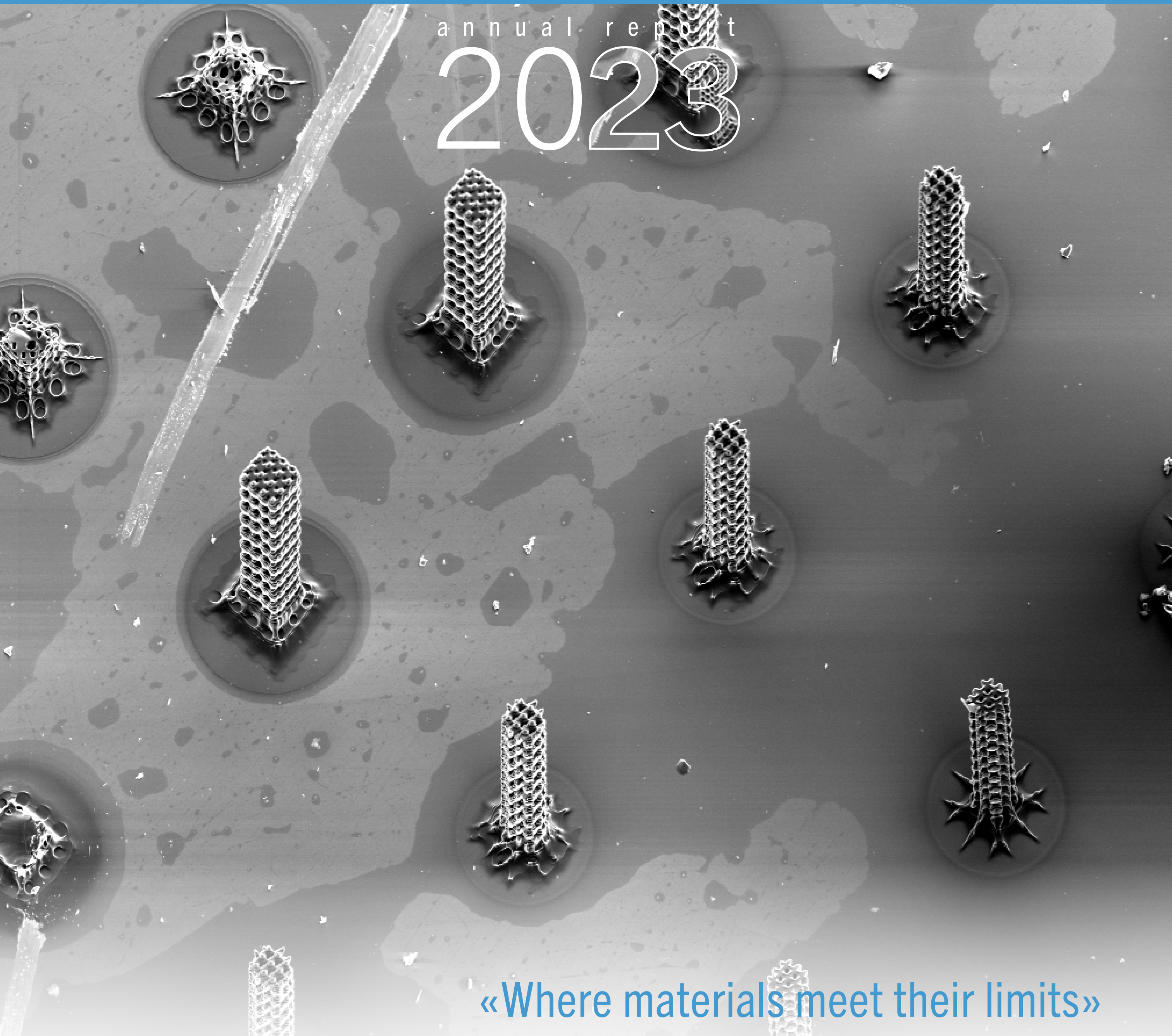
institute imdea materials

www.materials.imdea.org

annual report

2023



«Where materials meet their limits»

WORDS FROM THE DIRECTOR...

It is my pleasure to be addressing the readers of the IMDEA Materials Annual Report for the third straight year. Since taking over the role of Director in 2021, I have witnessed the growth of this Institute beyond what could surely have been imagined when it was founded by a small number of visionary materials scientists in a wing of the Technical University of Madrid more than 16 years ago.

From that initial handful of employees, IMDEA Materials has grown every year since, and now boasts a research staff more than 20 times its original size.

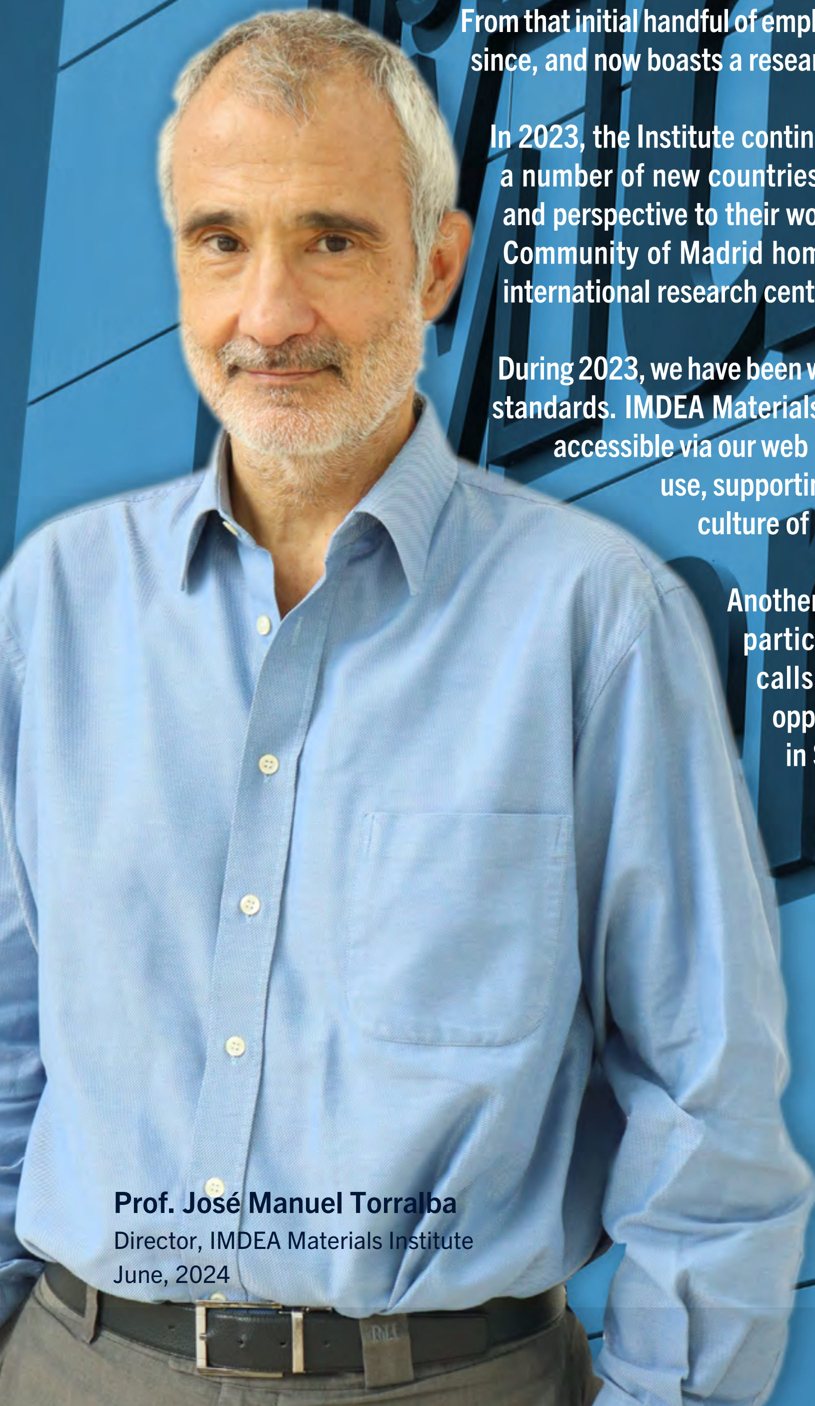
In 2023, the Institute continued to welcome many new researchers from a number of new countries. Each researcher brings a unique identity and perspective to their work, and, although IMDEA Materials calls the Community of Madrid home, this is what makes the Institute a truly international research centre.

During 2023, we have been working to strengthen ethical and compliance standards. IMDEA Materials updated the Ethics Channel, which is now accessible via our web page and offers the possibility of anonymous use, supporting our commitment to our Code of Ethics and culture of Compliance.

Another of the key pillars in attracting talent is our participation in leading fellowship and funding calls and programmes, which offer excellent opportunities to carry out world/leading research in Spain.

One example of this is that in 2023, IMDEA Materials once again achieved great success in the Marie Sklodowska-Curie Actions postdoctoral fellowship call, with the Institute placing in the top 5 of all research centres in Spain, with a success rate nearly three times the average in the engineering field.

I was also very pleased to see that Spain as a whole was the leading country in Europe attracting talent as part of this prestigious funding programme and was also the



Prof. José Manuel Torralba
Director, IMDEA Materials Institute
June, 2024

European country which received the fourth most ERC Advanced Grants. These are just two indicators of the important role that Spain is playing within the European science community, and IMDEA Materials is committed to that mission.

Projects and Partnerships

The incredible MSCA projects currently underway at IMDEA Materials are just a small sample of the research projects being carried out at the Institute. Within our 16 research groups, the scope of these projects ranges from developing AI tools to develop green steel technology, to cutting-edge research on carbon nanotube fibres, machine learning, 3 and 4D printing, and much, much more.

Throughout these research projects and Ph.D. theses being completed, our researchers were involved in the publication of more than 150 scientific articles, which received nearly 8000 citations (a new record).

It is important to remember that we do not carry out science for science's sake, but rather to have a direct impact on society, and to improve the lives of those who will directly benefit from the research being done by IMDEA Materials researchers.

Whether that be in in the form of less invasive surgeries thanks to new generations of implants, stents or other biomedical devices, or being able to breathe easier thanks to less polluting forms of transport taking advantage of lighter, stronger and more efficient materials.

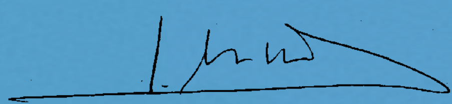
Our collaborations with industrial partners in sectors such as aerospace, technology, metal manufacturing and hydrogen storage have resulted, and will continue to result, in real advances in these fields. This technology transfer not only benefits our industrial partners, it also ensures that the great work being done every day at IMDEA Materials has a positive real-world impact.

Looking back on my third year as this Institute's Director, I feel incredibly grateful for having had the opportunity to be part of IMDEA Materials' continuing journey. I can only thank all of my colleagues for their hard work and commitment to making that journey possible.

To our Principal Investigators, who are so diligently forming the next generation of scientists, to those postdoctoral and predoctoral researchers who have dedicated themselves to the cause of science and research.

To our technicians who keep our world-class facilities and scientific equipment up and running, and to those in project management and administration, who ensure that our researchers have access to the resources, assistance and guidance they need to undertake their various projects.

2023 was another great year in the history of this great institute, and I look forward to taking yet another step forward in 2024.



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Dr. Monsur Islam. Winner imaging contest 2023. Materials Characterisation.

contents

About us

IMDEA Materials Institute is one of seven Madrid Institutes for Advanced Studies (IMDEA Institutes) based in the Madrid Region.

Founded as research centres of excellence at the initiative of the regional government in 2006 and 2007, these seven Institutes are focused on strategic areas for society from a business, scientific and technological point of view: water, food, energy, nanoscience, networks, software and materials.

Their objective? To encourage excellent R+D+I and create an efficient science and technology development model while collaborating with the productive sector.

IMDEA Materials Institute's goal is to carry out research at the forefront of Materials Science and Engineering, to attract talent from around the world, and to collaborate with companies to transfer fundamental and applied knowledge into valuable technology.

IMDEA Materials Institute at sunrise.
IMDEA Materials Imaging Contest 2024,
Open Subject Category.
Photo: Alejandro González.

Our…

…mission

Research of excellence in Materials Science to tackle the challenges facing society and to foster the sustainable development of the Madrid region.

…vision

To continue enhancing IMDEA Materials' reputation as a leading research institute, one which is internationally recognised for its excellence in Materials Science and its contributions to the positive transformation of society.

…facilities

IMDEA Materials Institute is located in the Scientific and Tecnological Park of the Technical University of Madrid in Tecnogetafe, Madrid, Spain.

Our 2,640 m^2 of state-of-the-art laboratories offer the capacity to manufacture, characterise and simulate advanced materials and nanomaterials, including their integration in lab-scale prototypes and devices. The Institute also boasts a 200-person auditorium and networking space for international conferences and workshops.

…technology

Metals, composites, polymers, 3D printing, multiscale modelling and artificial intelligence, nanostructured materials, multiscale characterisation of materials and processes, fire resistance, electrochemistry and biomaterials and cell culture.

...SECTORS AND AREAS OF APPLICATION

Research programmes: fundamental and applied

Strategic Partners

Global challenges

...people

In 2023, IMDEA Materials Institute's staff numbered some 138 researchers, technicians and members of the administrative team. This marked the second consecutive year in which our numbers have grown, following a similar year-on-year increase from 2021 to 2022.

Our staff is our most valuable resource, and the Institute remains committed to providing the best possible working environment for all those who share in our mission of promoting scientific excellence.

The Institute's efforts in this regard were officially recognised when IMDEA Materials saw its HR Excellence in Research Award renewed by the European Commission. This marks the latest renewal of this title, which the Institute has held since 2015, and which highlights our efforts to continuously improve our human resource policies, notably our dedication to achieving fair and transparent recruitment, and in providing a collaborative and flexible workspace.

The percentage of foreign researchers who call IMDEA Materials home remained high in 2023, with just under half of our scientists (and approximately two-thirds of our postdoctoral researchers) coming from outside of Spain. Our aim is to attract the best scientific talent from around the world and we can see this in the wide variety of nationalities and cultures represented throughout our research groups.

Our commitment to gender balance is highlighted by the ongoing implementation of our Gender Equality Plan which aims to establish mechanisms to detect inequality, and to ensure that all staff and potential employees are treated equally and have the same opportunities.

Meanwhile, 2023 saw the continuation of the Institute's popular transversal training programme opportunities, in topics related to time and stress management, entrepreneurship, forging a successful career path, and more.

Finally, the implementation of our new Ethics Channel reporting system enables all our employees the opportunity to report possible problems in the workplace without fear or favour.

All of these policies are designed to ensure that IMDEA Materials Institute boasts a talented, diverse and international research staff, who enjoy coming to work each day, and whose positivity and dedication drive the Institute's continued success and innovation.

Rosa Bazán
HR Manager

105
Researchers

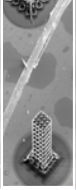
48%
Foreign Researchers

36%
PHDS

24
Nationalities

36%
Female researchers

16
Research groups



our structure

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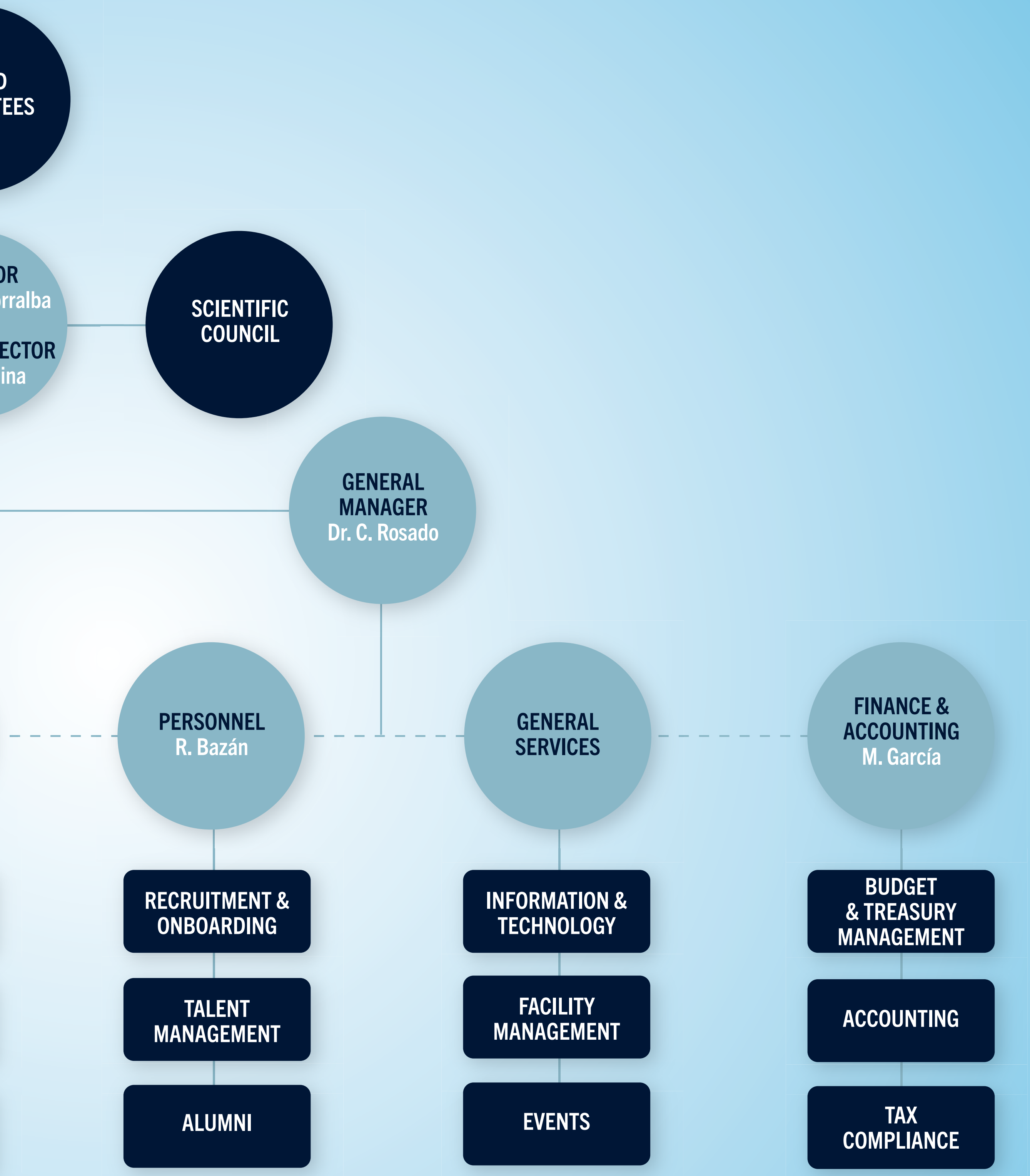
- TECHNOLOGY TRANSFER & INNOVATION
- COMMUNICATION & OUTREACH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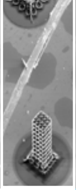

our structure

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in figures

human resources

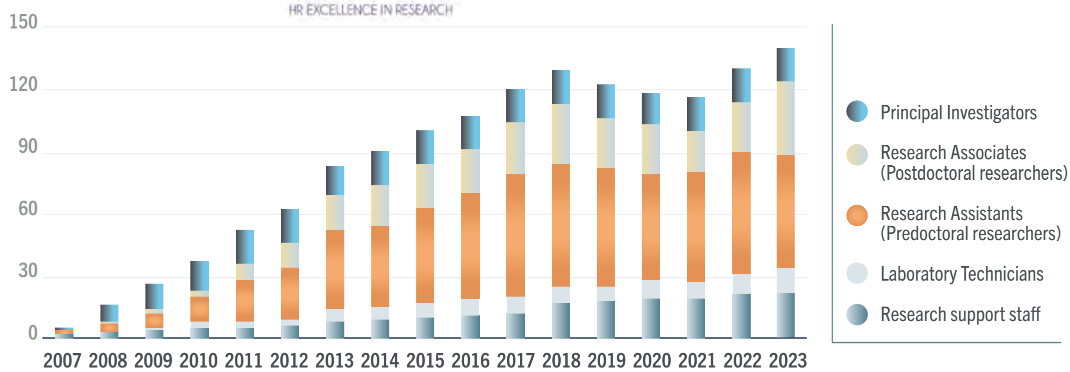
Talent attraction has been the key to the Institute's **success.**

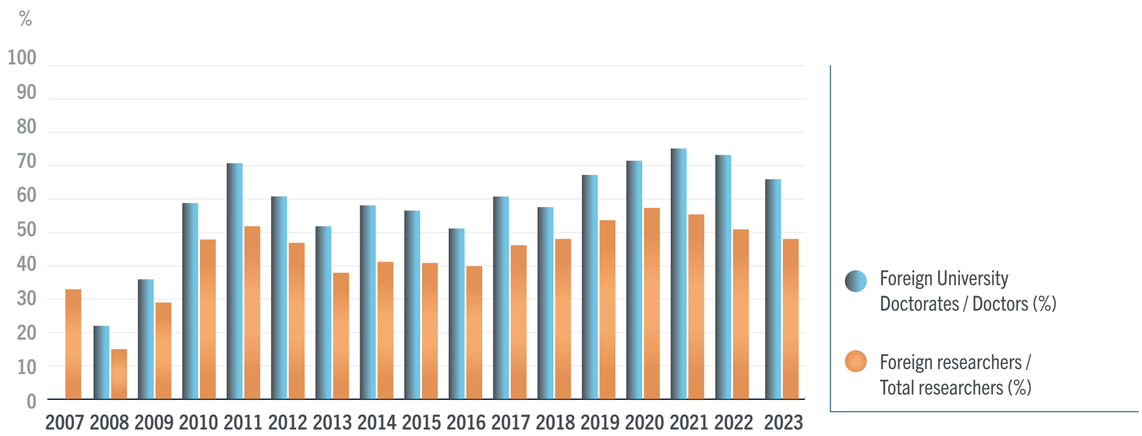
An open and transparent selection process along with regular evaluations performed by an independed Scientific Council ensures the excellence of our Principal Investigators.

IMDEA Materials has created a **multidisciplinary and international working environment** to attract and maintain talented researchers from all over the world.

Career development at IMDEA Materials is acknowledged by the EU's HR Excellence in Research seal.

HR EXCELLENCE IN RESEARCH





Technology and knowledge transfer to society through **talent transfer**

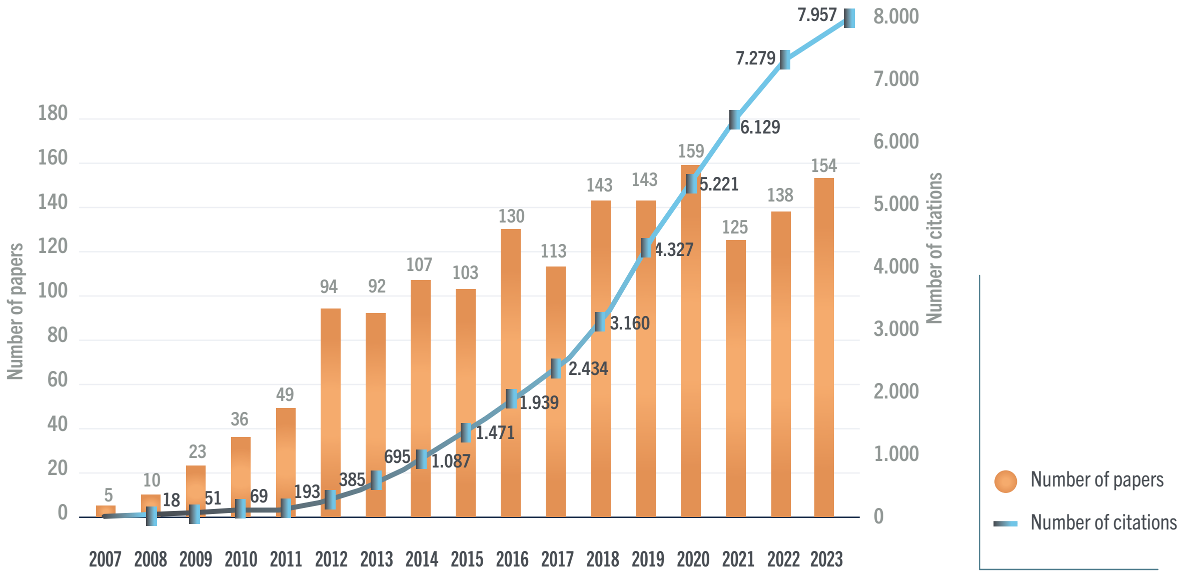
100 Defended PhD theses since 2007

55 Ongoing PhD theses

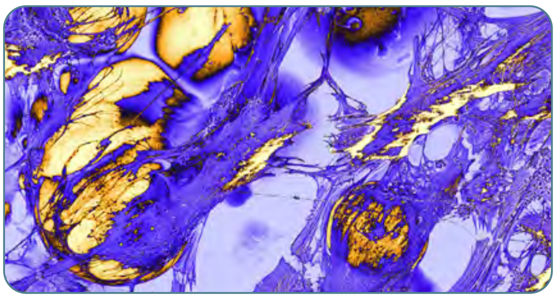
scientific results

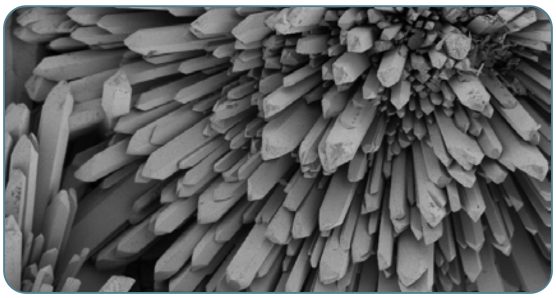
science

The scientific excellence of the Institute is accredited by the evolution of the number of publications (SCOPUS) and citations over the years.



