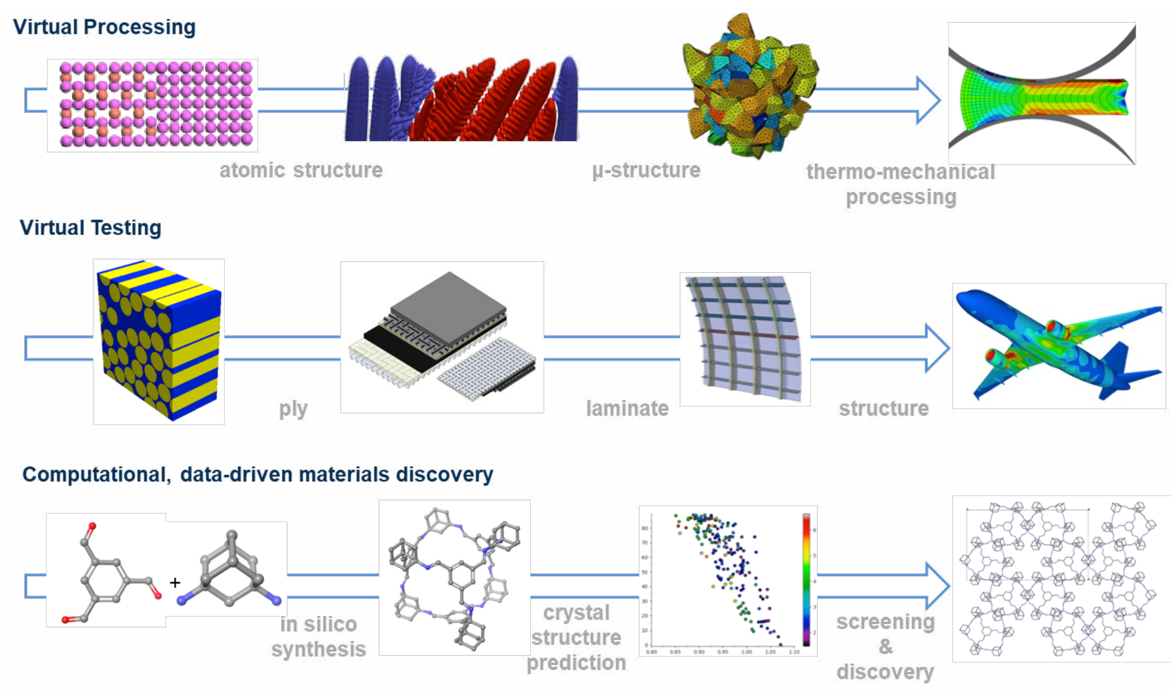
- Light (Al, Mg and Ti) metallic alloys and their composites. Ni-based superalloys. Multifunctional composite materials and structures. Materials for energy generation and storage.

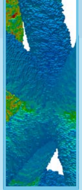
Materials modelling at different length and time scales

- First principles calculations. Molecular mechanics and molecular dynamics. Dislocation dynamics. Object and lattice Kinetic Monte Carlo. Computational thermodynamics and kinetics. Phase field. Multiscale modelling of dendritic growth (dendritic needle network approach). Numerical methods for solids (finite elements and other approximations for solid mechanics). Computational micromechanics. Computational mechanics. Material informatics for analysis of large material datasets. Data-driven materials design.

Multiscale materials modelling

- Bottom-up approaches (scale bridging). Development of modular multi-scale tools. High throughput screening integration. Concurrent models. Homogenisation theory. Modelling and simulation of multiscale transport phenomena (application to advanced materials for batteries).