2023





39 Keynote/ invited talks

154 Papers (SCOPUS)

7.957 Citations (SCOPUS)

26 Invited seminars and lectures

technology transfer and innovation

transfer

As part of our strategic plan 2020-2024, IMDEA Materials Institute has created a Technology Transfer and Innovation Office (TTIO), with the ultimate goal of fostering the output from our research results in terms of exploitation and commercialisation, maximising the impact of the Institute's activities on society.

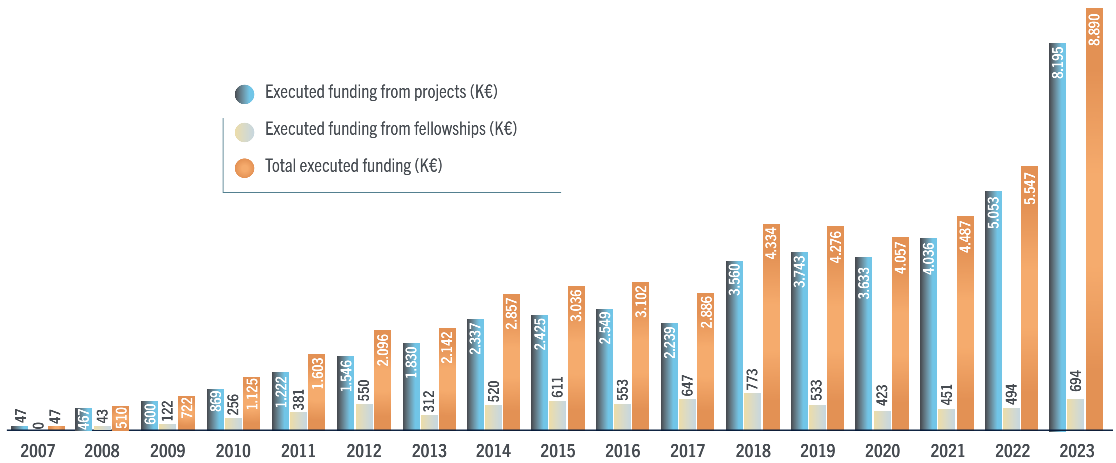
Companies which had active collaborations with the IMDEA Materials Institute in 2023:

Performance indicators in 2023

8	New bilateral projects with industry
3	Industrial Doctorates
1	Patent application
13	Patents in portfolio (granted and under evaluation)
14	Software tools licenses
1	**Spin-off:** (FLOATECH, S.L.) Floatech®

projects and fellowships

Research activities are performed in the framework of R&D projects and fellowships, which are funded either by regional/national/ international agencies or through direct contracts with companies.



2023

International projects 40%

National projects 30%

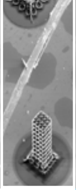
Regional projects 8.5%

Contracts with industry 21.5%

70
R&D projects

2
Active ERC projects

2
Active FET-OPEN / EIC Pathfinder Open projects



facilities

talent science transfer

New and Developing Capabilities

2023 saw IMDEA Materials Institute continue to expand and develop its cutting-edge facilities and laboratory technology. Here are some highlights of the new equipment and capacities from the previous 12 months.

Metallic Additive Manufacturing System RenAM 500

The Renishaw AM500 (RenAM 500) Laser Powder Bed Fusion (LPBF) system allows for the additive manufacturing of metallic materials such as Inconel, Aluminium, high entropy alloys, nitinol, nickel etc.

IMDEA Materials' RenAM 500 features four (500Q) high-power 500W lasers, and automatic or flexible (Flex) powder and waste handling, utilising intelligent gas flow and precision control to enable production of components with >99.9% density, maximised strength and ductility.

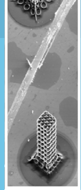
This system complements the Institute's existing RenAM 400 model.

Bioreactor TC-3F deformation system Ebers

The TC-3F Bioreactor allows for the integration of mechanical, electrical and biological evaluation into the one system.

The device offers the capability to evaluate, dynamically and by simulating physiological conditions, cultures in three-dimensional formats on scaffolds, produced at the institute.

It permits researchers to transition from a 2D to a 3D visualisation, giving a closer approximation to real-world conditions inside the body.



CreatBot PEEK-300

The CreatBot PEEK-300 is the most advanced high performance 3D printer designed and manufactured by CreatBot for industrial and medical purposes.

It features an ultra-high temperature nozzle/bed, an advanced thermal system, a direct annealing system, water cooling/heat isolation system and offers medical and industrial applications.

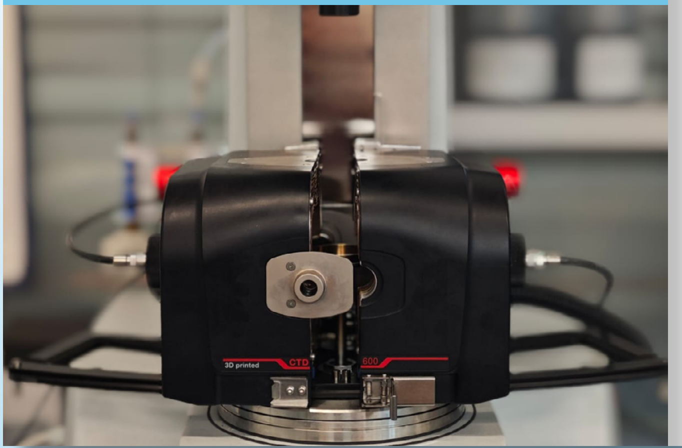
The direct annealing system employed by the machine is controllable during printing and aims to provide quality functional materials without warping or cracking.

Zeiss Xradia 620 Versa Laboratory Tomograph

The Xeiss Xradia 620 Versa offers a flat panel detector (3k × 2k pixels) and CCD camera (2k × 2k pixels) with the possibility of different objectives (0.4X, 4X, 20X, and 40X).

The equipment features a focused X-ray tube with a tungsten emitter and voltage up to 160 kV and allows for the acquisition of radiographs (RX) and computed tomography (XCT), as well as the possibility of performing diffraction tomography (DCT), which can determine the size and orientation of grains in metallic materials.

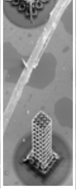
Modular Compact Rheometer: MCR 702e



IMDEA Materials' Anton Paar MCR 702e Multidrive is one of the most versatile rheometers available. Alongside all standard rheological test modes, it can also be equipped with a lower drive unit.

This means rheological tests with two torque transducers and drive units at once can be performed – opening up multiple research possibilities.

Additionally, there are no limitations regarding the used test modes, measuring systems, accessories, and temperature devices, and no limitations on measurement precision.



Synthesis, Processing and Integration of Materials

Metallic alloys

- Bulk processing techniques: induction casting and arc melting, GLEEBLE 3800 thermo-mechanical simulator equipped with tools for physical simulation of casting, rolling, forging, welding, sintering and controlled heat treatments. Powders manufactured by gas atomisation and mechanical milling. Selective laser melting technology for the additive manufacturing of metals.

Polymer-based composites and nanocomposites

- Liquid moulding processing: RTM (Resin Transfer Moulding), instrumented resin transfer moulding for digital twin deployment, VI (Vacuum Infusion), RFI (Resin Film Infusion), prepreg lamination using vacuum bagging of autoclave and out-of-autoclave prepregs (OoA) or laminate hot-press moulding (<400°C). Semi-industrial equipment for compounding (microcompounder and twin two-screw extruder) and injection moulding (industrial injector and mini-injector machine) of thermoplastics, integration of advanced nano-fillers, filament maker for 3D printing (3dvo) and melt flow index.

Nanomaterials

- Synthesis and chemical modification of nanocarbons, inorganic materials, nanoporous semiconductors, thin films, zeolites and other nanomaterials. Evaporation equipment in controlled atmospheres, high-pressure reactors and in-house chemical vapour deposition systems.

Energy storage and conversation devices

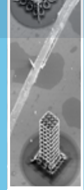
- Synthesis and characterisation of nanostructured electrode materials for energy storage. Fabrication of composite electrodes and integration in rechargeable batteries (Li-ion, Li-02, Na-ion, hybrid, etc.). Fabrication and testing of nanocarbon-based electrodes and their integration with liquid and solid electrolytes to form large-age (>100cm2) flexible supercapacitors. Integration of energy-storage functions in structural composites. Fabrication (solvent-based deposition), physical vapour deposition, high-temperature sintering ovens and hot plates and characterisation. Fire-testing devices for electrolytes and in situ XRD device for battery applications.

Microstructural and Chemical Characterisation

- 3D Microscopy at different length-scales, including X-ray tomography, X-ray diffraction, 3D-SEM, 3D-EDS and 3D-EBSD in the FIB, and 3D-TEM and 3D-EDS in the TEM.
- In-situ thermos-mechanical testing of miniaturised samples in the X-ray tomography system, as well as in the SEM and TEM.
- In-situ processing studies in the X-ray tomography system, such as casting, infiltration and curing of polymer-based materials.
- Raman spectrophotometer and Gel permeation chromatography.
- Particle size analyser, freeze dryer and in-situ thermal studies of polymers in the X-ray diffractor.
- In-situ thermal studies of polymers in X-ray diffractometer (SAXS/WAXS).
- C-Scan ultrasound non-destructive inspection system.
- High-resolution X-ray tomography allowing for the installation of in-situ devices for testing and the added ability to perform diffraction contrast tomography (laboratory-based DCT).

Mechanical Properties

- Mechanical materials testing, using electromechanical and hydraulic machines (quasi-static, dynamic and impact testing over a range of temperatures).
- Mechanical property characterisation at multiple length scales, including nanoindentation, micropillar compression, microtensile testing and microfracture mechanics.
- Tests can be carried our both ex-situ and in-situ in SEM, TEM and X-ray tomography, including measurements at elevated temperatures.
- Tensile tests can be carried out in-situ in dual cone calorimetry.
- Tensile tests on monofilaments, recycled fibres and nanotubes, fabimat and recycled fibres.



Biomaterials and Cell Culture

- Confocal, fluorescence, and brightfield microscopes.
- PCR instrument, multi-role plate reader, ultrasonic processor, lyophilizer, autoclave, Spectrofluorometer and dynamic light scattering equipment.
- Microfluidic system, gel electrophoresis and blotting system.
- Liquid nitrogen tank for cell storage and -80C freezer.
- Prusa Mini 3D printer and Phrozen Sonic Mini 8K resin 3D printer.
- Biosafety cabinets, benchtop and CO2 incubators.
- Centrifuge, microcentrifuges, vortex mixers, pipet controllers, hot plate stirrers, dry block heaters, UV lamps, ph. meter, balance and thermostatic water baths.
- Bioreactor TC-3F deformation system Ebers
- Histology area: Microtome, cryostat, staining station and paraffin embedding station.

Functional Properties

Fire resistance

- Rapid laboratory scale tests for screening (micro-scale combustion calorimetry and oxygen index).
- Dual cone calorimetry and UL9F Horizontal/Vertical Flame Chamber

Thermal

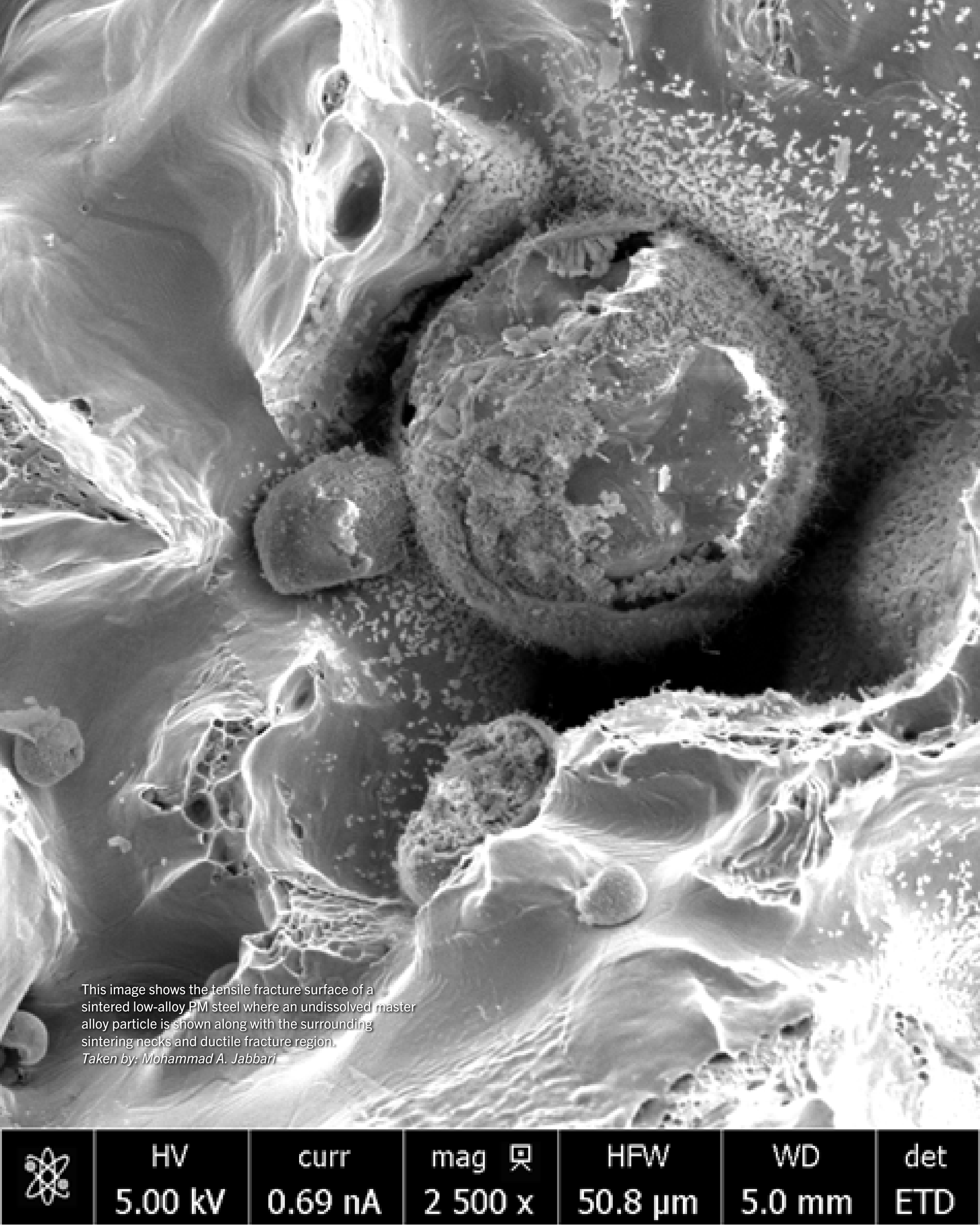
- DSC, TGA and Hot Disk Thermal Conductivity analyser. Thermal mechanical analysis (DMA and Rheology).
- Pushrod Dilatomer to measure dimensional changes.

Electrochemical

- Electrochemical characterisation of energy storage devices (Li-ion, Li-S, Li-02, Na-ion and hybrid batteries). Simultaneous testing for 100 batteries can be performed using multichannel battery testers.
- Galvanostatic/potentiostatic cycling at various current densities.
- Single channel ZIVE SP1 electrochemical workstation for cyclic voltammetry (CV) and electrochemical impedance spectroscropy (EIS) study of batteries.
- LCR equipment to quantify dielectric properties in composites.

Simulation

- Simulation techniques at different scales (electronic, atomistic, mesoscopic and continuum), to design or improve materials and components by means of virtual testing and processing.
- High performance computer cluster (600+ Intel Xeon CPU cores and NVIDIA GPU accelerating leading to a computational power of 90Tflops).
- In-house developed simulation tools including Iris, Muesli, FFTMAD, CAPSUL, phase-field simulations, etc. as well as commercial and open-source software tools for modelling and simulation in Materials Science and Engineering (ThermoCalc, Abaqus, FEniCS, LS-Dyna, PamCrash, LAMMPS, VASP, etc.).



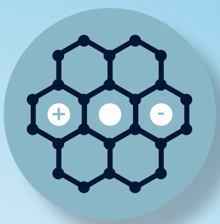
This image shows the tensile fracture surface of a sintered low-alloy PM steel where an undissolved master alloy particle is shown along with the surrounding sintering necks and ductile fracture region.
Taken by: Mohammad A. Jabbari

research programmes

talent science transfer

IMDEA Materials Institute is currently organised into sixteen research groups focused on distinct but interrelated areas in the field of Materials Science and Engineering. Each of these groups is led by one staff researcher, or Principal Investigator, who is in charge of coordinating and supervising a team of post and predoctoral researchers. The research groups, as key units of the institute, develop research projects and collaborations to drive the frontier of science and knowledge of their field forward and to transfer knowledge into valuable technology. The Institute's two newest research groups, Biomaterials and Regenerative Medicine (headed by Dr. Jennifer Patterson) and Mechanical and Acoustic Metamaterials (headed by Dr. Johan Christensen), have further extended the scope of IMDEA Materials' materials science research.

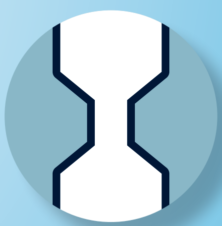
As a result of the high degree of internal collaboration within the Institute, and to take advantage of that fact, each of our research groups is divided into one of four Research Programmes: Advanced Manufacturing, Integrated Computational Materials Engineering, Multiscale Characterisation of Materials and Processes and Novel Materials. Driven by the talent of the researchers involved, each of these programmes combines cutting-edge fundamental-oriented research in topics at the frontiers of knowledge with applied research encompassing the midterm interests of our industrial partners to provide long-term leadership. As of 2023, the leaders of our Research Programmes were: Dr. Ilchat Sabirov, Prof. Javier Segurado, Dr. Federico Sket and Dr. De-Yi Wang.



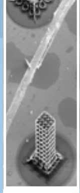
Novel Materials

Integrated Computational Materials Engineering

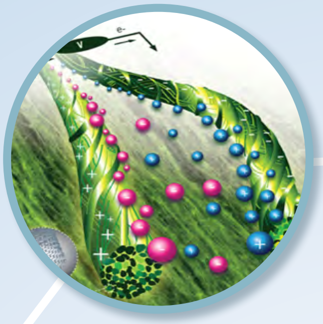
Advanced Manufacturing



Multiscale Characterisation of Materials and Processes



programme Novel Materials

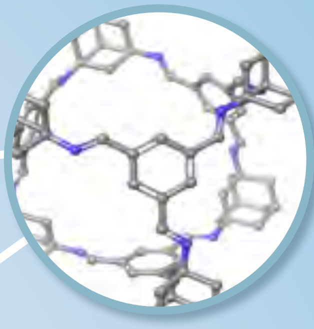


Multifunctional Nanocomposites

Goal and vision

The Novel Materials programme combines expertise in design and synthesis of nano and molecular building blocks with their integration into macroscopic materials and devices. The aim? Firstly, to develop solutions for high-performance structural composites with enhanced multifunctional capabilities such as thermal, electrical and fire resistance. Secondly, to explore the processing structure-property relationships in metallic alloys with particular emphasis on the role of microstructure on the mechanical response at all length scales. Formed by chemists, physicists and engineers (chemistry, materials, mechanical and aeronautical), this interdisciplinary research group carries out both fundamental and applied research via close collaboration with companies in the transport, aerospace, energy, safety and biomedical sectors. The programme's research facilities include state-of-the-art equipment for synthesis, processing, manufacturing, structural/materials characterisation and material properties.

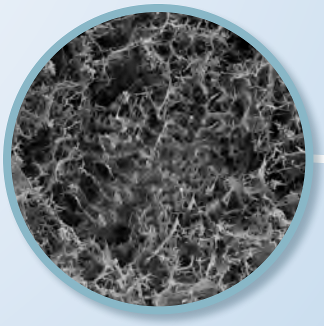
High Performance Polymer Nanocomposites



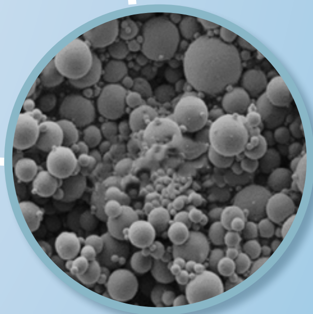
Computational and Data-Driven Materials Discovery

Structural Composites

Nanomechanics and Micromechanics



Biomaterials and Regenerative Medicine



Sustainable Powder Metallurgy

Main research lines

Synthesis and integration of nanomaterials (nanotubes, nanofibres, MXene, 2D nanofillers, etc.)

- Nanocarbon/semiconductor hybrids synthesis for photo- and electrocatalysis, interaction of nanocarbons with liquid molecules, polyelectrolytes and inorganic salts.
- Inorganic nanowire synthesis and assembly as macroscopic yarns and fabrics.
- Sensors: triboelectric, thermoresistive chemical, piezoresistive, piezoelectric.
- Hierarchical materials: nanoscale to macroscale materials design, nano-reinforced materials, composite materials with enhanced electrical and thermal conductivity.
- Electrospinning of polymetric nano-membranes.

Synthesis and properties of polymer-based multifunctional nanocomposites

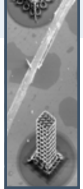
- Sustainable materials: bio-based nanocarriers, novel guest-host nanomaterials, nano-cross linkers, multifunctional polymer nanocomposites, renewable and recyclable polymeric materials, biodegradable polymers, carbon fibre reinforcement, etc.
- Fire retardant materials through nanodesign: multifunctional nanomaterials to increase fire retardancy: layered double hydroxides, Metal-Organic Framework, sepiolite, molybdenum disulphide, nanocarbons, nano metal hydroxide, graphene, cellulose nanocrystals, etc.
- Energy storage and energy saving materials, PCMs for thermal management.

Materials for the hydrogen economy

- High-throughput design and synthesis (magnetron sputtering) of novel catalysts for green hydrogen production and hydrogen energy generation via elastic strain engineering.
- Development of new metallic alloys for hydrogen embrittlement conditions.

Metallic materials

- Advanced high-strength steels combining enhanced mechanical and in-use properties.
- High-alloy steels, superalloys and high entropy alloys.
- Analysis of chemistry-processing-microstructure-properties relationship on macro- and microscales, emphasising strength, ductility, fatigue and fracture resistance.
- Study of solidification-microstructure relationships using traditional (vacuum induction melting, vacuum arc melting, gravity and tilt casting, directional solidification) and advanced techniques (centrifugal and suction casting, vacuum melt atomisation).
- Rapid phase screening, crystal structures, properties, microstructure and kinetics in bulk materials by the Kinetic Diffusion Multiple Technique.
- Multiscale functional coating layer deposition via blade casting, spin coating, spray coating, electrospining, etc.
- Structural-mechanical property relationships for lightweight porous metal structures.



Structural composites

- Structural composites manufacturing by liquid moulding (resin transfer moulding and vacuum infusion) and autoclave consolidation. Additive manufacturing of fibre-reinforced composites.
- Material design for damage tolerance and impact resistance, including multimaterial integration.
- Hierarchical integration of nano filler reinforcements for damage-tolerant, electrical and lightning impact applications.
- Recycling techniques for polymer-based composites.

Materials for extreme conditions

- Impact, high temperature, mechanical, fire, predictive simulation.
- Prediction and prevention strategy for metal-, and polymer-based composite materials under simultaneously extreme conditions such as high-temperature behaviour under structural loading.
- Alloys to be used at high temperature and in corrosive environments.

Materials for Lithium-ion Batteries (LIBs)

- Nanostructured silicon anodes.
- Carbon nanotube fabrics for hybrid electrodes and metal-free current collectors.
- Electrode development (defect-engineered, fire-retardant, flame-resistant all solid-state polymers, etc.).
- AI-accelerated electrolyte composition optimisation.
- Flexible and structural batteries.

Materials for post LIBs

- Fire-retardant electrolytes.
- AI-accelerated electrolyte composition optimisation.
- New electrodes and interfacial strategies for Zinc-ion batteries

Lightweight materials

- Composite materials, alloys, hybrids, sandwich-structured fire retardants, porous polymers, polymer-based aerogels and reversible crosslinking.

Green materials approaches

- Bio-based polymers fibres and additives as well as biobased thermal energy storage/phase change materials.
- Reprocessable composites.
- Valorisation of by-products in hydrogen production.
- Advanced alloy development avoiding the use of critical materials.

Regenerative engineering and medical treatments

- Bioresorbable metallic and composite scaffolds for bone regeneration and biodegradable cardiovascular metallic stents, both via 3D printing.
- New materials for tissue engineering and regenerative medicine.
- Materials and devices for organs-on-chips, spheroid/organoid generation, and in vitro tissue models.
- Degradable metal nanoparticles for biomedical applications (anticancer or antibacterial activity).
- Molecule-based material biofunctionalisation and surface modification for improved performance.
- Mechanotransduction.

Projects in focus

DIGIBIOFAM / Biobased flame-retardant system for sustainable polymers: molecule design, digital synthesis, digital analysis, data-driven approach

Funding: Spanish Ministry of Science and Innovation/Green and Digital Transition
Partners: IMDEA Materials Institute
Period: 2022 - 2024
Principal Investigator: Drs. M. Haranczyk and D.Y. Wang

Polymeric composites play a crucial role in various industries, from automotive to electronics. However, their environmental impact, sustainability, and fire safety remain pressing concerns.

As industries increasingly rely on durable and environmentally responsible solutions, addressing these concerns remains crucial for the continued success of polymer-based composites.

DIGIBIOFAM proposes an interdisciplinary and innovative approach to design and develop a novel bio-based flame-retardant system for sustainable polymers.

The main challenge for achieving this is the current technical limitations to develop high-performance materials, as they still rely on labour-intensive experiments. The project will work on implementing innovative and cost-efficient data-driven solutions to address this issue.

It's overarching objective, therefore, is to develop a bio-based flame-retardant system for bio-based composite

Figure 1: Bio-based Bio-based fire-safe polymeric materials: Green preparation and Digital Design.

materials by implementing novel and cost-efficient data-driven experimentation strategies.

This goal takes the form of three main objectives:

1. To develop bio-based flame retardants sourced from environmentally friendly materials such as chitosan, phytic acid (PA), nanoclay, etc.
2. The implementation of data-driven machine learning-based experimentation strategies to identify optimal formulations efficiently.
3. To demonstrate and fully characterise new bio-based flame retardant/bio-based polymer composites.

Furthermore, if successful, the developed data-driven design strategies can be applied in new material design workflows, including ones for robotic material discovery. The project's aims fit within the ambition of the Spanish Science, Technology and Innovation Strategy 2021-2027.

The success of these objectives could incentivise the substitution of fossil fuel-derived materials with fire-safe sustainable solutions with the same mechanical properties. Additionally, the materials developed within the project can impact many other research fields such as climate, energy and mobility.

For more information, please contact
Dr. Maciej Haranczyk at maciej.haranczyk@imdea.org

Research highlights

Fire-safe batteries: flame retardant materials and flame-resistant electrolytes

Rechargeable lithium-ion batteries (LIBs) have dominated the consumer market of electronic equipment and electric vehicles in the past few decades.

In Europe, in the current decade and where it is economically viable, everything that can be electrified will be electrified, thus making rechargeable LIB technology one of the most indispensable enablers for the green energy transition.

However, the pace of this energy storage and transition greatly relies on the safety of rechargeable LIBs technology. Despite significant advancement in other characteristic requirements, safety threats to rechargeable LIBs (caused by thermal runaway) persist.

To this end, IMDEA Materials is advancing in a number of projects related to improved battery safety and fire resistance. The project **SMARTBATT** proposes that safety threats to LIBs can be significantly reduced by introducing a temperature-responsive liquid electrolyte. As the internal temperature of the LIBs increases beyond 120 °C, IMDEA Materials' uniquely designed liquid electrolyte will undergo a supramolecular reaction to form oligomers. As a result, there will be a significant diminution in Li^+ ion conductivity (i.e., $\sigma_{Li^+} \approx 0$). This will eventually lead the LIBs to non-operational mode (i.e., the thermal shutdown of batteries) to prevent thermal runaway.

The electrochemical tests reveal that the traditional commercial electrolyte is incapable of ceasing the battery operation at a high temperature of 120 °C. However, IMDEA Materials' novel electrolyte could successfully terminate the battery operation at the same temperature. This suggests that this thermo-responsive electrolyte undergoes a chemical change that causes a decrease in Li^+ ion conductivity.

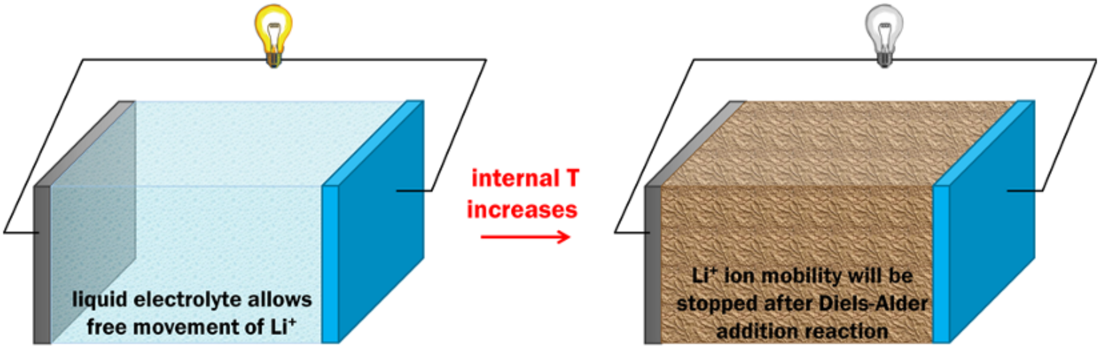


Figure 1: Schematic of the working principle of thermos-responsive electrolyte in lithium-ion batteries. With increasing battery temperatures, the Li^+ ion conductivity is significantly diminished. This will eventually lead the LIBs to non-operational mode (i.e. thermal shutdown) to prevent thermal runaway.

This chemical change within the electrolyte is attributed to the Diels-Alder reaction. Further experiments are ongoing to corroborate this hypotheses and proof of concepts.

LIBs have garnered particular attention due to their essential role in the rise of electric vehicles (EVs). As EV adoption accelerates and grid energy storage demands rise, the need for safe, high-energy-density batteries becomes urgent.

However, conventional LIBs rely on flammable liquid electrolytes and carbon anodes, which pose safety risks and limit energy density. Notably, 28% of global EV fire accidents reported between 2010 and 2019 occurred in the EU.

To enhance energy density, lithium metal, an anode material with high specific capacity, is a compelling choice. Yet, uncontrolled lithium dendrite growth and volume expansion during cycling compromises electrochemical performance and safety.

Research carried out by IMDEA Materials Institute in the **BIOFIRESAFE** project has shown that low amounts (around 5% by volume) of fluorinated phosphazene-based flame retardants can yield non-flammable electrolytes while improving electrochemical properties.

Additionally, researchers employed time-of-flight secondary-ion mass spectrometry (TOF-SIMS) and transmission electron microscopy to investigate the chemistry and structure of a flame retardant-derived cathode electrolyte interphase (CEI) layer formed on the cathode surface.

This CEI layer, rich in phosphorus and nitrogen, inhibits the formation of a thick parasitic LiF layer, ultimately improving the electrochemical integrity of the battery cells.

References

1. M. Zhang; A. Yusuf; D.Y. Wang - *A novel hierarchical "ceramic in polymer – polymer in ceramic" structure composite solid-state electrolyte for safer lithium ion batteries*. **Journal Of Power Sources 591**, 2024. DOI:10.106/j.jpowsour.2023.233812
2. A. Yusuf; V. S. Avvaru; J. De la Vega; M. Zhang; J. Garcia Molleja; D. Wang - *Unveiling the structure, chemistry, and formation mechanism of an in-situ phosphazene flame retardant-derived interphase layer in LiFePO4 cathode*. **Chemical Engineering Journal 455, Part 2**, 140678-140678, 2023. DOI:10.1016/j.cej.2022.140678

For more information, please contact
Prof. Dr. De-Yi Wang at deyi.wang@imdea.org

Paving the way for recyclable CNTs and sustainable industrial applications

Carbon nanotubes (CNTs), filaments 2,000 times thinner than a human hair, are gaining prominence in the construction, aerospace and automotive industries as substitutes for CO_2-intensive materials like copper, steel, and aluminum.

These materials are already utilised in batteries for portable electronic devices, structural composites, electrical cables, and sensors in smart textiles and wearable technology.

Their global production capacity could reach megaton scales in the future, with initiatives on the development of high-performance macroscale materials (fibres, fabrics) of CNTs. Despite their widespread use and potential, however, questions about the recyclability of CNTs have remained largely unaddressed.

IMDEA Materials has recently made significant strides in this area, demonstrating the feasibility of recycling high-performance CNT sheets while retaining their essential properties. This breakthrough indicates that CNT macromaterials (non-woven fabrics or sheets of CNTs) can be recycled and reused in various applications without losing their mechanical, electrical, and structural properties.

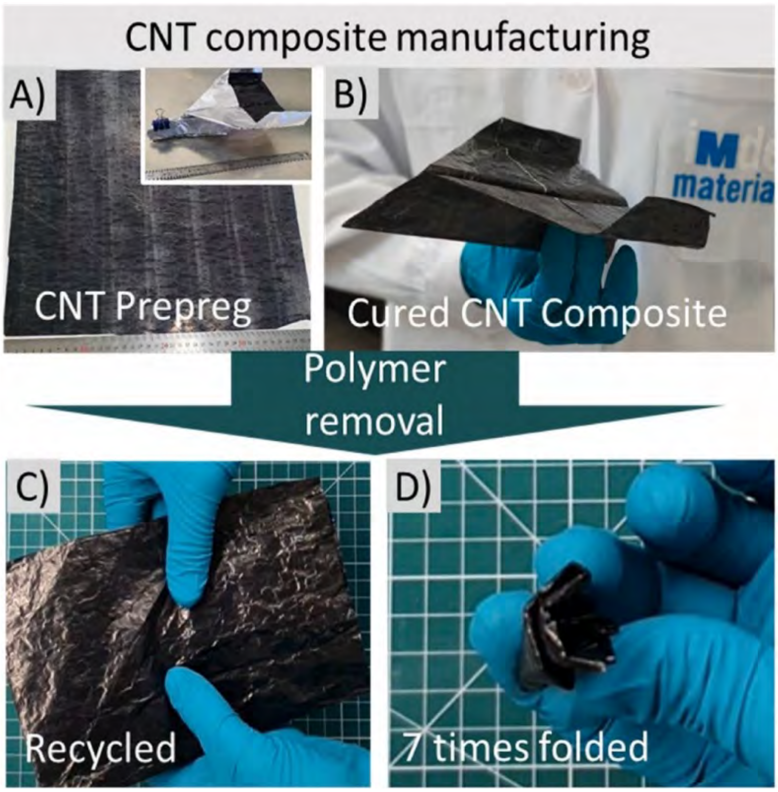


Figure 1: Demonstration of the recyclability of the CNT sheet from the complex-shape composite structure: A) commercial CNT prepreg, B) layup of the CNT plane ready for curing; C) flexible and robust recycled CNT sheet of ~17 × 22 cm size after polymer removal, D) which demonstrates retained ability to be handled and folded up to 7 times.

This research has involved subjecting CNT sheets of varying densities to a two-step thermal treatment process. This process effectively preserved their mechanical and electrical properties, demonstrating their recyclability and reusability in applications such as structural reinforcement, electrical conductors, and flexible battery anodes.

Unlike conventional carbon fibers, which cannot be broken down into individual crystallites and reformed into continuous filaments, CNTs can be dissolved and re-spun into new high-quality fibers. This recycling process is already being done on a commercial scale, and offers significant advantages over traditional carbon fiber recycling.

Researchers utilised both commercially-, and laboratory-produced CNT sheets to manufacture composites with aerospace-grade epoxy resin through compression moulding.

After removing the polymer phase through pyrolysis, the sheets retained their structure and could be reprocessed without further treatment. The commercial CNT sheets retained 95% of their longitudinal strength and 100% of their modulus and electrical conductivity, while the laboratory-grade sheets retained more than 50% of their strength.

This high level of property retention enables the recycled material to be reused for the same applications, a level of recycling potential that is currently unachievable for conventional carbon fibers.

The inherent toughness of the CNT network structure, demonstrated by the high essential work of fracture values, underscores their damage tolerance.

This research highlights the recycling capabilities of CNT macromaterials for various applications, while offering significant recycling capabilities, thus supporting a more sustainable and efficient use of resources in numerous industries.

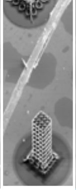
References

A. Mikhalchan; S.R. Lozano; A.F. Gorgojo; C. González; J.J. Vilatela - *Network structure enabling re-use and near full property retention in CNT sheets recycled from thermoset composites*. **Carbon 220**, 2024. DOI:10.1016/j.carbon.2024.118851

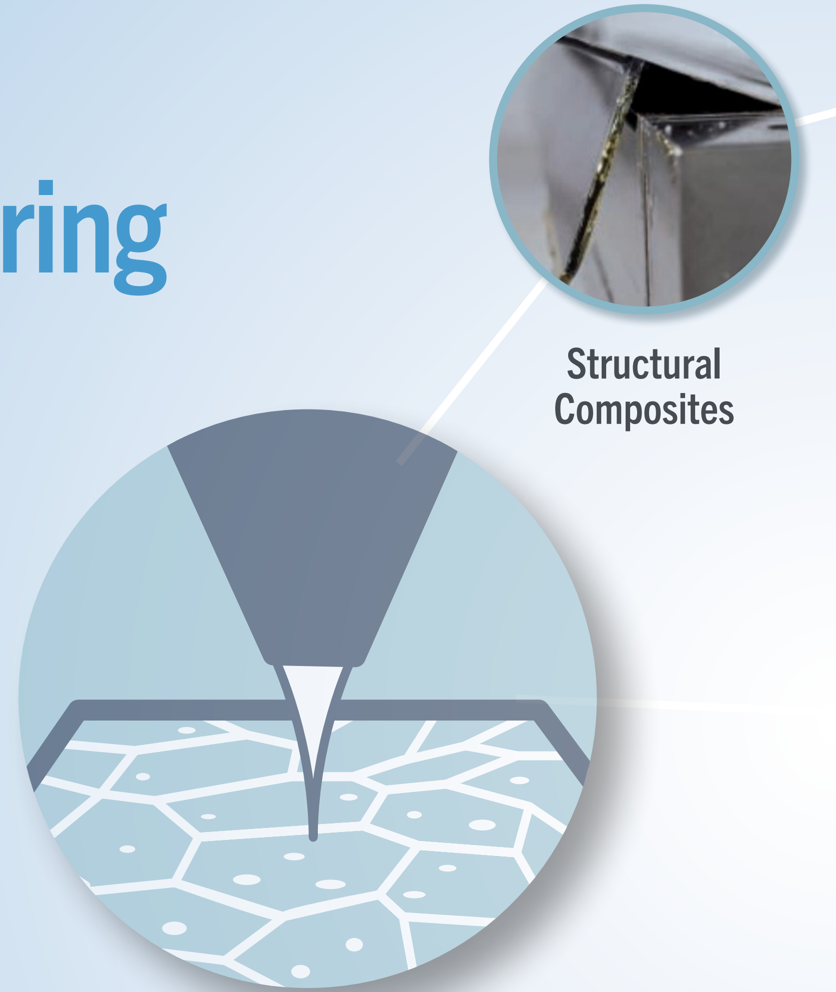
For more information, please contact

Dr. J.J. Vilatela at juanjose.vilatela@imdea.org /
Dr. A. Mikhalchan at anastasiia.mikhalchan@imdea.org

Ride the Lightning (OS) with the following caption: Argon plasma created by 700 V high voltage in vacuum.
Taken by: Jorge Redondo.



programme Advanced Manufacturing



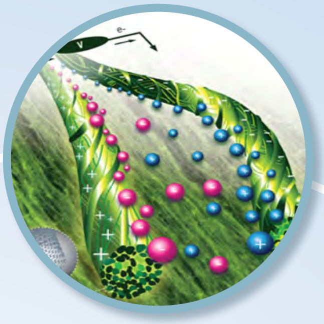
Goal and vision

The Advanced Manufacturing programme is highly interdisciplinary in nature, spanning the alloy, biomaterial, polymer, composite, nanostructured materials, and energy material fields, and involving both experimental and computational efforts.

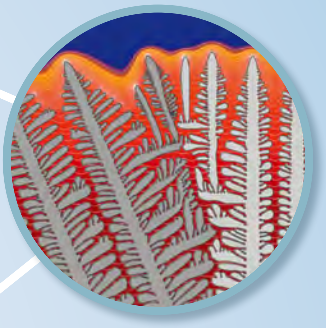
This programme's objective is to improve quality, productivity, cost efficiency and sustainability in current manufacturing paradigms, as well as conceiving and developing novel hybrid manufacturing techniques to enable the commercial realisation of emerging products in the transport, biomedical, energy, automotive and other industrial sectors.

Effective unit-process innovation and development derives from an understanding of the physical and chemical phenomena influencing manufacturing processes. Moreover, a key part of this programme involves the creation and development of models based on Artificial Intelligence (AI) to predict the optimum manufacturing routes and quality of the manufactured products, as well as the modelling of tool-material interactions.

The resulting fundamental knowledge is supplemented by state-of-the-art characterisation techniques needed to monitor the manufactured product quality, including micro(structure) and mechanical and functional properties.



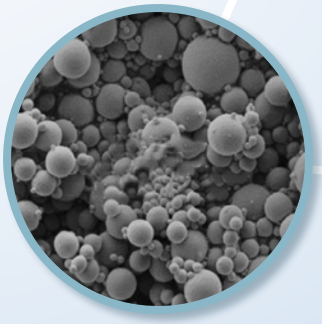
Multifunctional Nanocomposites



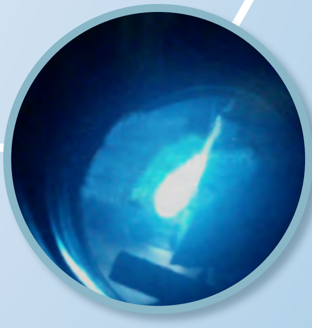
Modelling and Simulation of Materials Processing

Physical Simulation

Sustainable Metallurgy



Sustainable Powder Metallurgy



Solidification Processing & Engineering

Main research lines

Industry 4.0

- Virtual testing of structural composites and analysis of the effect of manufacturing defects on structural performance.
- Virtual processing of structural composites including hot-forming and out-of-autoclave (injection, infusion, compression moulding). Surrogate and reduced order models for manufacturing based on Multiphysics simulations.
- AI techniques applied to manufacturing. Digital twins for manufacturing processes. Smart detection of defects by sensors including the active control of manufacturing systems.
- Structural health monitoring (SHM) through sensors integrated with Carbon Nanotube (CNT) yarn and AI-based automated damage detection models.
- AI-guided materials design and chemical process.
- Electric-current-assisted curing for bonding and repairs.
- Multifunctional composites for structural and energy storage applications.
- High-throughput computational thermodynamics for multicomponent alloy screening.

Nanostructured materials, electrodes and devices

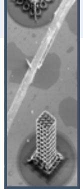
- Gas-phase assembly of continuous sheets and fibres of carbon nanotubes and inorganic nanowires (Si, SiC, MOx).
- Integration of these nanomaterials into electrodes and composite materials.
- Preparation of stable dispersions of nanowires for wet-processing of optoelectronic devices.

Liquid and solid-state processing

- Rapid alloy prototyping and manufacturing of bulk alloy libraries for the fast assessment of properties.
- Optimisation of casting processes.
- Development of novel thermomechanical processes and powder metallurgy routes via mechanical alloying and gas atomisation in non-oxidation conditions.
- Consolidation by field-assisted sintering and conventional press and sintering.
- Powder Injection Moulding.

3D printing

- Metallic materials, including powder design, fabrication and characterisation.
- Composites, polymers, recycled fibres and hybrids.
- PLA composite materials reinforced with Mg, Zn or CaPs nanoparticles and continuous metallic wires.
- Development of functional thermoplastic filaments (flame retardant, thermal conductive, biodegradable, reinforced, electrically conductive, etc.) for 3D printing.
- Data-driven design of 3D-printed metamaterials.
- Custom-made implants using new biocompatible alloys.
- Stereolithography, including resin synthesis and characterisation.
- Extrusion-based 3D printing of biomaterials and bioprinting.
- Predictive simulation.
- In-situ monitoring.



Projects in focus

AID4GREENEST / AI-powered Characterisation and Modelling for Green Steel Technology

Funding: European Commission/Horizon Europe Programme – Cluster 4
Partners: IMDEA Materials Institute (coordinator), Ghent University, University of Oulu, University of Liège, Fraunhofer Institute for Mechanics of Materials IWM, Ocas NV, Reinosa Forgings & Castings, Spanish Association for Standardisation-UNE, ePotentia and EurA AG
Project period: 2023 - 2026
Principal Investigators: Dr. I. Sabirov

European industrial manufacturing requires the development of novel and integrated characterisation methodologies and computational modelling, especially for establishing the processing-microstructure-property correlations for advanced materials in a reproducible and efficient way, allowing design of new and sustainable materials and processes, and rapid upscaling.

Parallel to the concerted development of these tools, an appropriate knowledge transfer mechanism needs to be established to ensure smooth interoperability of these characterisation methodologies with computational modelling.

In this context, the creation of data documentation standards and the exploitation of trusted, efficient and reliable open repositories for data exchange in European industrial manufacturing becomes a key aspect.

AID4GREENEST, coordinated by IMDEA Materials Institute, is committed to developing and providing solutions for these needs. At the same time, it seeks to address the challenges of the world's most important engineering and construction material: steel.

Steel is an essential factor in the development and deployment of innovative, CO2-mitigating technologies, improving resource efficiency and fostering sustainable development in Europe.

The fourth industrial revolution and market demands for advanced steels are driving the research towards transformation of the manufacturing processes and to ever-more sustainable steel compositions.

The conventional 'trial and error' approach traditionally used to develop metallurgical processes still prevails in industrial steel plants. However, it is a time-consuming, labour-intensive process entailing high material waste and associated carbon emissions.

Also, it can ultimately lead down a repetitive path that consists of creating a process design, putting it into production, and detecting possible process design flaws too late, resulting in high component rejection rates.

Ascertaining inadvertent flaws in the manufacturing approach before its implementation on industrial lines could be the key to major cost savings. With the introduction of AI- and simulation-driven design, back-and-forth interaction between part and process designs can be significantly diminished.

The main objective of AID4GREENEST is to develop six new AI – based rapid characterisation methods and modelling tools, whose scope will cover the steel design (chemistry and microstructure), process design (processing parameters), product design (processing and heat treatments) and product performance (creep) stages.

The proposed tools will be complemented by a roadmap designed to enable model-based innovation processes, from materials design to product development, while considering industry needs: enhanced material quality, reduction of carbon emission and waste generation, and reduced supply risk of critical raw materials.

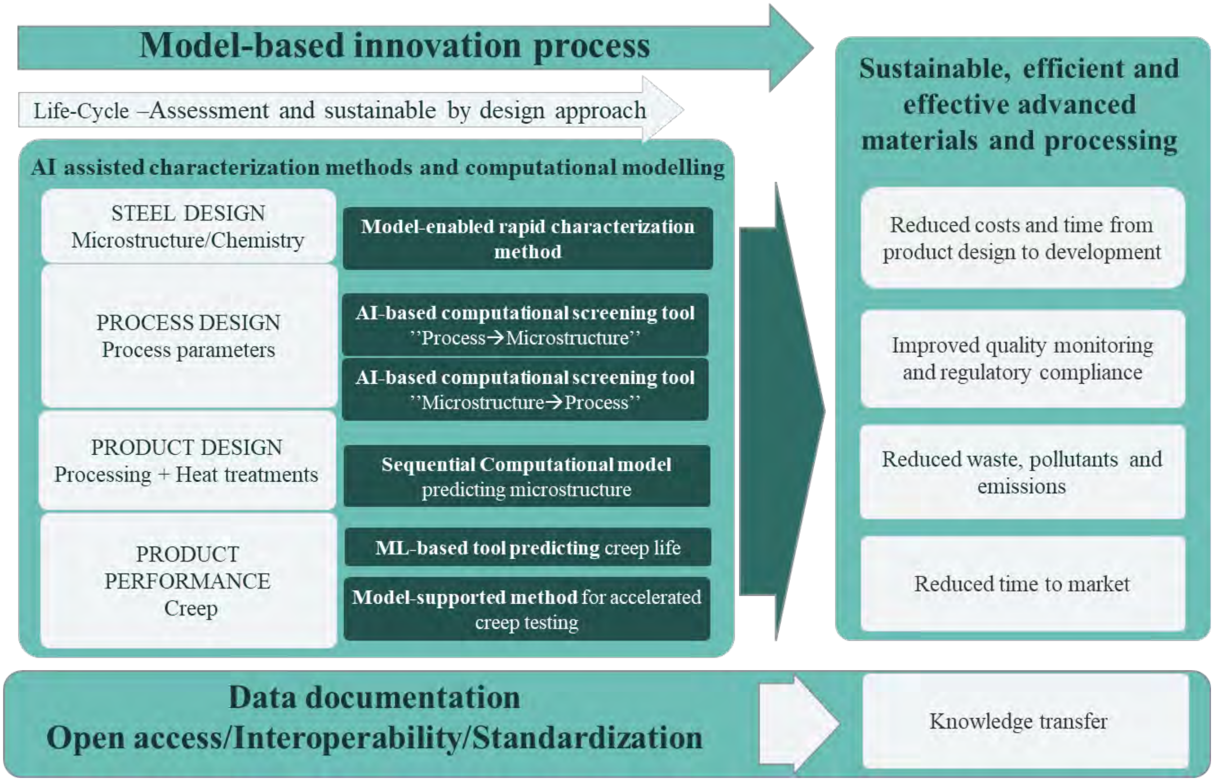


Figure 1: AID4GREENEST concept.