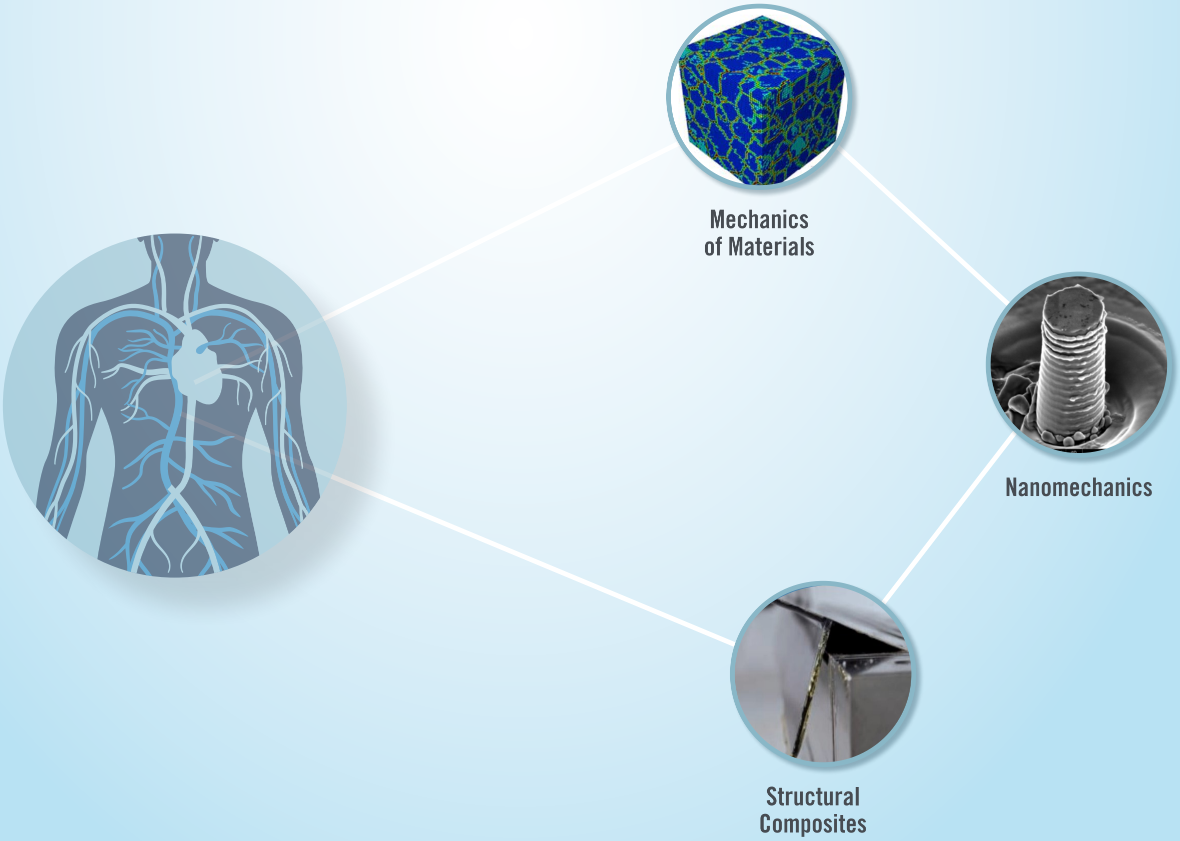




programme
Materials for Health Care

Goal and vision

Developing of novel materials-based approaches for addressing a number of challenges in medicine, ranging from treating organ/tissue damage to improving drug delivery. The programme is focused on key aspects of materials science and engineering, including chemical synthesis/modification and manufacturing of relevant materials (small molecules, polymers, biodegradable metals and composites, micro/nanoparticles, etc.), fabrication and functionalization of scaffolds (additive manufacturing, bioprinting), material characterization (microstructure, *in vitro* mechanical and chemical performance) and characterization of the biological effects and cytocompatibility of the materials using cell culture. This programme is supported by state-of-the-art new facilities for biomaterials processing and cell culture, to be fully operative in year 2021. The long-term vision is to develop collaborations with clinicians and biomedical researchers (at hospitals, research centers and industry) to enable translational research.



Main research lines

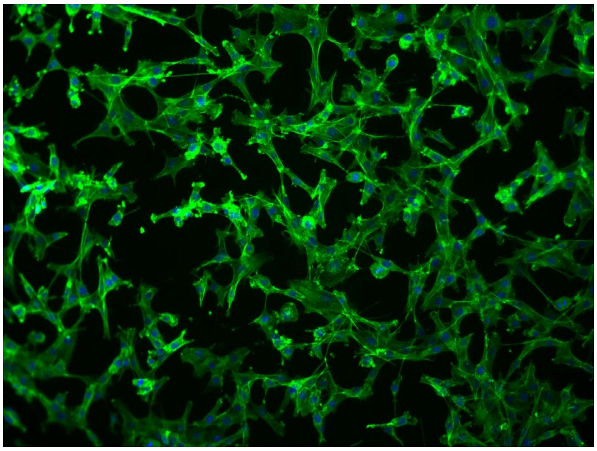
Additive manufacturing of biodegradable scaffolds (metallic, polymeric and composites) for tissue engineering (bone, cartilage, skin).

Biofunctionalization and surface modification on materials with molecules (proteins, peptides, grow factors, drugs) to improve the performance of materials for biological applications and medical devices.

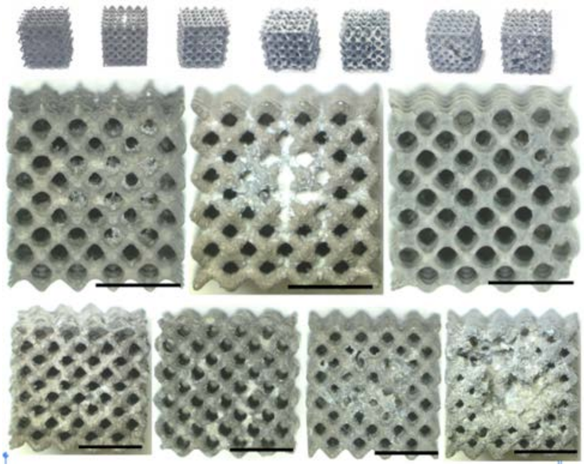
Mechanotransduction: effect of mechanical and electrical stimuli on biological actions

Manufacturing and application of **nanoparticles for drug delivery, disease treatment and antimicrobial activity**.