In order to facilitate the characterisation and modelling data knowledge transfer generated in this project, and across the wider European characterisation and modelling community, the project will also develop an open online platform, based on a standardised and interoperable data management system following the guidelines of the European Materials Modelling Council and European Materials Characterisation Council.

Ultimately, AID4GREENEST's ambition is to modernise the EU steel design and manufacturing sector by developing AI tools and characterisation methods which will not only increase its efficiency immensely, but also develop eco-friendly processes with reduced carbon emissions and waste generation.

For more information, please contact
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Research highlights

Resin Transfer Moulding and the development of Digital Twin technology

The Resin Transfer Molding (RTM) process offers great advantages in the manufacture of high-performance composite materials, such as the ability to obtain geometries with a high-surface finish and dimensions close to the final geometry (net-shape), excellent mechanical properties and the reduction of working times and resource consumption.

RTM is one of the most used production methods for high-performance structural composites. During this process, a dry textile preform is impregnated with a polymer resin injected in a closed mould.

As part of IMDEA Materials' research into RTM manufacturing, the institute has presented a digital twin (DT) to analyse the fabrication process of structural composites via RTM.

This DT is focused on detecting in-homogeneous resin flow produced by race-tracking channels that divert resin flow to the outlet gates of the mould, producing dry spots and lack of impregnation.

The core of the DT contains two surrogate models based on encoder/decoder deep learning architectures, providing the fast/accurate response necessary for interrogation during manufacturing.

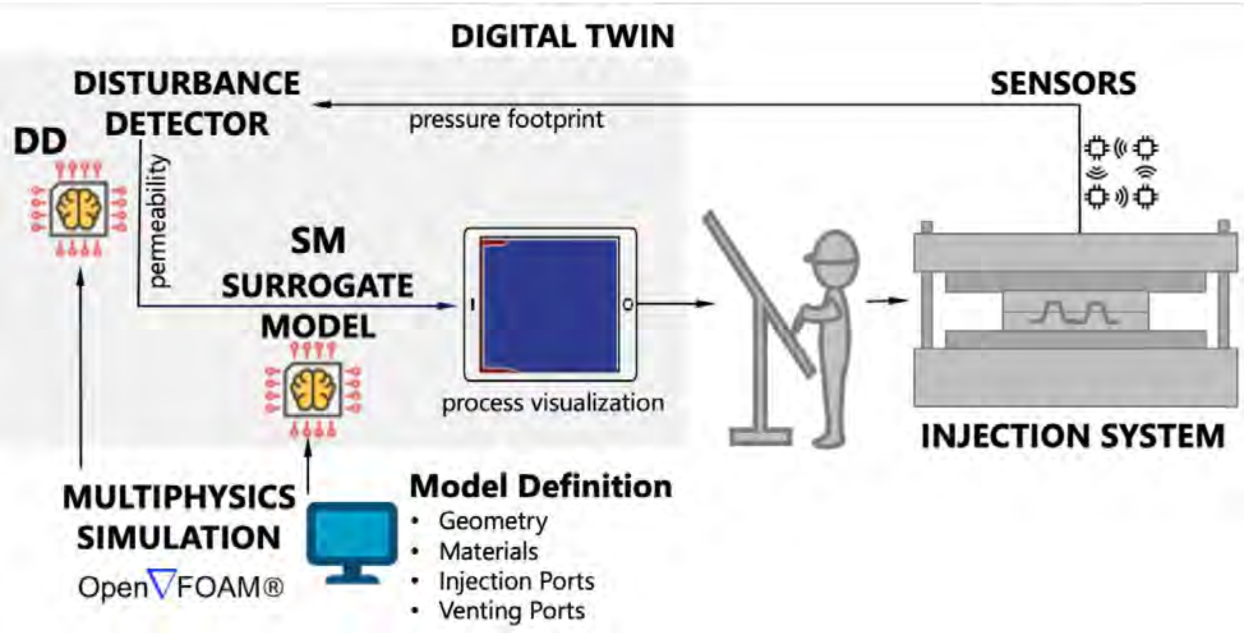

Figure 1: Digital Twin concept.

The first surrogate acts as the disturbance detector, providing on-the-fly representation of the fabric permeability, with the only information gathered by a set of five pressure sensors distributed across the mould surface.

The second offers real-time representation of a set of quantities of interest (QoI), namely: flow progress and the pressure field inside the mould. Training of both surrogates was performed with synthetic data generated by high-fidelity multi-physics simulations of the flow progress in a porous preform by following Darcy's law.

Errors in the pressure field predictions of the surrogates are lower than 1% with consultation time <50 ms, enabling encapsulation in the DT. The DT performance was evaluated by comparing the response against a set of RTM experiments for different race-tracking scenarios.

The work's two most relevant novelties are the use of the instantiated DT concept, which provides information on the current state of the process from data provided by a network of distributed sensors. This DT has also been trained exclusively with synthetic data from Multiphysics simulations while evaluated against experimental data from injection tests.

IMDEA Materials aims to build on its work in developing both RTM technologies and processes, as well as DTs through its participation in the **SM@RTM** project, which aims to improve the competitiveness of these processes, using predictive digital technologies, in-situ process monitoring and automated control systems, providing support at all stages of production.

The Institute will provide proven expertise in the main research lines of the project such as: manufacturing and mechanical testing of composite parts, the integration of sensors in RTM processes and data capture, and the development of behavioural models for composite materials based on their physical mechanisms of deformation and fracture.

IMDEA Materials will also provide its expertise regarding the simulation of fluid dynamics and artificial intelligence, and the development of DTs of manufacturing processes.

Prof. Carlos Gonzalez, head of our Structural Composite Materials group, leads IMDEA Materials' research in the project.

For more information, please contact
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Leading the way in the advanced manufacture of High Entropy Alloys

High Entropy Alloys (HEAs) have garnered significant research interest in the past decade since the advent of Cantor and Cantor-based alloys. This is due to their unconventional alloying approach which results in exceptional mechanical properties, such as high strength, wear resistance, corrosion resistance, and thermal stability, among others.

IMDEA Materials Institute is leading the way into research into these promising materials. One such research effort is in development of HEAs from recycled electronic waste (e-waste).

The amount of e-waste recycled worldwide is less than 20 % of the total amount produced. In a world where the need for critical and strategic metals is increasing almost exponentially, it is unacceptable that tons of these elements remain unrecycled.

One of the causes of this low level of recycling is that recycling is based on an expensive and complex selective sorting of metals. Extracting all metals simultaneously is much simpler and if this were done, it would significantly increase the recycling rate.

IMDEA Materials researchers have demonstrated how HEAs, which are in great demand in applications where very high performance is required, can be made from mixtures of complex alloys, hence reducing their dependence on pure critical metals.

Research shows that it is possible to obtain competitive HEAs from complex alloy mixtures corresponding to typical electronic waste compositions, combining two needs of high interest in our society, namely: to increase the level of recycling of electronic waste and the possibility of developing high-performance HEAs without the need for critical and/or strategic metals.

To validate the hypothesis that e-waste can be used to produce competitive HEAs, an alloy-design strategy was

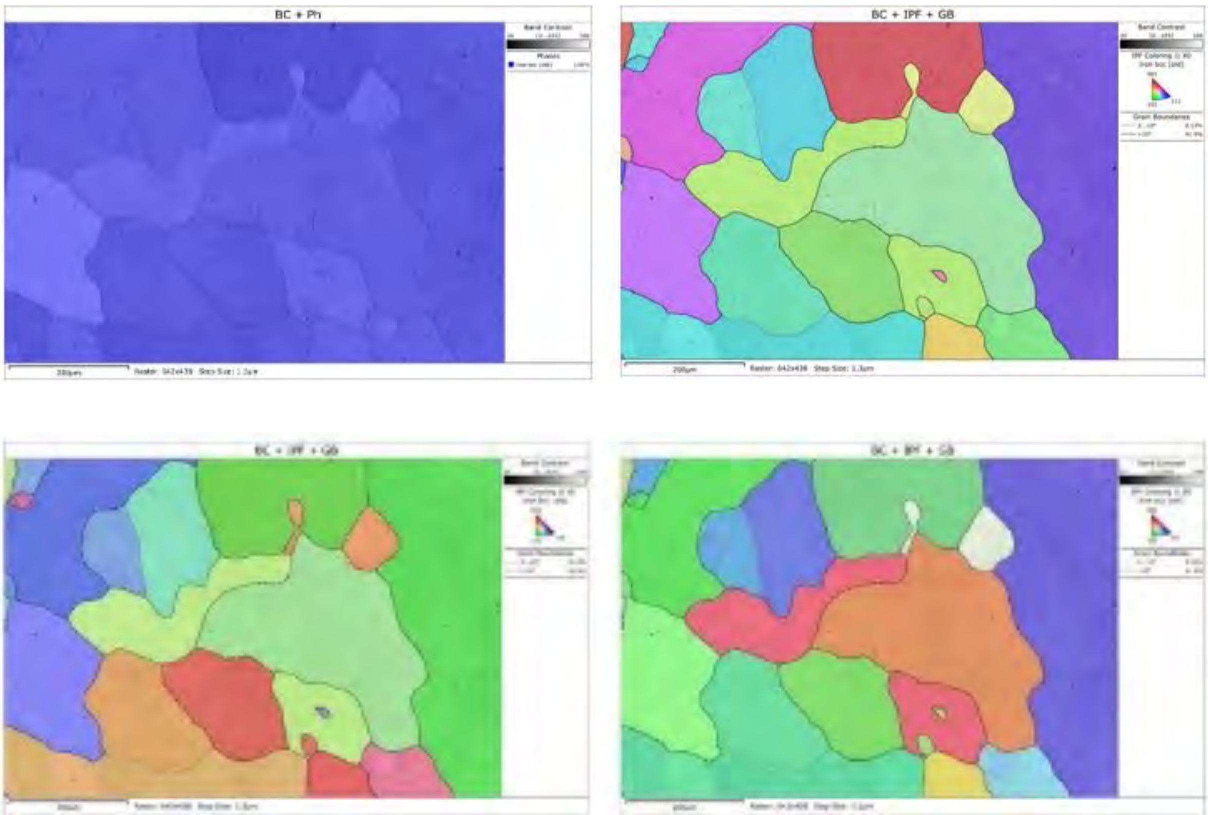

Figure 1: Phases map and IPF maps for the e-waste alloy 1. From left to right and top to bottom: phases map, IPF-x, IPF-y and IPF-z.

devised, which combines computational thermodynamic (CALPHAD) exploration of phase diagrams and phenomenological criteria for HEA design based on thermodynamic and structural parameters.

Four multicomponent alloys were produced from typical mixtures of e-waste alloy compositions representative of, e.g., smart phones, laptops, or Li-ion batteries (potentially mixed with some common commodity alloys). All four alloys exhibited typical HEA microstructures (solid solutions with one or two phases, without detrimental/brittle phases). Moreover, they exhibited excellent mechanical properties, making them all candidates for high-performance applications.

These results confirm that it is feasible to obtain HEAs from multi-component alloy mixtures from e-waste.

In another HEA-related study, a novel approach to developing HEAs using spark plasma sintering (SPS) was explored.

Therein, instead of pre-alloyed powders, a mix of commercial commodity powders like Ni625, CoCrF75, and 316L was used. This avoided the expensive pre-alloying steps like mechanical alloying or gas atomising.

Three non-equiatomic HEAs, based on Co, Cr, Fe, Ni, and Mo were designed and developed by blending the powders, which were sintered via SPS, resulting in a single FCC phase after homogenisation. The HEAs were microstructurally and mechanically characterised with tensile and hot compression tests up to a temperature of 750°C and displayed excellent properties.

Moreover, the same alloy exhibited a compression strength greater than 640 MPa with a ductility above 45% at a temperature of 750 °C.

This study paves the way for a novel fabrication route that offers more flexibility to more efficiently develop cost-effective HEAs, crucial for the discovery of new materials via high-throughput techniques. Meanwhile, using such commodity alloys also opens the door to the development of ingot casting from recycled scraps, thus avoiding the direct use of critical metals.

For more information, please contact

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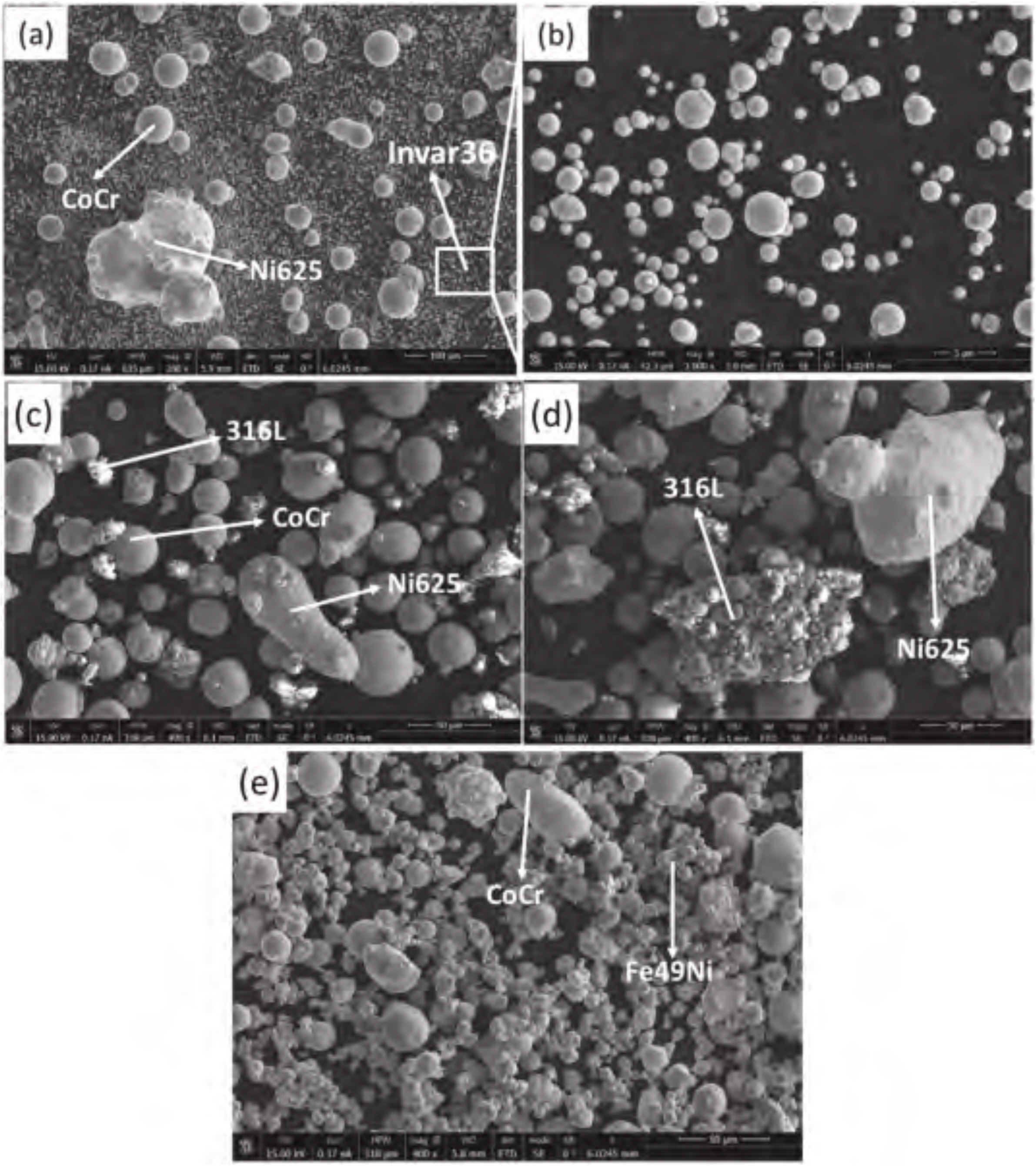
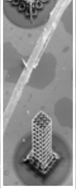


Figure 1: SEM images showing the powder morphology of (a) C1 mix; (b) magnified SEM image of Invar36 powders in the inset; (c) and (d) powder morphology of C2 mix; (e) powder morphology of C3 mix.

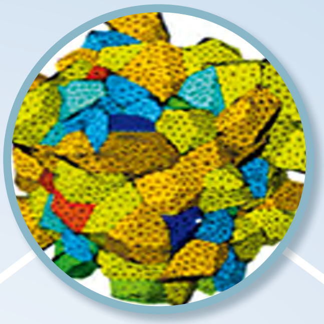


programme

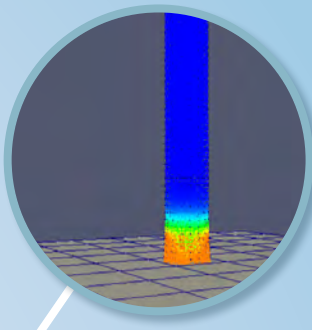
Integrated Computational Materials Engineering

Goal and vision

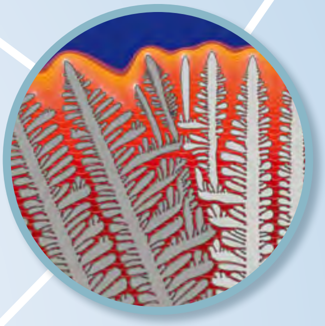
The Integrated Computational Materials Engineering (ICME) research programme is aimed at intergrating all available simulation tools into multiscale modelling strategies, capable of simulating the processing and behaviour of engineering materials. In this way, new materials can be designed, tested and optimised before manufacture in the laboratory. The programme's focus is on materials engineering, i.e. understanding how material microstructures develop during processing (virtual processing), the relationship between microstructure and behaviour (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 model calibration and validation at different length and time scales. The expertise of the programme's researchers covers a wide range of simulation techniques at different scales (electronic, atomistic, mesoscopic and continuum) and is supported by high-performance computer clusters with GPUs.



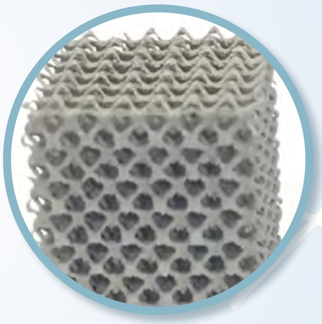
Multiscale Materials Modelling



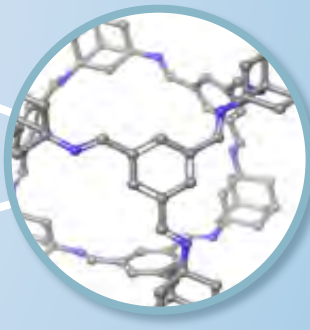
Computational Solid Mechanics



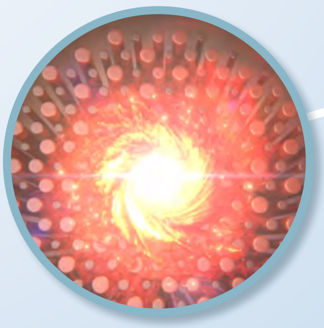
Modelling and Simulation of Materials Processing



Bio/Chemo/Mechanics of Materials



Computational and Data-Driven Materials Discovery



Acoustic and Mechanical Metamaterials

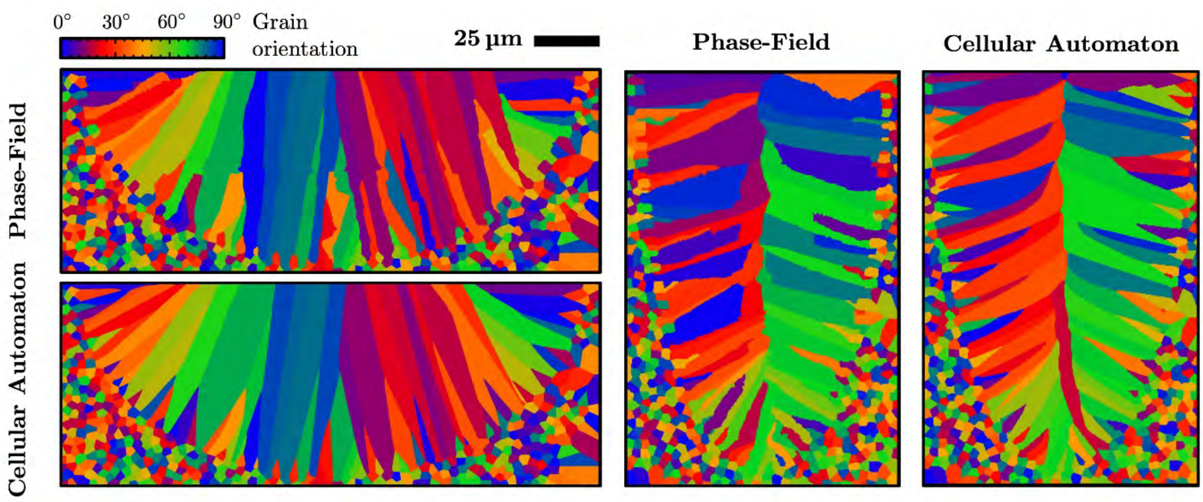
Main research lines

Virtual materials design, including virtual processing and virtual testing

- Virtual material discovery for functional applications using DFT, cluster expansion and atomistic approaches combined with AI.
- **Virtual processing**: Integration of modelling tools (atomistic, computational thermodynamics and kinetics, phase-field and cellular automata) to simulate microstructure formation and evolution during processing.
- **Virtual testing of metallic alloys**: Development of microstructural-based constitutive models to predict the mechanical behaviour of single crystals. Simulation of the mechanical response of polycrystalline metals by means of FFT and FEM-based homogenisation.
- **Virtual testing of composites**: Implementation of the constitute models in finite element codes to simulate the mechanical behaviour of structural components.
- **Smart manufacturing:** Multiphysics models of autoclave and out-of-autoclave curing of composite materials accounting for porosity evolution during the process. Simulation-based smart manufacturing processes. Sensoring and process control.
- These approaches are applied to several materials, in particular:
  - Metallic alloys for engineering and biological applications
  - Multifunctional composite materials and structures.
  - Materials for catalysis.

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.
- Finite Element solvers for Multiphysics problems.
- Fast Fourier based solvers for Multiphysics problems.



Predicted grain structures by phase-field and cellular automaton models in a solidified melt pool.

Multiscale materials modelling

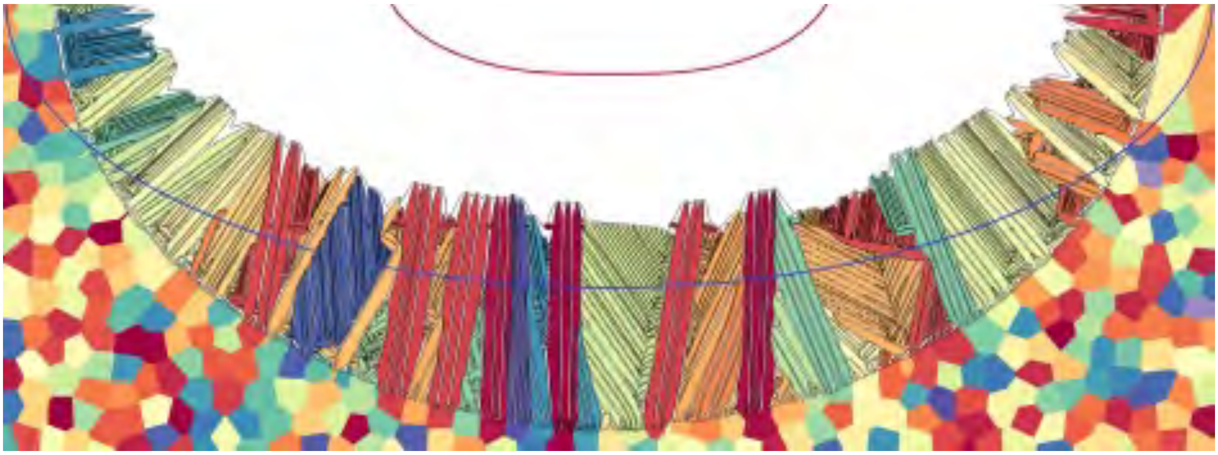
- Bottom-up approaches (scale bridging).
- Development of modular multi-scale tools.
- High-throughput screen integration.
- Concurrent models.
- Mean-field homogenisation.
- Computational homogenisation including FEM and Fast Fourier Transform – FFT-based solvers.
- Surrogate models of micromechanical models based on AI.

Modelling and simulation strategies for different applications

- Material informatics for large material dataset analysis.
- Modelling and simulation of H_2 embrittlement in metallic tanks and pipes.
- Study of H_2 diffusion mechanisms in metals.
- Discovery of new catalysts for H_2 production and fuel cells.
- Discovery of new catalysts for CO_2 reduction reaction.
- Modelling and simulation of multiscale transport phenomena (application to advanced materials for batteries).
- Virtual design and testing of mechanical metamaterials and architectured metamaterials.
- Simulation of the additive manufacturing process in metals including macroscopic simulation of the thermomechanical process by Multiphysics finite element models, microstructure evolution through phase field and prediction of mechanical response using polycrystalline homogenisation.
- Modelling and simulation of elastic waves and sound propagation in complex additive-manufactured media.
- Exploring new physical phenomena in the wave-based and elastostatic context.

Computational and data-driven materials discovery

- Discovery of porous materials for energy applications (CO_2 capture and methane storage).
- Design of ionic liquids.
- Materials discovery: structures with high H2 working capacity and H2 adsorption-desorption performance.
- Design of Metal-Organic Frameworks (MOFs) for separation of gases for anaesthesia (Xe/Kr).



Dendritic grain growth competition in a solidifying melt pool. Red and blue lines show liquidus and solidus temperatures, respectively.

Projects in focus

MOAMMM / Multi-scale optimisation for additive manufacturing of fatigue resistant shock-absorbing metamaterials/MOAMMM

European Commission | Horizon 2020 European Union funding for Research & Innovation

Funding Institution/Programme: European Commission/Horizon 2020 Programme – FET Open
Partners: University of Liège (Coordinator), IMDEA Materials Institute, KU Leuven, Johannes Kepler University Linz and CIRP
Period: 2020 - 2024
Principal Investigators: Prof. J. Segurado and Dr. M. Monclús

The **MOAMMM** *(Multi-scale optimisation for Additive Manufacturing of fatigue resistant shock-absorbing MetaMaterials)* project focuses on the development of advanced metamaterials and their integration with additive manufacturing to create optimised structural parts.

These parts are designed to adapt to varying loading conditions and user needs, leveraging the unique properties of polymeric materials to meet structural, mechanical, and functional requirements simultaneously.

Key challenges within this project have included improving damage tolerance in metamaterial design and fabrication, developing robust multiscale optimisation methods, and creating uncertainty quantification techniques to manage uncertainties in microstructure and material properties.

Addressing these challenges has required both experimental and numerical multi-scale methods. However, existing approaches have been limited by difficulties in microstructure representation, material characterisation, and high computational costs.

MOAMMM's overall goal has been to create a data-driven methodology that links structural properties to microstructures, enabling the design of optimised shock-absorption devices. Targeted applications include fatigue-resistant sport shoe soles and energy-dissipating bicycle helmets. IMDEA Materials researchers have contributed to different tasks performed in the project.

First, a simulation framework based on the Fast Fourier Transform (FFT)-based algorithm has been developed to simulate lattice materials produced by additive manufacturing (AM) using realistic 3D microstructures directly obtained from tomography, see Figure 1. This method demonstrated very high accuracy and numerical performance, quantifying the effect of defects from AM (e.g. porosity or roughness) in the mechanical performance [1].

To obtain the properties of the models, a complete experimental campaign was performed combining both macro and microtests [2] on Polyamide 12 processed by Selective Laser Sintering (SLS). This campaign has helped to understand the effect of fabrication parameters, such as strut diameter, on the material response. This data has then been used in a sequential Bayesian Inference (SBI) framework to identify parameters of the constitutive model of the strut material [3]. This method improved the parameter selection, enhancing model accuracy.

Finally, to upscale the modelling of unit cells to full specimens fabricated with lattice structures, an enhanced second-order computational homogenisation technique has been proposed which allows improved capture behaviour during local instabilities [4]. This approach reduces the dependency of the Representative Volume Element (RVE) size on the homogenised response, improving the accuracy of simulations for elastic and elasto-plastic metamaterials and cellular materials.

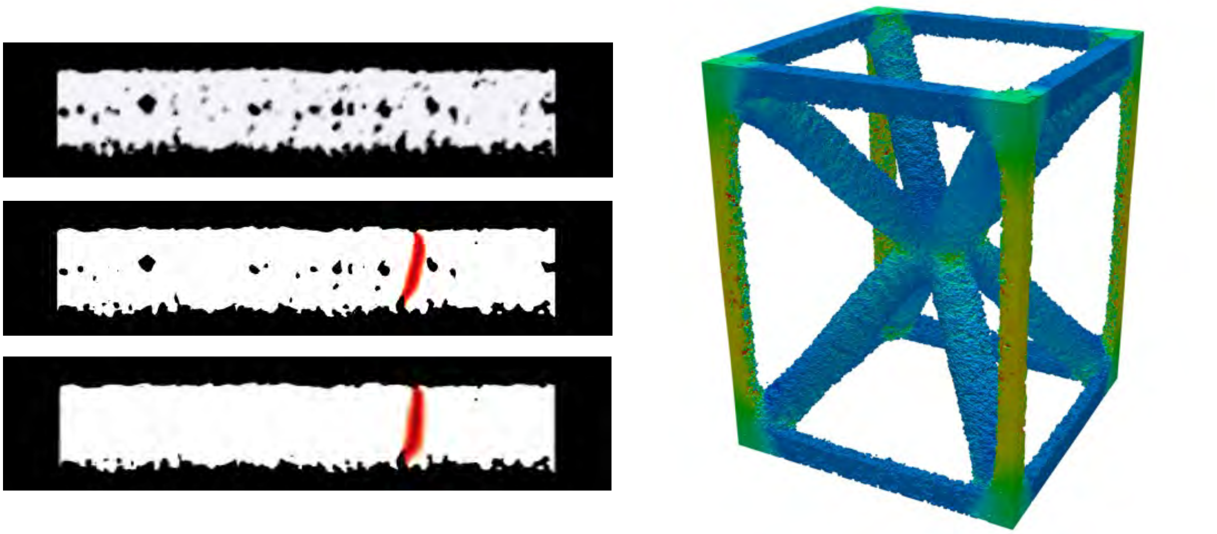


Figure 1. FFT simulation of a strut (left) and unit cell lattice (right) with microstructural data obtained from tomography.

These advances have contributed to MOAMMM's overall objectives by providing new methodologies and tools for designing and optimising shock-absorption devices, ultimately paving the way for innovative applications in sports equipment and safety gear.

For more information, please contact
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Research highlights

Advances in modelling and processing of titanium alloys: enhancing performance

Intricate microstructures of titanium (Ti) alloys are crucial to their strength, corrosion resistance, and biocompatibility. Hence, accurate simulations of microstructure evolution using computational modelling are key to optimising mechanical properties, reducing costs, improving sustainability, and facilitating innovation in manufacturing.

This research is also instrumental in exploring new applications and expanding the use of titanium alloys in emerging technologies such as aerospace components, medical devices, and renewable energy systems.

Phase-field models are widely employed to simulate microstructure evolution during processes such as solidification or heat treatment. The underlying partial differential equations may be solved by a broad range of numerical methods, but this often results in a high computational cost, which calls for advanced numerical methods to accelerate their resolution.

To address these challenges, researchers at IMDEA Materials have explored the use of advanced semi-implicit Fourier spectral methods, combined with parallelisation on graphics processing units (GPUs) to accelerate phase-field models of microstructure evolution.

Using similar hardware and a GPU parallelisation strategy, the resulting semi-implicit Fourier spectral (FS) solvers outperform the standard explicit finite difference (FD) resolution significantly (i.e. by several orders of magnitude), allowing for much faster simulations with the same accuracy (or much more accurate simulations at the same computational cost).

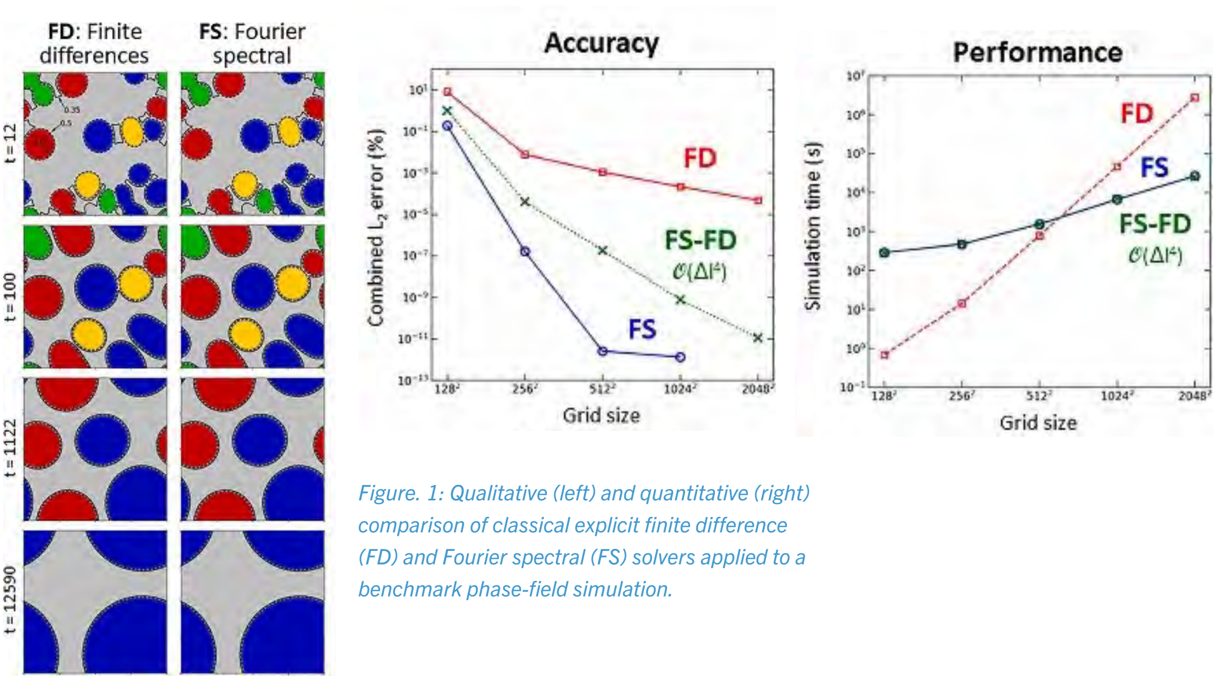

Figure. 1: Qualitative (left) and quantitative (right) comparison of classical explicit finite difference (FD) and Fourier spectral (FS) solvers applied to a benchmark phase-field simulation.

These advances are crucial for accelerating phase-field simulations and applying them at realistic length and time scales of engineering applications.

These advanced phase-field solvers were applied to simulate martensite decomposition kinetics during post processing of additively manufactured Ti-6Al-4V alloy.

Laser powder-bed fusion of Ti-6Al-4V alloy results in non-equilibrium martensitic microstructures, characterised by high strength but poor ductility and toughness. These properties can be altered through heat treatments, where the martensitic phase decomposes into more ductile equilibrium phases, yet potentially retaining microstructural features of the fine martensitic lath structure, and hence an elevated strength.

In collaboration with partners at the University of Galway (Ireland) and the University of Nottingham (UK), researchers of IMDEA Materials have combined experimental techniques, including electron microscopy and diffraction, with computational simulations using a phase-field model to investigate the kinetics of martensite decomposition.

This integrated experimental/computational approach offered critical and quantitative insights into the underlying mechanisms of phase transformations and microstructure evolution during the post-processing of 3D printed Ti-6Al-4V components.

These developments open the way to virtual postprocessing of digital microstructure and to designing microstructures "on demand" with properties tailored specifically to a broad range of applications across various industrial sectors.

Furthermore, these simulations provide an alternative to classical trial-and-error experimental strategies for optimising heat treatments, which will also result in substantial savings in both time and resources.

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Dr. D. Tourret at damien.tourret@imdea.org

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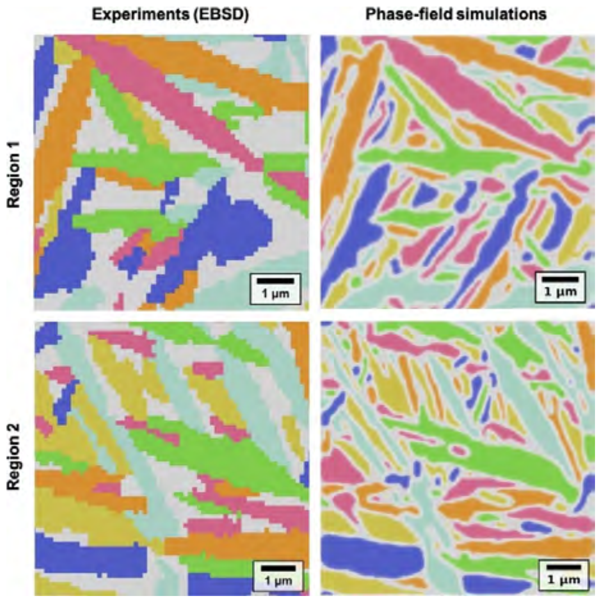

Figure 2: Computational simulation results (right) compared to experimental microstructures (left) in two different regions, after 300 s of isothermal annealing at 850 °C.

Exploring polycrystalline growth dynamics in fusion-based additive manufacturing

In metal additive manufacturing (AM), microstructural features are sensitive to processing parameters like laser power and scanning speed, as well as melt pool geometry.

Grain growth competition during solidification critically influences microstructural features such as dendritic arm spacings, segregation patterns, and grain textures. It plays a central role in texture selection during melt pool solidification in fusion-based AM processes.

In turn, microscopic grain structures and textures directly impact macroscopic material properties such as strength, ductility, thermal conductivity, and their potential anisotropy.

Hence, understanding their formation is crucial for optimising AM processes like laser powder-bed fusion (LPBF) and ensuring high-quality parts with minimised defects and desired properties.

A broad range of computational models has been proposed to predict microstructure development during solidification processing, but quantitative and systematic comparisons between these models are rare.

In this context, within the **MiMMoSA** and **ENVIDIA** projects, IMDEA Materials researchers have studied grain growth competition during melt pool solidification, comparing accurate-yet-costly phase-field (PF) and fast-yet-approximate cellular automaton (CA) models.

The comparison of predicted grain structures are aimed at quantifying the effect of CA spatial discretisation and that of melt pool aspect ratio on grain texture selection. Indeed, in technological applications, the CA computational grid size is often adjusted (i.e. coarsened) to accelerate simulations, with little regard to consequences on the quantitative accuracy of resulting predictions.

IMDEA Materials' research has highlighted that PF simulations capture detailed microscopic features like transient growth conditions, solid-liquid interface stability, and resulting grain boundary roughness, which are inaccessible to CA models. Although refining CA grid resolution partially improves agreement with PF predictions, significant variability persists depending on melt pool shape and CA grid size.

Overall, averaged grain distributions over multiple simulations and numerous grains show reasonable agreement between PF and CA, indicating a high potential for modelling microstructure selection at process-relevant

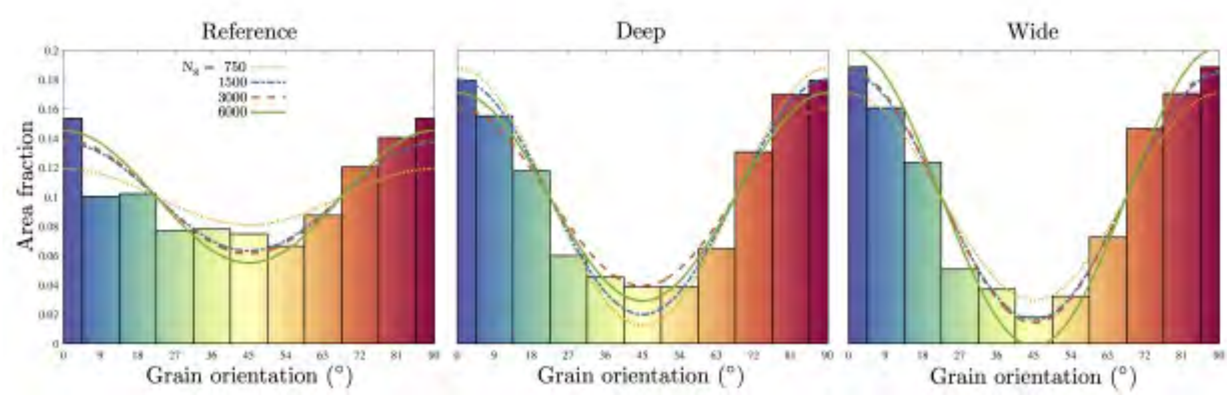

Figure 1: Histograms of grain orientation distributions in solidified melt pools of different aspect ratios: ≈ 1 (left), deep/narrow (centre), and wide/shallow (right).

scales, while acknowledging the need for further research to quantify the effect of CA parameters.

Results have also revealed a transition from a weak to strong texture as a function of the melt pool aspect ratio. Influenced by the thermal gradient directions during solidification, pronounced textures were found in wider and shallower melt pools. Within the range of grain size explored, initial grain density along the fusion line was found not to significantly affect texture transition.

Research in this area advances fundamental understanding of phase transformations and microstructure evolution, contributing to ongoing innovations in materials science and engineering. This knowledge also supports the development of new alloys and processing conditions to reach tailored material properties for applications in aerospace, automotive, biomedical, and energy sectors.

For more information, please contact:
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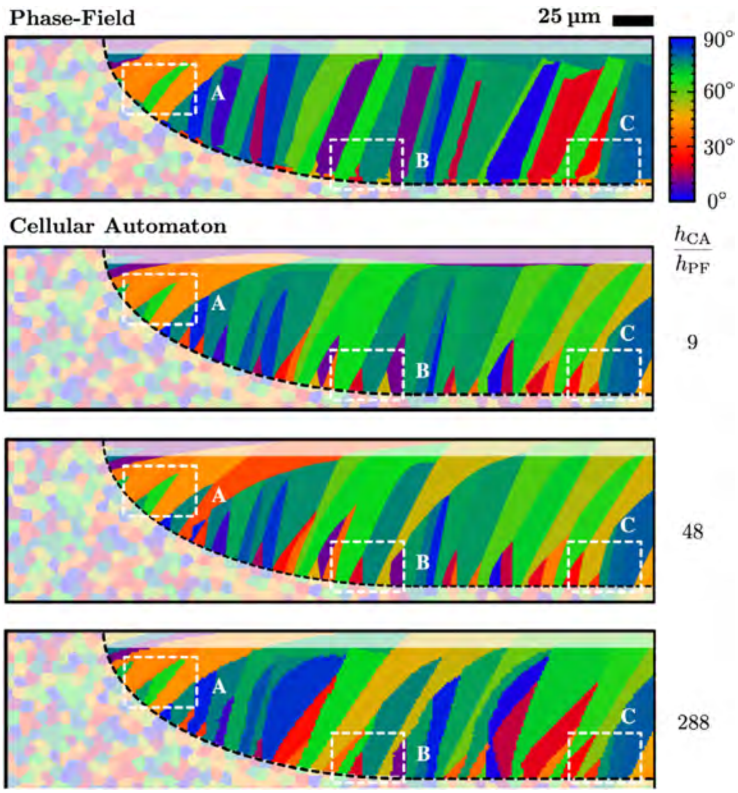


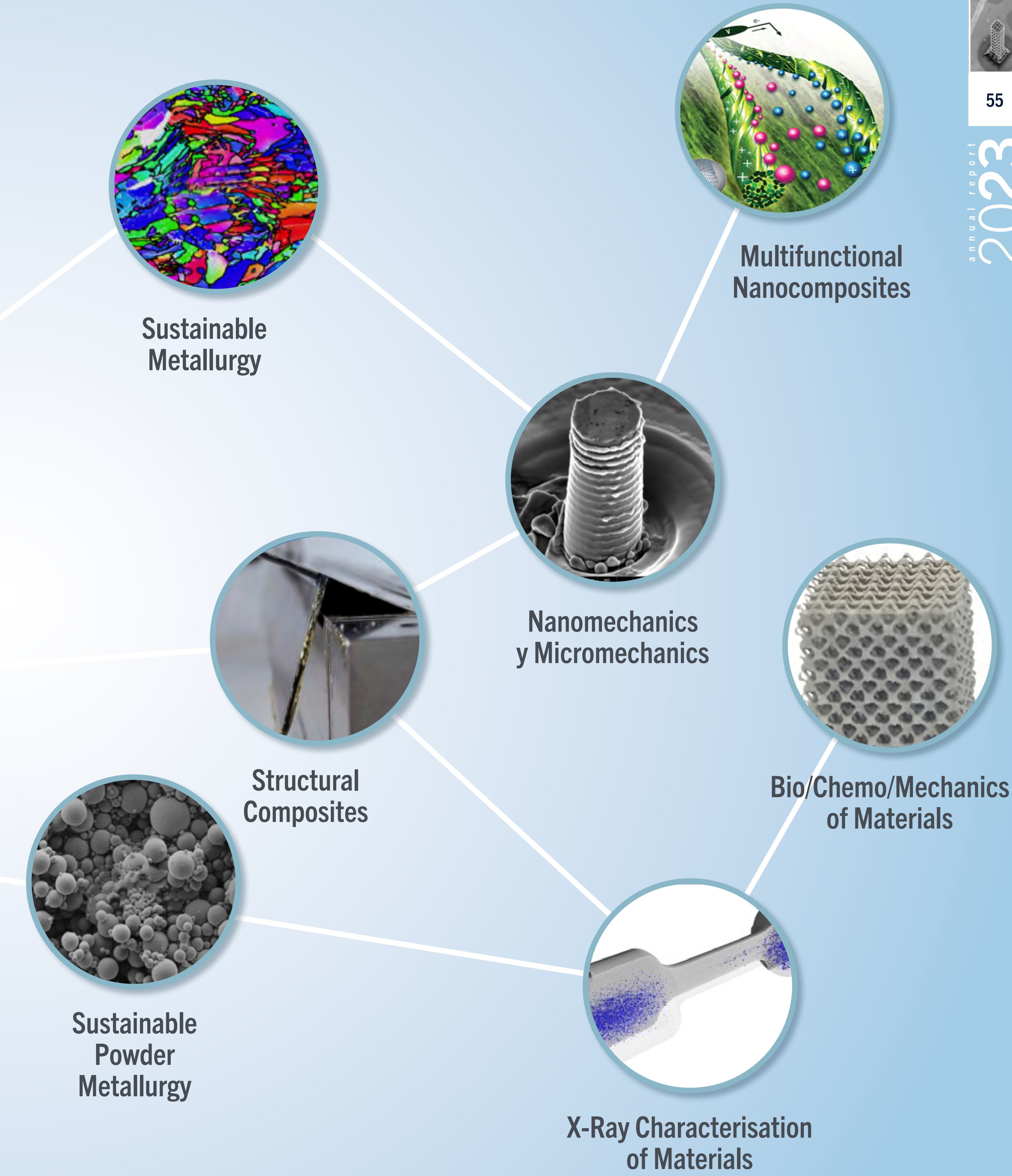
Figure 2: Selected grain orientations (color map) predicted by phase-field (top row) and cellular automaton (bottom rows) with different coarsening levels.

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 the microstructure of the material in focus, its evolution during either processing or service operation, and its influence on the relevant properties for the purpose it was designed. Since the microstructural features that determine material behaviour usually span several length scales (for instance, from macroscopic defect distribution to nanometre 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 3D microstructure over time at different length scales; hence the term 4D. This is precisely the objective of this programme: to understand microstructure/defect distribution and evolution in advanced materials during processing and service using advanced characterisation techniques.


Multifunctional Nanocomposites
Sustainable Metallurgy
Nanomechanics y Micromechanics
Structural Composites
Bio/Chemo/Mechanics of Materials
Sustainable Powder Metallurgy
X-Ray Characterisation of Materials

Main research lines

Advanced material characterisation, including microstructural, chemical and crystallographic information across several length scales and using different techniques

- Multiscale characterisation with optical and electron microscopy, X-rays, atomic force microscopy, Raman spectroscopy and ultrasonic inspection. Some of the equipment used for this is:
  - FIB-FEG-SEM, including 3D-EDS and 3D-EBSD. In-situ stages for thermomechanical testing;
  - FEG-TEM including 3D-STEM and 3D-EDS with in-situ stage for mechanical testing;
  - X-ray Tomograph (XCT) with in-situ stage for thermomechanical testing, furnaces for thermal treatments and observation of chemical reactions, in-situ composite curing and in-situ composite infiltration;
  - Diffraction Contrast Tomography (DCT). This new technique at IMDEA Materials permits tomography from a diffracted beam in crystalline samples, revealing the 3D orientation and size of grains within specimens;
  - X-ray Diffractometer (XRD) equipped for residual stresses and texture determination, reflectometry analysis, Cu and Cr radiation, linear detector and an in-situ furnace;
  - Raman micro-spectrometer 5x, 20x, 50x, 100x microscope objectives, 532 nm Nd:YAG laser (50W) and diffraction grating of 1800 l/mm, 100 nm resolution;
  - Small angle X-ray scattering and Wide angle X-ray scattering (SAXS/WAXS) for the study of crystallisation in polymers, chemical composition or phase composition of a film, film texture (preferred alignment of crystallites), crystallite size and presence of film stress.
- Characterisation of a broad range of materials e.g. biomaterials, plastics, metal matrix composites, fibre-reinforced composites, metals, nanomaterials, etc.
- Use of large facilities such as neutron or synchrotron radiation facilities for characterisation.
- Development of new methodologies (e.g. hardware for in-situ testing and software tools) for material characterisation and analysis while also applying artificial intelligence methods.
- Correlative studies of materials, i.e. combining insights from different techniques.

4D characterisation: in-situ multiscale characterisation of processes

- Thermo-mechanical testing across several length scales: tension, compression, fatigue, creep, etc. in the Scanning Electron Microscope (SEM) and X-ray tomograph.
- Properties and deformation mechanisms of small volumes by nanomechanical testing in the scanning and Transmission Electron Microscopes (TEM): properties of metallic phases, interfaces, nanoparticles, carbon-based nanomaterials (carbon nanotubes, graphene, etc.).
- Elevated temperature nanomechanical testing.
- 4D characterisation of processes by X-ray tomography and X-ray diffraction: eg. metallic alloy solidification, metallic alloy phase formation and chemical reactions, infiltration and resin flow in composites, composite curing, etc.