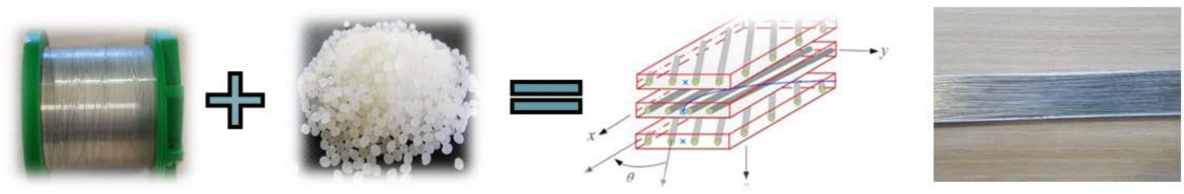
Characterization of cytocompatibility and biological functionality *in vitro*.



Pre-osteoblast MC3T3-E1 attached on Poly(DL-lactide) medical grade polymer used in the manufacturing of 3D scaffolds for bone regeneration. In blue the nucleus and in green the cytoskeleton. Winner imaging contest 2021. Characterization



3D printed Mg scaffolds for bioresorbable bone implants



PLA-Mg fiber", con pie de figura "Bioresorbable PLA/Mg fiber composite plate for biomedical applications

3 graduate study and life in madrid

研究生学习以及马德里生活介绍

3.1. Why Madrid

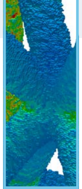
- Madrid is the capital of Spain.
- 6.5 million inhabitants in its Metropolitan Area and 3.3 million in the Capital. It is the third most populous city in the European Union.
- Capital of Spanish language and culture.
- Europe's third largest metropolitan area after Paris and London.
- Fourth richest city in Europe.
- Home to the 'Cortes Generales'- the Spanish Houses of Parliament - the Government of Spain, and the home of the Spanish Royal Family
- Average height above sea level: 667 m.
- Average temperature: 12 °C.
- Area: 605.77 km^2.
- Income per capita in Madrid is $40,000 and contributes 18% of the total national GDP.
- Barajas Airport, with annual passenger traffic of 50 millions,it is the fourth largest in Europe and tenth in the world. It is connected by metro and bus to the centre of the city.
- The Madrid metro is the second largest underground network in the world.
- There are five transport interchanges that connect the city bus network to the metro and railways.
- Madrid is linked by high-speed trains to the main Spanish cities.

Madrid is not just any city; it is a place full of energy and passion with a flavor of its own, rich in heritage to explore, full of spice and yet focused and highly sophisticated. In Madrid international students soon find themselves integrated into a multicultural environment to enjoy a city packed with creativity and fun where learning comes easy.

As the financial, political and cultural centre of Spain, Madrid is a modern, cosmopolitan city with a strong economy and a vibrant life. In recent years the growth and development of Madrid have placed it firmly within the network of global cities as the third great European metropolis and as the economic and cultural capital of the Spanish Speaking World.

The City of Madrid has a population of nearly three million people and is also the capital of the Madrid Region (Comunidad Autonoma de Madrid). This region is the economic powerhouse of Spain and also of Southern Europe; its six million inhabitants and their readiness to succeed make it possible every day... and night.

As a large metropolitan area, Madrid is tirelessly striving to attract productive investment, new technology businesses, scientific capability, creative talent, international institutions, a steady flow of tourists, and the staging of important events. Indeed, Madrid now stands out in many of these aspects over other major cities.



3.2. Resource directory

MADRID

Strategy and International Action Office Madrid Global
http://www.munimadrid.es/madridglobal

Madrid City Council Official websites
Resources for Culture and Leisure, Economy, Education, Environment, Immigration, Housing, Research, Sports and Youth
http://www.munimadrid.es/

Entertainment and tourism
http://www.esmadrid.com/en

Madrid Regional Government Official Website for Higher Education Information on Madrid Higher Education
http://www.emes.es/

Madrid Regional Government Official Website for R&D Madri+d
http://www.madrimasd.org/empleo/default.asp

The European Space for Higher Education
European policy for Higher Education with Bologna process
http://www.eees.es/

Chinese Students Association in Madrid
www.cn-es.org

UNIVERSITIES

Universidad Politécnica
www.upm.es

Introduction (English)
www.dit.upm.es/aalvarez/UPM.Introduction.pdf

Introduction (Chinese)
www.dit.upm.es/aalvarez/MadeliGong.pdf

Practical Information for Students
http://www.upm.es/internacional/Students/

Universidad Autónoma
www.uam.es

Orientation, Information and Employment
http://www.uam.es/estudiantes/coie.html

Graduate Studies and Continuing Education
http://www.uam.es/estudios/doctorado/presentacion.html

Scholarships
http://www.uam.es/estudiantes/becas.html

Orientation and Student Support
http://www.uam.es/estudiantes/acceso/

Universidad Carlos III
www.uc3m.es
English version:
http://www.uc3m.es/portal/page/portal/home

Masters and PhD
http://www.uc3m.es/portal/page/portal/postgraduate_studies

Living and Studying in Madrid
http://www.uc3m.es/portal/page/portal/get_know_us/living_studying_mad

Comunidad de Madrid

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