Cross-correlation between experiments and multiscale simulations (molecular dynamics, dislocation dynamics, crystal plasticity, finite elements, etc.)

- Digital modelling from 3D structures.
- Integration of experimental statistical measurements into models.
- Experimental confirmation of modelling results.
- Experimental design based on models.

Projects in focus

3D-METJET / New generation of parts for sustainable mass production by 3D-Metal Jet with improved quality and reliable manufacturing process

Funding Institution/Programme: Spanish Ministry of Science and Innovation/Public-Private Collaboration
Partners: HP Printing and Computing Solutions (Coordinator), IMDEA Materials Institute and AMES
Period: 2023 - 2026
Principal Investigators: Prof. J.M. Torralba and Dr. F. Sket

Today's society demands clean manufacturing processes that consume low levels of energy and are efficient in their consumption of raw materials, while still able to mass-produce high-performance components to meet industrial application requirements.

Starting with an additive manufacturing (AM) technology developed in Spain and based on binders and sintering (Metal Jet Technology), 3D-METJET will undertake an in-depth review of the existing technology to make it more robust and ready to enter the high-performance components manufacturing market.

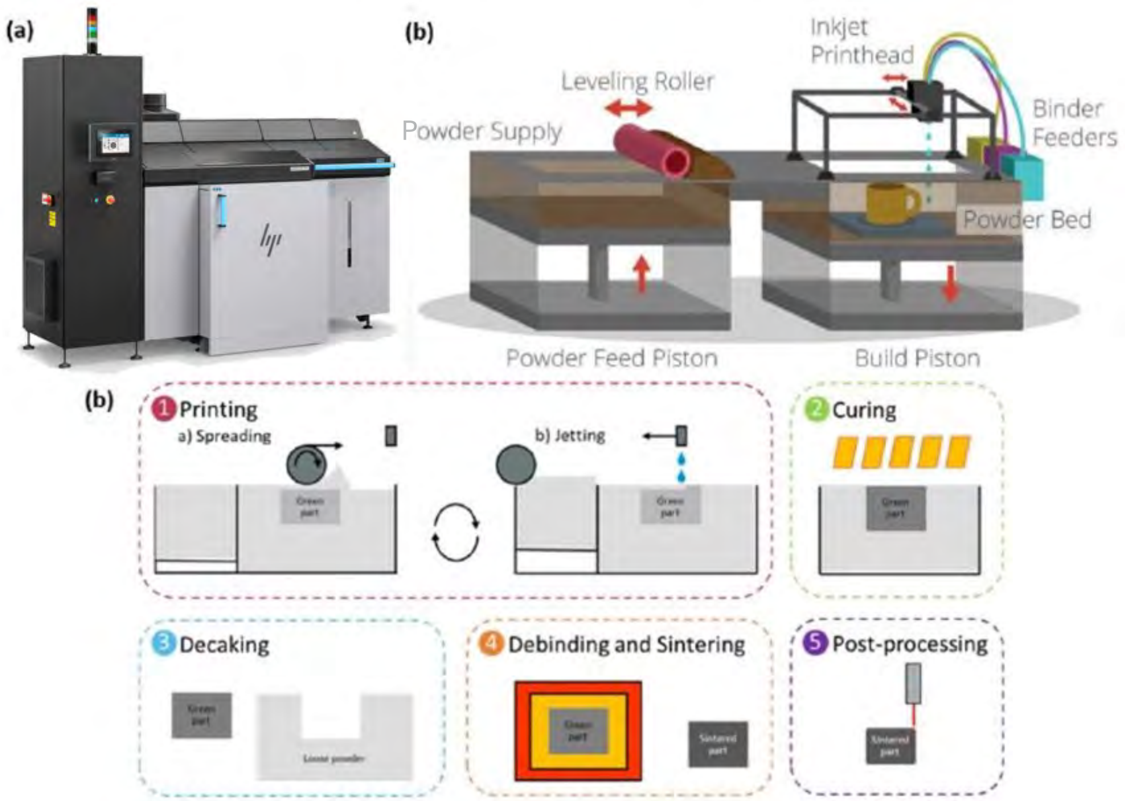


Figure 1: (a) HP Metal Jet Printer. Courtesy of HP, (b) Scheme of the working principle of the Metal Jet printing process, (c) Workflow of the part fabrication.

The three primary objectives of 3D-METJET are:

1. To improve the robustness of the process by deeply understanding the powder-binder relationship throughout the 3D printing process.
2. To improve printing process reliability.
3. Debinding and sintering optimisation.

The complete vision of the process (printing, removal of the binder and sintering), presents a sustainable and efficient “near-net-shape” technology. Through a complete study of the recyclability process of used powders, of the printing variables, the parameters linked to the elimination of the binder and sintering, a process guide will be prepared that allows the technology to enter the market.

3D-METJET also has two companies covering the entire manufacturing cycle. These are: HP, which has the experience and capacity to produce 3D-printed components and is considered a benchmark in the development of printing methods, and AMES, a key player in the Spanish powder metallurgical sector. AMES has extensive experience in the development of stainless-steel components for the automotive industry.

As a complement to both companies, IMDEA Materials has excellent capacity to develop and characterise materials.

From a technological point of view, the project envisages a complete study of the raw materials to be used (powder and binder) in order to generate the appropriate metrics for the characterisation of the printing process as well as allowing both reusability and the layout of the inks used in the composition of the binder.

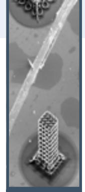
Being able to convert reused powder into new powder is linked to the optimisation of raw materials and an improvement in the circular economy. The next important milestone will be the definition/optimisation of printing parameters.

Once the materials have been printed, and before undergoing the sintering process, the removal of the binder necessary for printing must be optimised. These two stages could be done subsequently in the same thermal cycle, which would facilitate and optimise the manufacturing process.

Throughout the project, large amounts of data will be generated. In a project where data generation is important, having the ability to analyse it properly, and extract relevant information, becomes a fundamental task.

As a whole, 3D-METJET can be considered a highly multidisciplinary project with complementary disciplines (such as material science, metallurgical engineering, organic chemistry, manufacturing, sintering and artificial intelligence).

For more information, please contact
Dr. F. Sket at federico.sket@imdea.org



Research highlights

Optimising Inconel 718 lattices for high-performance applications

Research into Inconel 718 lattices is crucial due to the material's exceptional properties and applications in high-performance environments. Inconel 718, a nickel-chromium alloy, is known for its high strength, durability at high temperatures, and resistance to corrosion and oxidation. These properties can be further enhanced through optimised lattice structures.

Additive manufacturing methods, such as selective laser melting (SLM) and electron beam melting (EBM), are key to this research. These techniques enable the creation of complex lattice structures that are challenging to produce with traditional methods. This research aims to improve the mechanical properties and material efficiency of Inconel 718 lattices.

Lattice structures are lightweight due to their porous nature, which is essential for aerospace and automotive industries. They also enhance heat dissipation, making them valuable high-temperature applications and heat exchangers. Moreover, lightweight and durable Inconel 718 components can improve engine performance and efficiency, leading to fuel savings and reduced emissions.

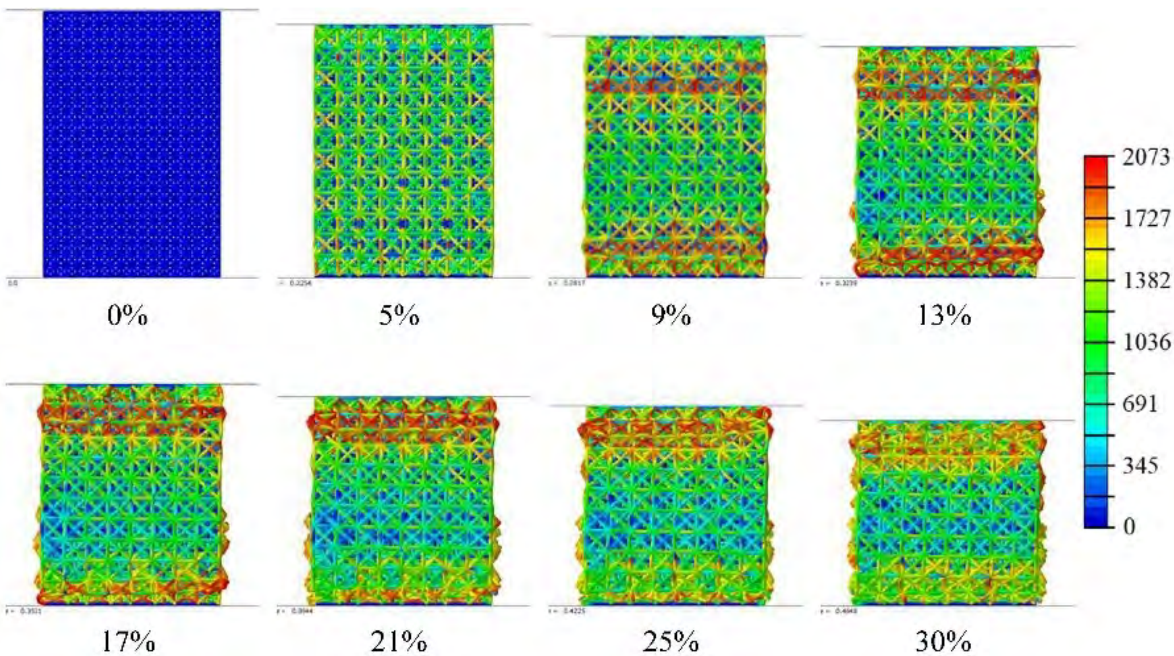


Figure 2: Stress distribution at different global compression strain levels (indicated below each image) in the peak-aged D1 lattices. The scale bar indicates the Von Mises stress levels in MPa, measured by FEA.

Advances in Inconel 718 lattice research can also lead to innovative applications in the aerospace, automotive, biomedical, and other sectors, providing enhanced performance, weight reduction, and improved efficiency.

Recent research carried out by IMDEA Materials Institute [1] has been investigating dynamic strain ageing (DSA) in Inconel 718 body-centred cubic (BCC) and face-centred cubic (FCC) strut-based lattices manufactured via Laser Powder Bed Fusion (LPBF).

This involved uniaxial compression tests at temperatures from 25 to 600 °C and strain rate jump tests to detect serrated flow and analyse strain rate sensitivity. DSA manifestations were found to be highly dependent on lattice topology, with the FCC architecture exhibiting more pronounced DSA. This emphasises the importance of understanding DSA in additively manufactured lattice structures for structural applications.

Further research [2] explored the effect of microstructure on the effectiveness of hybridisation in additively manufactured Inconel 718 strut-based lattices. In doing so, researchers compared two microstructures: the as-built solid solution and a peak aged condition. Hybrid architectures combining face-centred cubic (matrix) and octet-truss (reinforcement) domains with varying unit cells were analysed.

Results showed that in the as-built condition, hybrid lattices behaved similarly to single-oriented components, regardless of reinforcement size. However, in peak-aged lattices, small-sized octet-truss reinforcements improved mechanical stability, damage tolerance, and absorbed energy due to interphase boundaries acting as obstacles to shear band propagation.

The effectiveness of hybridisation was found to be a function of reinforcement size, with smaller sizes resulting in a reinforced “single-phase” structure rather than a two-phase architecture. These findings provide guidelines for designing robust lattices manufactured by LPBF.

Research into these areas highlights the potential for optimising Inconel 718 lattices through additive manufacturing techniques, offering significant improvements in mechanical properties and material efficiency for high-performance applications.

For more information, please contact
Dr. M.T. Pérez-Prado at teresa.perez.prado@imdea.org

References

1. S. Banait; M. Campos; M.T. Pérez-Prado – *Dynamic strain aging in Inconel718 additively manufactured lattices*. **Materials Letters 353**, 2023. DOI:10.1016/j.matlet.2023.135314
2. S. Banait; C. Liu; M. Campos; M.S. Pham; M.T. Pérez-Prado – *Effect of microstructure on the effectiveness of hybridization on additively manufactured Inconel718 lattices*. **Materials & Design**. DOI:10.1016/j.matdes.2023.112484

Surface modification of magnesium for improved mechanical characteristics and performance

Magnesium (Mg), a biocompatible and bioabsorbable material, has been extensively researched during recent decades in the biomedical industry. Due to its similarities with the mechanical properties of bone, Mg is a promising candidate for orthopedic implants.

However, mechanical properties and corrosion resistance are still concerns for clinical use. IMDEA Materials Institute has been involved in a number of studies regarding how suitable surface modification of Mg by plasma-electrolytic oxidation (PEO) can improve its corrosion resistance and biological performance.

In one such study [1], Mg samples were processed in a galvanostatic mode using an electrolytic solution of a phosphate compound supplemented with either potassium pyrophosphate or sodium-potassium tartrate. The coatings obtained were physiochemically characterised by SEM, XRD, EDS, and micro-Raman spectroscopy. The corrosion resistance of the coatings was studied using a hydrogen evolution setup and electrochemical tests.

Finally, the biological performance of the material was evaluated by using an indirect test with osteoblasts. Obtained coatings showed a porous morphology with thicknesses ranging from 2 to 3 µm, closely dependent on the PEO solution.

The corrosion resistance tests improved the degradation rate compared to the raw material. Additionally, an unreported active–passive corrosion behaviour was evidence of a protective layer of corrosion products underneath the anodic coating. Indirect in vitro cytotoxicity

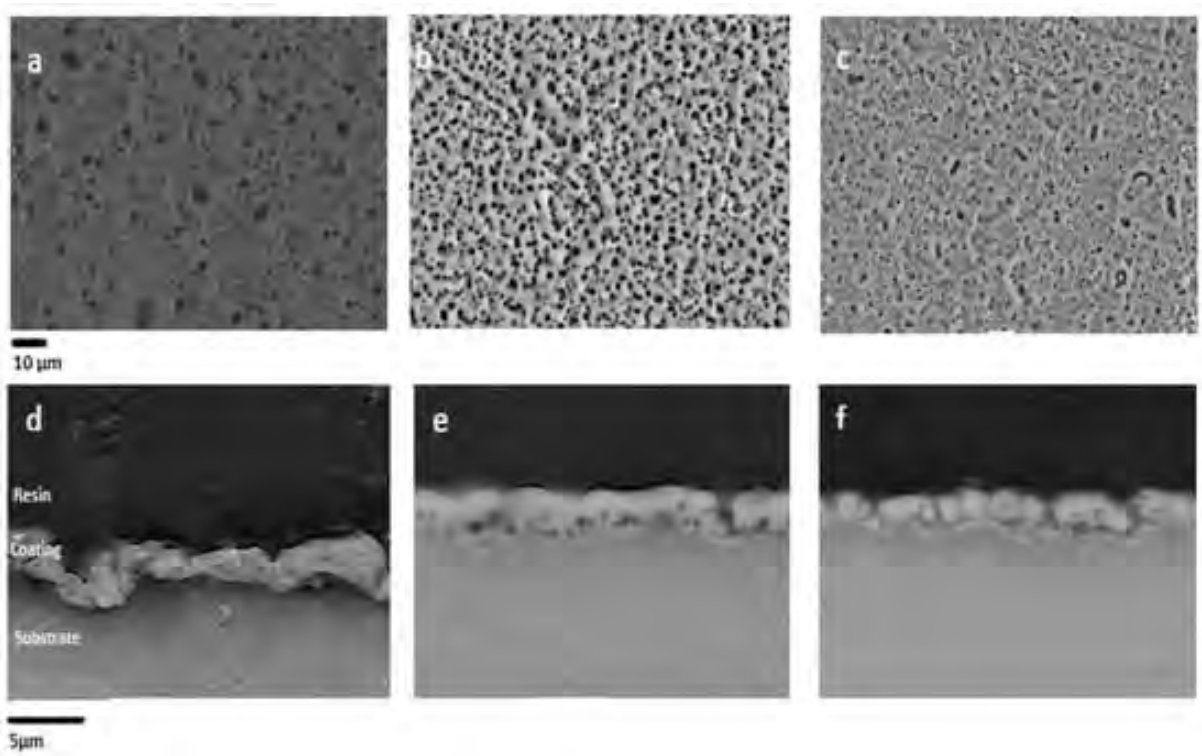


Figure 1: SEM Images of the PEO coatings surfaces and their respective cross-sections: M1 (a,d), M2 (b,e), and M3 (c,f).

assays indicated that the coatings improved the material's biocompatibility.

In conclusion, it was found that the coatings produced not only led to material protection, but also improved the material's biological performance and ensured cell survival, indicating its potential for bone implants.

In further research [2, 3], a novel processing strategy for the continuous fabrication and surface modification of wires from Mg alloy WE43 by means of PEO was presented.

In the first step, wires with a strong basal texture and small grain size (≈ 1 µm) were manufactured by combined cold drawing and in-line stress-relief heat treatment steps that optimised the mechanical properties (in terms of strength and ductility) by means of annealing.

In a second step, for the first time ever, the wires were continuously surface-modified with a novel PEO process, which created a homogeneous porous oxide layer made of MgO and Mg3(PO4)2 on the wire surface. While the oxide layer slightly diminished the tensile properties, the strength of the surface-modified wires could be maintained close to 300 MPa with a strain-to-failure of ≈ 8 %.

Furthermore, the thickness of the oxide layer could be controlled by immersion time within the electrolytic bath and was adjusted to achieve a thickness of ≈ 8 µm, which could be obtained in less than 20 seconds. These experiments showed that the chemical composition, morphology, and porosity of the oxide layer could be tailored by changing electrical parameters.

The combined cold drawing and heat treatment process, with additional continuous plasma electrolytic oxidation processing, can be upscaled to produce a novel generation of bioabsorbable Mg wires with optimised mechanical, degradation and biological performance for use in biomedical applications.

For more information, please contact
Prof. J. LLorca at javier.llorca@imdea.org

References

1. M. Echeverry-Rendón; L.F. Berrio; S.M. Robledo; J.A. Calderón; J.G. Castaño; F. Echeverria - *Corrosion Resistance and Biological Properties of Pure Magnesium Modified by PEO in Alkaline Phosphate Solutions.* **Corrosion And Materials Degradation 4**, 196-211, 2023. DOI:DOI10.3390/cmd4020012

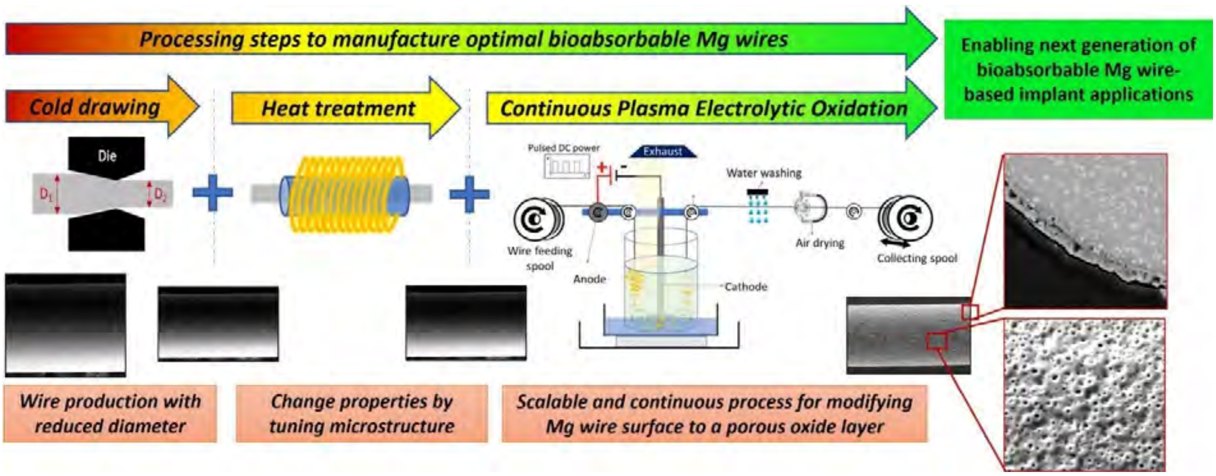
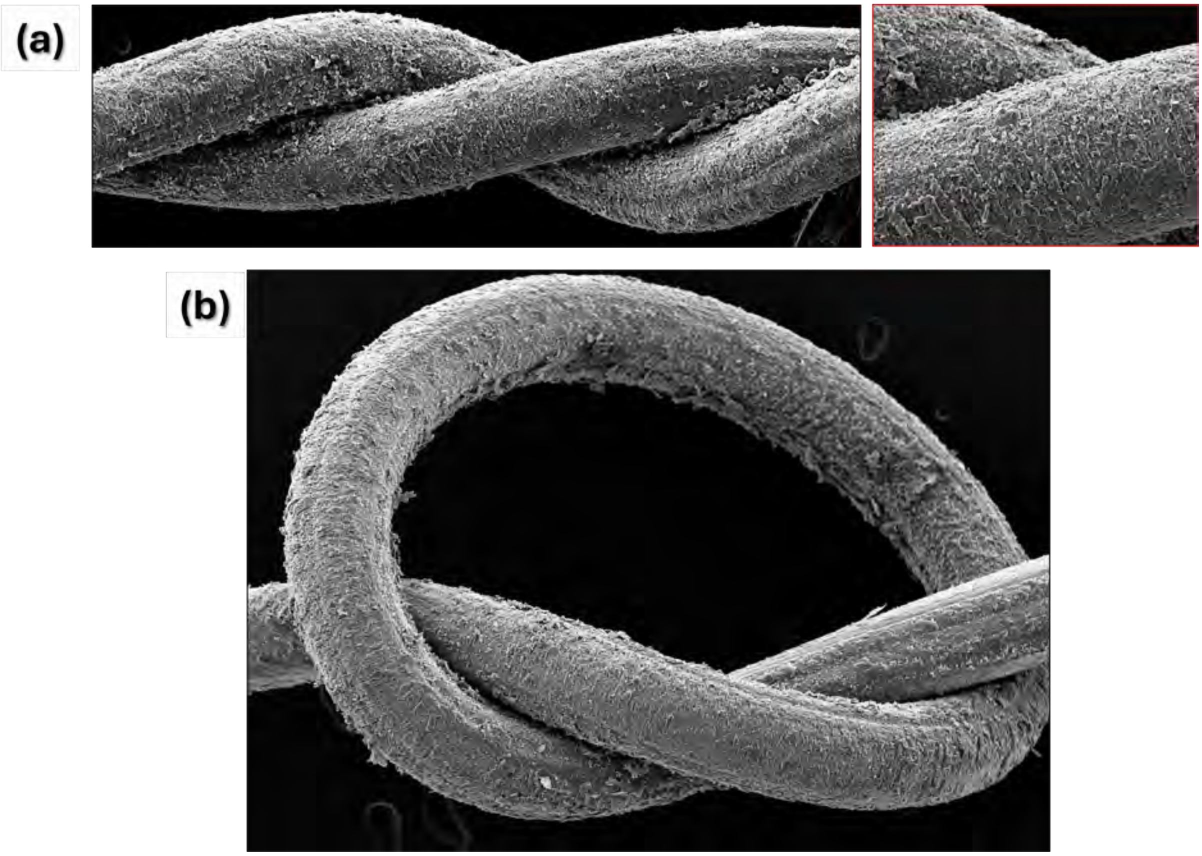


Figure 2: Processing steps to manufacture optimal bioabsorbable Mg wires.

2. W. Ali; M. Li; L. Tillmann; T. Mayer; C. González; J. LLorca; A. Kopp – *Bioabsorbable WE43 Mg alloy wires modified by continuous plasma-electrolytic oxidation for implant applications. Part 1: Processing, microstructure and mechanical properties.* **Biomaterials Advances,** 146, 2023. DOI:10.1016/j.bioadv.2023.213314
3. W. Ali; M. Echeverry-Rendón; G. Domínguez; K. van Gaalen; A. Kopp; C. González; J. LLorca - *Bioabsorbable WE43 Mg alloy wires modified by continuous plasma-electrolytic oxidation for implant applications. Part 2: Degradation and biological performance.* **Biomaterials Advances,** 147, 2023. DOI:10.1016/j.bioadv.2023.213325
4. W. Ali; M. Echeverry-Rendón; A. Kopp; C. González; J. LLorca - *Effect of surface modification on interfacial behaviour in bioabsorbable magnesium wire reinforced poly-lactic acid polymer composites.* **Npj Materials Degradation,** 7, 2023. DOI:10.1038/s41529-023-00386-x



SEM images of (a) twisted and (b) knotted PEO500 Mg wires, showing a fine network of cracks on the PEO oxide layer upon deformation.

principal investigators

Senior Researchers

Prof. José Manuel Torralba

Director. Sustainable Powder Metallurgy

Ph.D. in Metallurgy from Technical University of Madrid. Spain. Ph.D. in Armament Engineer from the Technical School of Elche. Spain

Research Interests

Powder metallurgy, powder development, characterisation and advanced consolidation methods (field assisted sintering, metal injection moulding, additive manufacturing…) in particular. He has worked with most families of materials in powder metallurgy, such as low-alloyed steels, special steels, hardmetals, superalloys, light alloys and metal matrix composites, high entropy alloys, etc…

Dr. Jon M. Molina-Aldareguia

Deputy Director. Micromechanics and Nanomechanics

Ph.D. in Materials Engineering from the University of Cambridge. UK.

Research Interests

Micro- and nano-mechanical testing and advanced focused-ion beam and electron microscopy analysis of advanced structural materials; microstructural and mechanical characterisation of thin-films; mechanical testing inside the scanning and transmission electron microscopes.

Prof. Javier LLorca

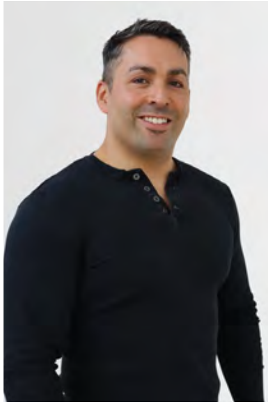
Scientific Director, Bio/Chemo/Mechanics of Materials

Ph.D. in Materials Science from the Technical University of Madrid. Spain

Professor of Materials Science, Technical University of Madrid

Research Interests

Development of new materials for engineering applications in transport, energy and health. The processing-structure-properties relationships of materials are established by means of different computational tools and multiscale modeling strategies as well as in situ and in operando characterisation techniques. Particular emphasis is given to the interaction among biological, chemical and mechanical processes. This information is used to design new materials that are manufactured by means of advanced processing techniques (including additive manufacturing of metallic alloys, polymers and composites, magnetron sputtering, etc.).



Dr. Johan Christensen

Senior Researcher, Acoustic and Mechanical Metamaterials.

Ph.D. in Condensed Matter Physics, Autonomous University of Madrid, Spain.

Research Interests

Theoretical description and numerical modelling of metamaterials and topological insulators.The investigation comprises the exploration of novel material properties and physical effects, both in the context of wave propagation, as well as topology induced deformations and wave guiding. The driving force is predominantly to nurture fundamental science but technological implications are also targeted.

Prof. Carlos González

Senior Researcher, Structural Composites

Ph.D. in Materials Science from the Technical University of Madrid. Spain

Professor of Materials Science, Technical University of Madrid

Research Interests

Materials processing, charactersation and modelling from a theoretical and numerical perspective of the mechanical performance of advanced structural materials with special emphasis in polymeric-matrix composites; development of physically-based constitutive models including multiscale strategies for virtual testing as well as virtual processing for manufacturing optimisation.

Dr. Maciej Haranczyk

Senior Researcher, Computational and Data-Driven Materials Discovery

Ph.D. in Chemistry from the University of Gdansk. Poland

Research Interests

Computational and data-driven materials discovery and design. Novel methodologies that effectively combine materials informatics approaches with computational material science techniques such as electronic structure calculations and/or molecular simulations. The developed methodologies are verified and/or integrated with experiments conducted in collaborating groups. Their applications are broad but can be collectively described as the design of materials for clean and energy efficient technologies.

Dr. Srdjan Milenkovic

Senior Researcher, Solidification Processing & Engineering

Ph.D. in Materials Engineering from the State University of Campinas. Brazil

Research Interests

Advanced solidification processing techniques (centrifugal and suction casting, reactive infiltration) with special emphasis on small scale gas atomisation of powders for additive manufacturing and development of novel high-throughput casting methods for accelerated material discovery by means of materials libraries. Alloy development, processing-structure-property relationships of Ni-based superalloys, intermetallic compounds, eutectic alloys and other advanced materials for high-temperature applications.

Dr. María Teresa Pérez-Prado

Senior Researcher. Sustainable Metallurgy

Ph.D. in Materials Science from the Complutense University of Madrid, Spain

Research Interests

Dr. Teresa Pérez-Prado, Ph.D. in Physics at the Complutense University in Madrid in 1998 and an MBA at INSEAD, France, in 2008, has led IMDEA Materials Institute's Sustainable Metallurgy group since 2008. Her current research interests are focused on sustainable metals and advanced manufacturing technologies that can enable energy efficient and low carbon solutions.

Prof. Ignacio Romero

Senior Researcher, Computational Solid Mechanics

Ph.D. in Civil Engineering, from the University of California Berkeley. USA

Professor of Mechanics, Technical University of Madrid

Research Interests

Numerical methods for nonlinear mechanics of solids, fluids, and structures. Development of time integration methods for Hamiltonian and coupled problems, models and numerical methods for nonlinear beams and shells, improved finite elements for solid mechanics, error estimators in nonlinear dynamics and multiscale methods for material modelling.

Dr. Ilchat Sabirov

Senior Researcher, Physical Simulation

Ph.D. in Metallurgy from Montanuniversitaet Leoben. Austria

Research Interests

Physical simulation of metallurgical processes, their optimisation and study of their effect on the microstructure and properties of metallic materials. Development of novel tools for physical simulation of emerging manufacturing processes. Development of unique thermo-mechanical processing routes that optimise performance of metallic materials.

Dr. Javier Segurado

Senior Researcher, Multiscale Materials Modelling

Ph.D. in Materials Engineering from the Technical University of Madrid. Spain

Associate Professor of Materials Science, Technical University of Madrid

Research Interests

Multiscale modelling of structural materials; physically-based models to simulate the mechanical behaviour of metals at different length scales: molecular dynamics, discrete dislocation dynamics and single-crystal plasticity models; computational homogenisation models and concurrent multiscale techniques for polycrystalline materials; and development of computational micromechanics strategies to simulate the mechanical behaviour until failure of both particle- and fibre-reinforced composites.

Dr. Federico Sket

Senior Researcher, In-situ processing and mechanical characterisation of materials

Ph.D. in Materials Engineering from Max-Planck Institute for Iron Research. Germany

Research Interests

Microstructural evolution of metal alloys and fibre-reinforced composites for engineering applications using advanced laboratory and synchrotron X-ray tomography as well as X-ray diffraction; processing of composite materials and relationship between processing conditions and microstructural evolution; mechanical deformation of materials and evolution of mechanical and microstructural properties; development of in-situ devices (based on in-situ X-ray microtomography and X-ray diffraction) for testing mechanical properties and processing using X-rays; and incorporation of experimental results to the development of physically-based models for optimisation of material processing and properties.

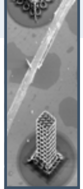
Dr. Damien Tourret

Senior Researcher, Modelling and Simulation of Materials Processing

Ph.D. in Materials Science and Engineering from Mines ParisTech. France

Research Interests

Microstructure selection, formation, and evolution; solidification processing (e.g. casting, welding, additive manufacturing); structural materials; metals and alloys; crystal growth; phase transformations; multiscale modelling; phase-field modelling; parallel computing (e.g. using graphics processing units); non-equilibirum solidification; directional solidification experiments; in-situ imaging of metals and alloys.



Dr. Juan José Vilatela
Senior Researcher. Multifunctional Nanocomposites

Ph.D. in Materials Science from the University of Cambridge, United Kingdom

Research Interests
Dr. Vilatela has devoted his scientific career to the development of methods for synthesis and assembly of 1D nanomaterials into macroscopic nanotextiles with high-performance properties for structural and energy applications. His group is focused on multiscale models of network materials to overcome the limits of traditional materials, expanding floating catalyst CVD synthesis to multiple chemistries, and supporting industrialisation of nanomaterials through scalable manufacture and integration in components as electrodes for batteries and reinforcement in structural composites, amongst others.

Dr. De-Yi Wang
Senior Researcher, High Performance Nanocomposites

Ph.D. in Polymer Chemistry and Physics from Sichuan University. China

Research Interests
Application-oriented fundamental problems and novel technologies in multifunctional nanomaterials, eco-benign fire retardants, high-performance environmentally friendly polymers and nanocomposites (bio-based and/or petro-based); synthesis and modification of novel multifunctional nanostructure materials, design and processing of high-performance polymers and their nanocomposites, with particular emphasis in structural properties and behaviour under fire.

Researchers

Dr. Jennifer Patterson
Researcher, Biomaterials and Regenerative Medicine

Ph.D. in Bioengineering from the University of Washington. USA

Research Interests
Synthesis of novel biomaterials, with a particular focus on hydrogels; processing of biomaterials into complex 3D structures; characterisation of the physical and chemical properties of biomaterials; evaluation of cytocompatibility and biological functionality in vitro; preclinical evaluation in small animal models in vivo; tissue engineering applications; development of 3D in vitro tissue models and organ-on-chip devices.

Visiting Scientists

Prof. Carl Boehlert
Visiting researcher

Ph.D. in Materials Science and Engineering, University of Dayton

Professor, College of Engineering, Michigan State University, United States

Prof. Douglas Spearot
Visiting researcher

Ph.D. in Mechanical Engineering, Georgia Institute of Technology, United States

Professor, Department of Mechanical & Aerospace Engineering, Hebert Wertheim College of Engineering at the University of Florida, United States

Dr. Jian Yang
Visiting researcher

Ph.D. in Materials science, Yanshan University, China

Professor, Department of Materials Processing Engineering, School of Materials Science and Engineering, University of Science and Technology Beijing (USTB), China.

Dr. José Antonio Rodríguez Martínez
Visiting researcher

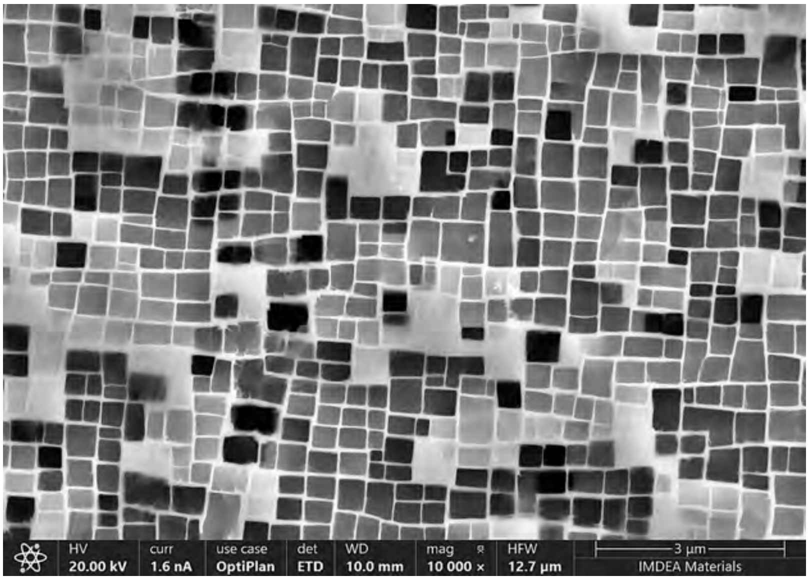
Ph.D. in Mechanical Engineering, Carlos III University of Madrid, Spain

Professor, Department of Materials Processing Engineering, School of Materials Science and Engineering, University of Science and Technology Beijing (USTB), China.

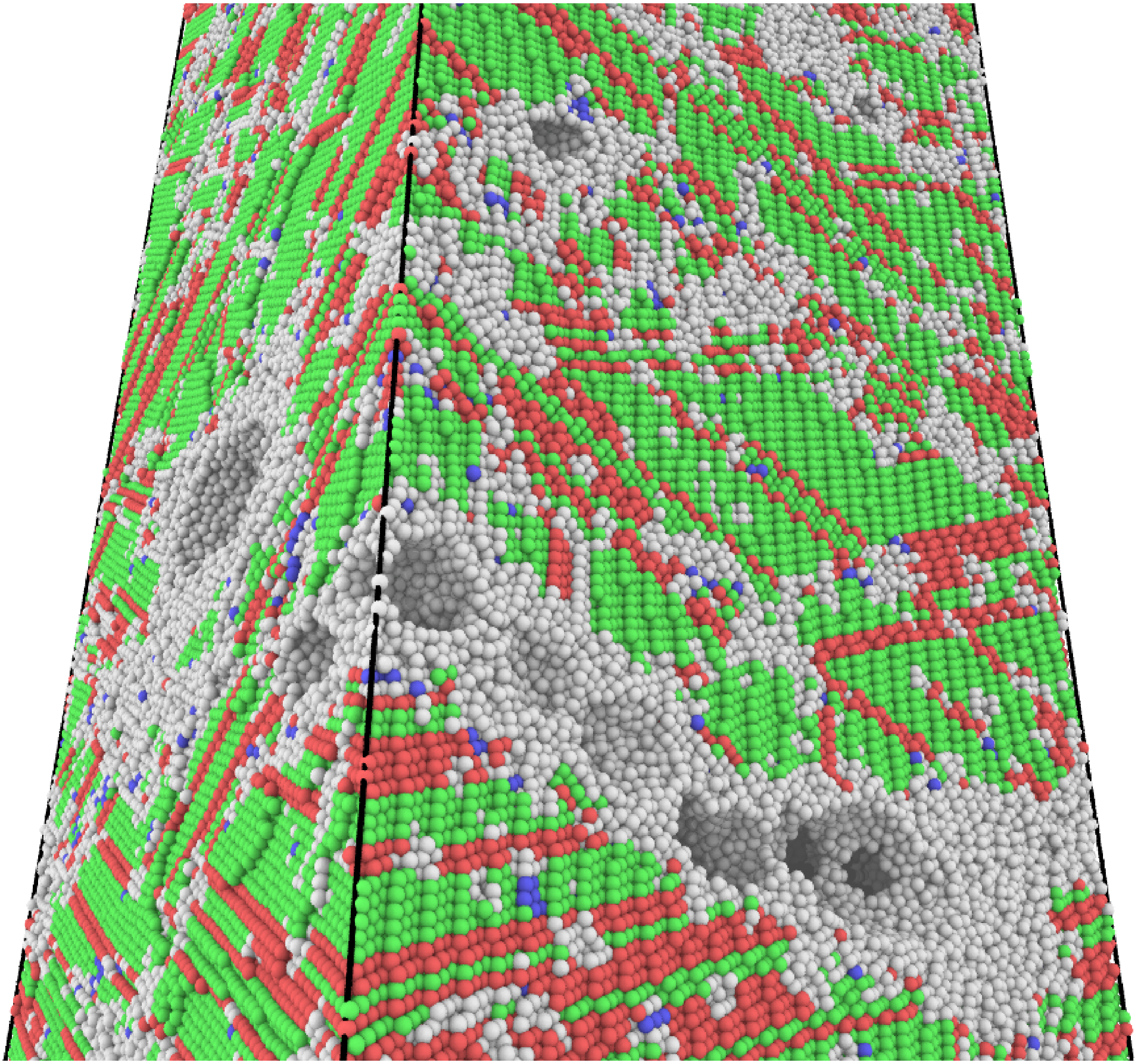
Dr. Michael Shaw Titus
Visiting researcher

Ph.D. in Materials, University of California, United States

Associate Professor of Materials Engineering, School of Materials Engineering, Purdue University, United States



Cubism's Favourite Material. IMDEA Materials Imaging Contest 2024. Materials Characterisation Category.
Taken by: Dr. María de Nicolás Morillas, Diego Iriarte Hernández and Adrián Cotobal Gómez.



MEA Spall. IMDEA Materials Imaging Contest 2024. Winner: Simulation Category.
Taken by: Dr. Carlos Ruestes.

annex

1. R&D projects and contracts

1.1. European R&D Projects (European Commission)

Title/Acronym: AI-powered characterisation and modelling for green steel technology/ AID4GREENEST
Partners: IMDEA Materials Institute (coordinator), Ghent University, University of Oulu, University of Liège, Fraunhofer Institute, Ocas NV, Spanish Association for Standardisation-UNE, ePotentia and EurA AG
Period: 2023 - 2026
Funding Institution/Programme: European Commission/Horizon Europe Programme – Cluster 4
Principal Investigator: Dr. I. Sabirov

Title/Acronym: Digital laser production: digital twins of laser processing for multi-capability manufacturing of complex components and certification/DILAPRO
Partners: Danish Technological Institute (coordinator), IMDEA Materials Institute, Centre de Recherches Métallurgiques ASBL, Dublin City University, Technical University of Denmark, European Federation for Welding, Joining and Cutting, Fieldmade AS, Prima Additive SRL, Welltec AS, Pepite SA and Amiquam SA
Period: 2023 - 2026
Funding Institution/Programme: European Commission/Horizon Europe Programme – Cluster 4
Principal Investigator: Dr. I. Sabirov

Title/Acronym: 3D printing of pyrolytic and graphitic carbon/3D-Carbon
Partners: IMDEA Materials Institute
Period: 2023 - 2025
Funding Institution/Programme: European Commission/Horizon Europe Programme – Marie Skłodowska-Curie Actions – PF
Principal Investigator: Dr. M. Islam; Supervisor: Dr. D.Y. Wang

Title/Acronym: Hierarchical porous PEEK via combined physical foaming and additive manufacturing: bringing circularity to advanced engineering materials/HIPPEEK
Partners: IMDEA Materials Institute
Period: 2023 - 2025
Funding Institution/Programme: European Commission/Horizon Europe Programme – Marie Skłodowska-Curie Actions – PF
Principal Investigator: Dr. L. Doyle; Supervisor: Dr. C. González

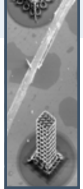
Title/Acronym: Hydrogen storage and carriage as opportunity for renewable energy transition/HYSCORE
Partners: RWTH Aachen University (Coordinator), IMDEA Materials Institute, Ghent University, Aalto University, Corinth Pipeworks SA, OTH Regensburg, University of Thessaly and Serimax
Period: 2023 - 2026
Funding Institution/Programme: European Commission/Research Fund for Coal and Steel (RFCS)
Principal Investigator: Dr. I. Sabirov

Title/Acronym: Toward desirable metal organic framework mixed matrix materials through machine learning-guided interface design/M4MID
Partners: IMDEA Materials Institute
Period: 2023 - 2025
Funding Institution/Programme: European Commission/Horizon Europe Programme – Marie Skłodowska-Curie Actions – PF
Principal Investigator: Dr. P. Vo; Supervisor: Dr. M. Haranczyk

Title/Acronym: Smart electrolyte with inherent flame-retardancy for next generation fire-safe lithium-ion batteries/SMARTBATT
Partners: IMDEA Materials Institute
Period: 2023 - 2025
Funding Institution/Programme: European Commission/Horizon Europe Programme – Marie Skłodowska-Curie Actions – PF
Principal Investigator: Dr. A. Ghosh; Supervisor: Dr. D.Y. Wang

Title/Acronym: Electrode assembly from floating nanowires for sustainable next generation batteries/ELECTROFLOAT
Partners: IMDEA Materials Institute
Period: 2023 - 2024
Funding Institution/Programme: European Commission/Horizon 2020 Programme – ERC Proof of Concept
Principal Investigator: Dr. J.J. Vilatela

Title/Acronym: Dynamic coil-shaped polylactic acid-reinforced extracellular matrix-derived scaffold with oriented pores for articular cartilage tissue engineering/RECOIL3D
Partners: IMDEA Materials Institute
Period: 2023 - 2025
Funding Institution/Programme: European Commission/Horizon Europe Programme – Marie Skłodowska-Curie Actions – PF
Principal Investigator: Dr. P.J. Díaz Payno; Supervisor: Dr. J. Patterson



Title/Acronym: Metals against Leishmaniasis/METALEISH
Partners: IMDEA Materials Institute
Period: 2023 - 2025
Funding Institution/Programme: European Commission/Horizon Europe Programme – Marie Skłodowska-Curie Actions – PF
Principal Investigator: Dr. B. Gomes; Supervisor: Prof. J. LLorca

Title/Acronym: High-throughput discovery of catalysts for the Hydrogen economy through machine learning/HIGHHYDROGENML
Partners: IMDEA Materials Institute
Period: 2023 - 2025
Funding Institution/Programme: European Commission/Horizon Europe Programme – Marie Skłodowska-Curie Actions – PF
Principal Investigator: Dr. V. Vassilev; Supervisor: Prof. J. LLorca

Title/Acronym: Multiscale-multiphysics modelling of Ti alloy medical implants based on additive manufacturing technology/M3TIAM
Partners: IMDEA Materials Institute
Period: 2023 - 2025
Funding Institution/Programme: European Commission/Horizon Europe Programme – Marie Skłodowska-Curie Actions – PF
Principal Investigator: Dr. A. Boccardo; Supervisor: Dr. D. Tourret

Title/Acronym: Hybrid-electric regional architecture/HERA
Partners: Leonardo SpA, Airbus Defence and Space SA, Italian Aerospace Research Center, German Aerospace Center (DLR), Dream Innovation SRL, EASN, Fraunhofer Institute, GE AVIO SRL, HIT09 SRL, Aertec Solutions SL, Collins Aerospace, Honeywell International SRO, Israel Aerospace Industries LTD, National Institute for Aerospace Research “Elie Carafoli” (INCAS), MTU Aero Engines AG, Netherlands Aerospace Centre – (NLR, ONETA The French Aerospace Lab, PIAGGIO Aero Industries SPA, Politecnico di Torino, Rolls-Royce Deutschland LTD, Siemens Industry Software NV, Technical University of Delft, Università degli Studi di Napoli Federico II, Technical University of Madrid, Patras University, SAFRAN SA, Warsaw Institute of Aviation, INEGI, Almadesign, Aernnova Aerospace SA, ISQ, THALES AVS France SAS, Protom Group SpA, Aeromechs SRL, Unified International, ISAE-SUPAERO and Politecnico di Milano
Period: 2023 - 2026
Funding Institution/Programme: European Commission/Horizon Europe Programme – Clean Aviation
Principal Investigator: Prof. I. Romero

Title/Acronym: Universal processing route for high-performance nanostructured yarns/ UNIYARNS
Partners: IMDEA Materials Institute
Period: 2022 - 2027
Funding Institution/Programme: European Commission/Horizon Europe Programme – ERC Consolidator Grant
Principal Investigator: Dr. J.J. Vilatela

Title/Acronym: Mechanics of Nanoporous W under irradiation/MENAWIR
Partners: IMDEA Materials Institute
Period: 2022 - 2024
Funding Institution/Programme: European Commission/Horizon Europe Programme – Marie Skłodowska-Curie Actions – PF
Principal Investigator: Dr. C. Ruestes; Supervisor: Prof. J. Segurado

Title/Acronym: Resource-efficient steel construction using additive manufacturing/ CONSTRUCTADD
Partners: Politecnico di Milano (Coordinator), IMDEA Materials Institute, RWTH Aachen University, University of Pisa, Prima Industrie, Vallourec, Mimete, Cimolai, ArcelorMittal, BLM and DNV Netherlands
Period: 2022 - 2026
Funding Institution/Programme: European Commission/Research Fund for Coal and Steel (RFCS)
Principal Investigator: Dr. I. Sabirov

Title/Acronym: Smart 4D biodegradable metallic shape-shifting implants for dynamic tissue restoration/BIOMET4D
Partners: IMDEA Materials Institute (Coordinator), Technical University of Madrid, Aerosint, Meotec GmbH, University Hospital Cologne, National University of Ireland Galway and Gregorio Marañón Hospital Biomedical Research Foundation
Period: 2022 - 2026
Funding Institution/Programme: European Commission/Horizon Europe Programme – EIC Pathfinder Open
Principal Investigator: Dr. J. Patterson

Title/Acronym: Additive manufacturing of amorphous metals for soft magnetics/ AM2SOFTMAG
Partners: Saarland University, IMDEA Materials Institute, Italian National Institute of Metrology Research and Heraeus
Period: 2022 - 2026

Funding Institution/Programme: European Commission/Horizon Europe Programme – EIC Pathfinder Open
Principal Investigator: Dr. M.T. Pérez-Prado

Title/Acronym: Study and understanding of gas phase entangled reactions for yarn assembly via robust nanomaterial aerogelation/SUPERYARN
Partners: IMDEA Materials Institute
Period: 2022 - 2023
Funding Institution/Programme: European Commission/Horizon 2020 Programme – Marie Skłodowska-Curie Actions – IF
Principal Investigator: Dr. M. Vázquez; Supervisor: Dr. J.J. Vilatela

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Title/Acronym: Development of gamma prime strengthened CoNi superalloy for advanced sustainable manufacturing technologies/CNSTECH
Partners: IMDEA Materials Institute
Period: 2021 – 2023
Funding Institution/Programme: European Commission/Horizon 2020 Programme – Marie Skłodowska-Curie Actions – IF
Principal Investigator: Dr. A. Mohammadzadeh; Supervisor: Prof. J.M. Torralba

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Title/Acronym: Digital method for improved manufacturing of next-generation multifunctional airframe parts/DOMMINIO
Partners: AIMEN (Coordinator), IMDEA Materials Institute, Tortech Nano Fibers, IRES, National Technical University of Athens, Aciturri Engineering, IPC, BAE Systems, EASN, ESI Group, Arts et Métiers, INCAS and Dasel
Period: 2021 - 2024
Funding Institution/Programme: European Commission/Horizon 2020 Programme - Societal Challenges - Smart, Green and Integrated Transport
Principal Investigators: Prof. C. González and Dr. J.J. Vilatela

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Title/Acronym: European database for multiscale modelling of radiation damage/ENTENTE
Partners: CIEMAT (Coordinator), IMDEA Materials Institute, Bay Zoltan Nonprofit Ltd. for Applied Research (BZN), French Alternative Energies and Atomic Energy Commission (CEA), CNRS, Electricité de France (EDF), Framatome, Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Institut de Radioprotection et de Surete Nucleaire (IRSN), KTH Royal Institute of Technology in Stockholm, University of Cantabria, National Nuclear Laboratory Limited (NNL), Phimeca, SCK CEN, The University of Warwick, The University of Bristol, The Materials Performance Centre of the University of Manchester, University of Alicante, Universitat Politècnica de Catalunya – BarcelonaTech, Technical University of Madrid, Culham Centre for Fusion Energy, UJV Rez, VTT Technical Research Centre of Finland, State Enterprise State Scientific and Technical Center for

nuclear and radiation safety (SSTC), Chalmers University of Technology and Central Research Institute of Electric Power Industry (CRIEPI)
Period: 2020 - 2024
Funding Institution/Programme: European Commission/EURATOM
Principal Investigators: Drs. J.M. Molina-Aldareguia and M. Monclús

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Title/Acronym: Design of lightweight steels for industrial applications/DELIGHTED
Partners: IMDEA Materials Institute (Coordinator), Ghent University, Ocas NV, Politecnico di Milano and Max Planck Institute for Iron Research
Period: 2020 - 2023
Funding Institution/Programme: European Commission/Research Fund for Coal and Steel (RFCS)
Principal Investigator: Dr. I. Sabirov

Title/Acronym: Multi-scale optimisation for additive manufacturing of fatigue resistant shock-absorbing metamaterials/MOAMMM
Partners: University of Liège (Coordinator), IMDEA Materials Institute, KU Leuven, Johannes Kepler University Linz and CIRP
Period: 2020 - 2024
Funding Institution/Programme: European Commission/Horizon 2020 Programme – FET Open
Principal Investigators: Prof. J. Segurado and Dr. M. Monclús

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Title/Acronym: European Training Network to develop improved bioresorbable materials for orthopaedic and vascular implant applications/BIOIMPLANT ITN
Partners: National University of Ireland Galway (Coordinator), IMDEA Materials Institute, The Queens University of Belfast, RWTH Aachen, Boston Scientific, 3D Technology, Vascular Flow Technologies, Meotec GmbH and ITA Textil Technologie Transfer
Period: 2018 - 2023
Funding Institution/Programme: European Commission/Horizon 2020 Programme – Marie Skłodowska-Curie Actions - ITN
Principal Investigator: Prof. J. LLorca

1.2. Other International R&D Projects

Title/Acronym: Metamaterial fibres of intercalated bundles/METACALATED
Partners: IMDEA Materials Institute
Period: 2023 - 2026
Funding Institution/Programme: US Air Force Office of Scientific Research (AFOSR)
Principal Investigators: Drs. J.J. Vilatela and J. Christensen

Title/Acronym: Materials libraries in the bulk form for accelerated material discovery and development/MALIBU
Partners: IMDEA Materials Institute
Period: 2023
Funding Institution/Programme: US Army Research Office
Principal Investigator: Dr. S. Milenkovic

Title/Acronym: Multiscale virtual testing capability for composites/MUVITCAPCOM
Partners: IMDEA Materials Institute
Period: 2019 – 2023
Funding Institution/Programme: US Air Force Office of Scientific Research (AFOSR)
Principal Investigator: Prof. C. González

1.3. National R&D Projects

Title/Acronym: New generation of parts for sustainable mass production by 3D-Metal Jet with improved quality and reliable manufacturing process/3D-METJET
Partners: HP Printing and Computing Solutions (Coordinator), IMDEA Materials Institute and AMES
Period: 2023 - 2026
Funding Institution/Programme: Spanish Ministry of Science and Innovation/Public-Private Collaboration
Principal Investigator: Dr. F. Sket and Prof. J.M. Torralba

Title/Acronym: 4D Printing of Smart Materials for Sustainable Mobility/PRIORITY
Partners: IMDEA Materials Institute
Period: 2023
Funding Institution/Programme: Spanish Ministry of Science and Innovation/Knowledge Generation
Principal Investigators: Drs. S. Milenkovic and M.T. Pérez-Prado

Title/Acronym: The introduction of geometrical gradients in Zn based scaffolds by powder bed laser fusion/BIOFUN3D
Partners: Technical University of Madrid and IMDEA Materials Institute
Period: 2023 - 2026
Funding Institution/Programme: Spanish Ministry of Science and Innovation/Knowledge Generation
Principal Investigator: Dr. F. Sket

Title/Acronym: No dissipation in sonic flatlands/NODISONICS
Partners: IMDEA Materials Institute
Period: 2023 - 2025

Funding Institution/Programme: Spanish Ministry of Science and Innovation/Research consolidation
Principal Investigator: Dr. J. Christensen

Title/Acronym: European Project Office IMDEA Materials Institute 2023-2024/OPE - IMDEA Materials 2023-2024
Partners: IMDEA Materials Institute
Period: 2023 - 2024
Funding Institution/Programme: Spanish Ministry of Science and Innovation/ Preparation and management of European projects
Coordinator: M.A. Rodiel

Title/Acronym: Advanced materials and nanomaterials Spanish technological platform 2023-2024 /MATERPLAT 2023-2024
Partners: IMDEA Materials Institute (Technical Secretariat)
Period: 2023 – 2024
Funding Institution/Programme: Spanish Ministry of Science and Innovation/ Technological Platforms
Coordinator: M.A. Rodiel

Title/Acronym: Implantable device for brain tumour treatment using electrical fields/ DITTCE
Partners: Technical University of Madrid (Coordinator), IMDEA Materials Institute, Institute of Health Carlos III, Niño Jesús Hospital Biomedical Research Foundation, La Princesa University Hospital Biomedical Research Foundation and Insyte
Period: 2022 - 2025
Funding Institution/Programme: Spanish Ministry of Science and Innovation/Strategic Lines
Principal Investigator: Dr. M. Echeverry-Rendón

Title/Acronym: Nanostructure network electrodes to realise the high energy density 3b/4a battery/MAT4BAT
Partners: IMDEA Materials Institute
Period: 2022 - 2024
Funding Institution/Programme: Spanish Ministry of Science and Innovation/Green and Digital Transition
Principal Investigator: Dr. J.J. Vilatela

Title/Acronym: Biobased flame-retardant system for sustainable polymers: molecule design, digital synthesis, digital analysis, data-driven approach/DIGIBIOFOAM
Partners: IMDEA Materials Institute
Period: 2022 - 2024

Funding Institution/Programme: Spanish Ministry of Science and Innovation/Green and Digital Transition
Principal Investigator: Drs. D.Y. Wang and M. Haranczyk

Title/Acronym: Consolidation and study of behavior under hydrogen/NATURE
Partners: Carlos III University of Madrid (Coordinator), IMDEA Materials Institute and Technical University of Madrid
Period: 2022 - 2024
Funding Institution/Programme: Spanish Ministry of Science and Innovation/Green and Digital Transition
Principal Investigator: Drs. S. Milenkovic and D. Tourret

Title/Acronym: High-throughput strategies for the discovery of new catalysts for the hydrogen economy through elastic strain engineering/CATBYESE
Partners: IMDEA Materials Institute
Period: 2022 - 2024
Funding Institution/Programme: Spanish Ministry of Science and Innovation/Green and Digital Transition
Principal Investigator: Prof. J. LLorca

Title/Acronym: Porous metal genomics for tailoring mechanical properties of light-weight 3D-printed architectures/PORMETALOMICS
Partners: IMDEA Materials Institute (Coordinator), Institute of Mathematics of the Polish Academy of Sciences and Technion
Period: 2022 - 2025
Funding Institution/Programme: Spanish Ministry of Science and Innovation - European Commission/M-ERA.Net
Principal Investigator: Dr. M. Haranczyk

Title/Acronym: Synthesis and assembly of long metal oxide nanowires for energy/SALMONE
Partners: IMDEA Materials Institute
Period: 2022 - 2026
Funding Institution/Programme: Spanish Ministry of Science and Innovation/Knowledge Generation
Principal Investigator: Drs. J.J. Vilatela, D. Tourret and A. Pendashteh

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Title/Acronym: Design of master alloys for sintered steels/DAMAS
Partners: AMES (Coordinator), IMDEA Materials Institute and Carlos III University of Madrid
Period: 2022 - 2025
Funding Institution/Programme: Spanish Ministry of Science and Innovation/Public-Private Collaboration
Principal Investigator: Dr. D. Tourret

Title/Acronym: Micro/macro-modeling of solidification in additive manufacturing/ MIMMOSA
Partners: IMDEA Materials Institute
Period: 2022 - 2024
Funding Institution/Programme: Spanish Ministry of Science and Innovation/ International joint programming actions (seal of excellence European Commission/ Horizon 2020 Programme – Marie Skłodowska-Curie Actions – IF)
Principal Investigator: Dr. R. Tavakoli; Supervisor: Dr. D. Tourret

Title/Acronym: Biobased, self-reinforced and flame-resistant all-solid-state polymer electrolytes for new generation fire-safe battery/BIOFIRESAFE
Partners: IMDEA Materials Institute
Period: 2021 - 2024
Funding Institution/Programme: Spanish Ministry of Science and Innovation/Research Challenges
Principal Investigator: Dr. D.Y. Wang

Title/Acronym: X-ray microtomograph with capacity for in situ testing and laboratory-based diffraction contrast tomography/LAB-BASED DCT
Partners: IMDEA Materials Institute
Period: 2021 - 2023
Funding Institution/Programme: Spanish Ministry of Science and Innovation/Scientific and Technical Infrastructures and Equipment
Principal Investigator: Dr. F. Sket

Title/Acronym: Advanced materials and nanomaterials Spanish technological platform 2021-2022 /MATERPLAT 2021-2022
Partners: IMDEA Materials Institute (Technical Secretariat)
Period: 2021 – 2023
Funding Institution/Programme: Spanish Ministry of Science and Innovation/ Technological Platforms
Coordinator: M.A. Rodiel

Title/Acronym: Microstructure-topology-mechanical properties relationship of Mg-based scaffolds fabricated by 3D printing for biomedical applications/TOPOMAG-3D
Partners: IMDEA Materials Institute
Period: 2020 - 2023
Funding Institution/Programme: Spanish Ministry of Science and Innovation/Research Challenges
Principal Investigators: Drs. J.M. Molina-Aldareguia and F. Sket

Title/Acronym: Multiscale design of Mg alloys with high strength and ductility for sustainable transport/ENLIGHTED
Partners: IMDEA Materials Institute
Period: 2020 - 2023
Funding Institution/Programme: Spanish Ministry of Science and Innovation/Research Challenges
Principal Investigators: Drs. M.T. Pérez-Prado and S. Milenkovic

Title/Acronym: Development of multi-material and multifunctional 3D parts through additive manufacturing assisted by intelligent material and process design/MULTI-FAM
Partners: Arcelor Mittal (Coordinator), IMDEA Materials Institute and AIMEN
Period: 2020 - 2023
Funding Institution/Programme: Spanish Ministry of Science and Innovation/ Collaboration Challenges
Principal Investigators: Drs. I. Sabirov and D. Tourret

Title/Acronym: Excellence Unit María de Maeztu/MdM 2018
Partners: IMDEA Materials Institute
Period: 2019 – 2024
Funding Institution/Programme: Spanish Ministry of Science and Innovation/Severo Ochoa - María de Maeztu
Principal Investigator: Prof. J. LLorca

1.4. Regional R&D Projects

Title/Acronym: Development of biomaterials for processable transparent aligners by thermoforming and 3D printing/3DALIGNER
Partners: Secret Aligner SL and IMDEA Materials Institute
Period: 2023 - 2026
Funding Institution/Programme: Regional Government of Madrid/Industrial Doctorate
Principal Investigator: Dr. J.P. Fernández; Doctoral Researcher: J. Delgado

Title/Acronym: Bioengineering of skeletal muscle satellite cells as a new strategy for cardiomyocyte differentiation and cardiac regeneration/CARDIOBOOST
Partners: CNIC (Coordinator), IMDEA Materials Institute, Complutense University of Madrid, IIBM-CSIC and CBM Severo Ochoa
Period: 2023 - 2026
Funding Institution/Programme: Regional Government of Madrid/Biomedicine
Principal Investigator: Dr. J. Patterson

Title/Acronym: Design and scaling of new hard coatings deposited by HiPIMS for high-speed milling/ HIPDUR
Partners: NANO4ENERGY and IMDEA Materials Institute
Period: 2022 - 2025
Funding Institution/Programme: Regional Government of Madrid/Industrial Doctorate
Principal Investigator and Supervisor: Drs. J.M. Molina-Aldareguia and M. Monclús; Doctoral Researcher: A García

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Title/Acronym: Metamaterial printing using shape memory alloys and functional gradients for a new generation of smart implants/i-MPLANTS-CM
Partners: Technical University of Madrid and IMDEA Materials Institute
Period: 2021 - 2024
Funding Institution/Programme: Regional Government of Madrid/Synergy projects
Principal Investigator: Dr. J.M. Molina-Aldareguia

Title/Acronym: Improvement of the 3D Metal Jet Part quality through print mode development supported by HRXCT characterization of the printed parts
Partners: HP Printing and Computing Solutions and IMDEA Materials Institute
Period: 2020 - 2023
Funding Institution/Programme: Regional Government of Madrid/Industrial Doctorate
Principal Investigator and Supervisor: Drs. M.T. Pérez-Prado and F. Sket; Doctoral Researcher: S. Bafaluy

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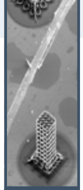
Title/Acronym: Advanced manufacturing technologies for the new generation of composite materials/TEMACON
Partners: Airbus Operations (Coordinator), IMDEA Materials Institute, Zinkcloud, Obuu Tech and FIDAMC
Period: 2019 – 2023
Funding Institution/Programme: Regional Government of Madrid/Open Innovation Hubs
Principal Investigator: Prof. C. González

Title/Acronym: Smart manufacturing of advanced materials for transport, energy and health applications/MAT4.0-CM
Partners: IMDEA Materials Institute (Coordinator), National Centre of Metallurgical Research (CENIM-CSIC), Carlos III University of Madrid, Technical University of Madrid, FIDAMC and Hospital La Paz Institute for Health Research
Period: 2019 – 2023
Funding Institution/Programme: Regional Government of Madrid/Technologies
Principal Investigator: Dr. J.M. Molina-Aldareguia



Title/Acronym: New generation of multifunctional materials for artificial photosynthesis/ FotoArt-CM
Partners: IMDEA Energy Institute (Coordinator), IMDEA Materials Institute, Centre of Astrobiology (CSIC-INTA), IMDEA Nanoscience Institute, Autonomous University of Madrid and National Centre of Metallurgical Research (CENIM-CSIC)
Period: 2019 – 2023
Funding Institution/Programme: Regional Government of Madrid/Technologies
Principal Investigator: Dr. J.J. Vilatela

Title/Acronym: Two-dimensional disruptive materials for the new technological transformation\MAD2D
Partners: Complutense University of Madrid (Coordinator), IMDEA Materials Institute, IMDEA Energy Institute, Autonomus University of Madrid and Technical University of Madrid
Period: 2022 - 2025
Funding Institution/Programme: Regional Government of Madrid - Spanish Ministry of Science and Innovation/Complementary R&D&I plans-REACT EU resources
Principal Investigators: Prof. J. LLorca and Drs. J.J. Vilatela and M. Haranczyk

1.5. Privately Funded R&D Projects

Title/Acronym: Industrial technologies for sustainable and competitive aeronautics/ TIANA
Company: Acciona Construccion SA
Period: 2023 - 2025
Principal Investigator: Dr. J.P. Fernández

Title/Acronym: Multi-material additive manufacturing of multi-functional moulds for out-of-autoclave infusion processes/FAUNO
Company: IDAERO Solutions SL
Period: 2023 - 2025
Principal Investigator: Prof. I. Romero

Title/Acronym: Toughness, damage tolerance and recyclability of thermoplastic CNT fabric composites/ CHUB-COMP
Company: RICE University
Period: 2023 - 2024
Principal Investigator: Dr. J.J. Vilatela

Title/Acronym: Circular economy in the thermoset composites industry/EOCENE
Company: Acciona Construcción SA

Period: 2023 - 2024
Principal Investigator: Dr. J.P. Fernández

Title/Acronym: Research into intelligent electrical control and actuation systems through the development of health monitoring technologies for sustainable aviation/I-SISTEHMA
Company: Compañía Española de Sistemas Aeronáuticos SA – Heroux Devtek
Period: 2023 - 2024
Principal Investigator: Dr. J.J. Vilatela

Title/Acronym: Development of biomaterials for processable transparent aligners by thermoforming and 3D printing/3DALIGNER
Company: Secret Aligner SL
Period: 2023 - 2025
Principal Investigator: Dr. J.P. Fernández

Title/Acronym: Development of biomedical device to support venous lymphatic return/RETOVEN
Company: ZOETECH SL
Period: 2023 - 2024
Principal Investigator: Dr. D.Y. Wang

Title/Acronym: Smart, adaptive and sustainable technologies for agile and zero-defect manufacturing of composite materials by resin transfer process/SM@RTM-CITD
Company: CITD, Engineering & Technologies, S.L.
Period: 2023 - 2024
Principal Investigators: Prof. C. González

Title/Acronym: IMDEA Materials-ITP Aero collaboration in the development of advanced materials for aeronautical applications/IMDEA-ITP
Company: ITP Aero
Period: 2023
Principal Investigators: Drs. J.M. Molina-Aldareguia, M.T. Pérez-Prado, F. Sket, and D. Tourret and Prof. J. Segurado.

Title/Acronym: Smart, adaptive and sustainable technologies for agile and zero-defect manufacturing of composite materials by resin transfer process/SM@RTM-IDAERO
Company: IDAERO SOLUTIONS SL
Period: 2022 - 2024
Principal Investigators: Prof. C. González

Title/Acronym: Design and scaling of new hard coatings deposited by HiPIMS for high-speed milling/ HIPDUR
Company: NANO4ENERGY
Period: 2022 - 2025
Principal Investigator: Drs. J.M. Molina-Aldareguia and M. Monclús

Title/Acronym: Carbon nanotube fabrics for displacement of metallic current conductors in next generation Li-ion batteries/NANOCARBAT2
Company: RICE University
Period: 2022 - 2023
Principal Investigator: Dr. J.J. Vilatela

Title/Acronym: Computed tomography inspection/XCTVSUS
Company: Airbus Operations
Period: 2022-2023
Principal Investigator: Dr. F. Sket

Title/Acronym: Evaluating the potential of high-entropy alloys elaborated by powder metallurgy for horology applications/HEAH
Company: Rolex
Period: 2022-2023
Principal Investigator: Prof. J.M. Torralba

Title/Acronym: Microstructural and mechanical characterization of hard coatings/ MICROATING
Company: NANO4ENERGY
Period: 2022-2023
Principal Investigator: Dr. J.M. Molina-Aldareguia

Title/Acronym: Advice for Shanghai Research Institute of Chemical Technology/ CONSULT
Company: Shanghai Research Institute of Chemical Technology
Period: 2022-2024
Principal Investigator: Dr. D.Y. Wang

Title/Acronym: Optimisation of the processing route of polyurethane-coated composite material/NEOTAIL
Company: 3M España
Period: 2021 - 2024
Principal Investigator: Prof. C. González

Title/Acronym: Evaluation of damage made by ballast impact in composite materials/ BINOMIAL
Company: Patentes TALGO
Period: 2019-2023
Principal Investigator: Prof. C. González

2. Fellowships

2.1. International Fellowships

Programme: China Scholarship Council fellowships
Project: Functional properties of polymeric fabrics
Period: 2019-2024
Funding Institution: China Scholarship Council
X. Li

Programme: China Scholarship Council fellowships
Project: Fire behaviours of composite materials
Period: 2020-2024
Funding Institution: China Scholarship Council
X. Ao

Programme: China Scholarship Council fellowships
Project: New generation biodegradable polymers in tissue engineering
Period: 2021-2025
Funding Institution: China Scholarship Council
Y. Liu

Programme: China Scholarship Council fellowships
Project: New generation fire retardant materials for Lithium-ion battery
Period: 2021-2025
Funding Institution: China Scholarship Council
M. Zhang

Programme: China Scholarship Council fellowships
Project: Marine-derived chitosan-based thermosensitive hydrogels and their applications in anti-ageing
Period: 2021-2025
Funding Institution: China Scholarship Council
S. Du

Programme: China Scholarship Council fellowships
Project: New generation environment-friendly halogen-free flame retardant with combination of N-substituted alkoxy hindered amines
Period: 2021-2025
Funding Institution: China Scholarship Council
W. Ye

2.2. National Fellowships

Programme: Ramón y Cajal
Period: 2020-2025
Funding Institution: Spanish Ministry of Science, Innovation and Universities
Dr. F. Sket

Programme: Ramón y Cajal
Period: 2021-2026
Funding Institution: Spanish Ministry of Science and Innovation
Dr. D. Tourret

Programme: Juan de la Cierva
Period: 2023-2024
Funding Institution: Spanish Ministry of Science and Innovation
Dr. P.J. Navarrete Segado

Programme: Training University Lecturers (FPU)
Period: 2020-2024
Funding Institution: Spanish Ministry of Universities
C. Martínez Alonso

Programme: Predoctoral Fellowships
Period: 2020-2024
Funding Institution: Spanish Ministry of Science and Innovation
E. Kazemi

Programme: Predoctoral Fellowships
Period: 2020-2024
Funding Institution: Spanish Ministry of Science and Innovation
O. Contreras

Programme: Predoctoral Fellowships
Period: 2021-2025
Funding Institution: Spanish Ministry of Science and Innovation
D. Martín

Programme: Predoctoral Fellowships
Period: 2021-2025
Funding Institution: Spanish Ministry of Science and Innovation
I. Rodríguez

Programme: Predoctoral Fellowships
Period: 2021-2025
Funding Institution: Spanish Ministry of Science and Innovation
J. García

Programme: Predoctoral Fellowships
Period: 2021-2025
Funding Institution: Spanish Ministry of Science and Innovation
M. Castillón

Programme: Grants for predoctoral contracts for the training of PhD candidates
Period: 2022 - 2026
Funding Institute: Spanish Ministry of Science and Innovation
J. Redondo

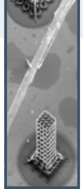
Programme: Grants for predoctoral contracts for the training of PhD candidates
Period: 2022 - 2026
Funding Institute: Spanish Ministry of Science and Innovation
B. Ozdemir

Programme: Grants for predoctoral contracts for the training of PhD candidates
Period: 2023 - 2027
Funding Institute: Spanish Ministry of Science and Innovation
A. Pascual

2.3. Regional Fellowships

Programme: Youth Employment Programme/Research assistants and laboratory technicians
Period: 2021-2023
Funding Institution: Madrid Regional Government
G. Domínguez

Programme: Youth Employment Programme/Research assistants and laboratory technicians
Period: 2021-2023
Funding Institution: Madrid Regional Government
J. Espinoza



Programme: Youth Employment Programme
Period: 2022 - 2024
Funding Institute: Madrid Regional Government
A. Vicente

Programme: Talent Attraction Programme – Modality 1
Period: 2022 - 2023
Funding Institute: Madrid Regional Government
Dr. A. Ma

Programme: PIPF
Period: 2023 - 2027
Funding Institute: Madrid Regional Government
B. Limones

Programme: PIPF
Period: 2023 - 2027
Funding Institute: Madrid Regional Government
M. Hernández

Programme: PIPF
Period: 2023 - 2027
Funding Institute: Madrid Regional Government
J. León

Programme: PIPF
Period: 2023 - 2027
Funding Institute: Madrid Regional Government
G. Ortíz

Programme: PIPF
Period: 2024 - 2027
Funding Institute: Madrid Regional Government
N. Mollaei

3. Scientific results

3.1. Scientific Publications

1. Wan. K; Kernin. A; Ventura. L; Zeng. C; Wang. Y; Liu. Y; Vilatela. J.J; Lu. W; Bilotti. E; Zhang. H. *Toward Self-Powered Sensing and Thermal Energy Harvesting in High-Performance Composites via Self-Folded Carbon Nanotube Honeycomb Structures*. **ACS Applied Materials and Interfaces**. 15. 37. 44212-44223. 2023.
2. Revilla-Cuesta. A; Abajo-Cuadrado. I; Medrano. M; Salgado. M; Avella. M; Rodríguez. M.T; García-Calvo. J; Torroba. T. *Silica Nanoparticle/Fluorescent Dye Assembly Capable of Ultrasensitively Detecting Airborne Triacetone Triperoxide: Proof-of-Concept Detection of Improvised Explosive Devices in the Workroom*. **ACS Applied Materials and Interfaces**. 15. 26. 32024-32036. 2023.
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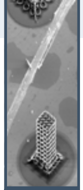

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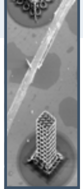

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3.2. Book chapters

1. M. Haranczyk and G. Lo Dico. *Big Data Science in Nanoporous Materials: Datasets and Descriptors* (Chapter 12). **AI-Guided Design and Property Prediction for Zeolites and Nanoporous Materials**. Edited by German Sastre, Frits Daeyaert. ISBN: 978-1-119-81975-2. March 2023

3.3. Patents

1. *Method of inspecting a volume of a composite component, apparatus for inspecting the composite component and a computer program,* IMDEA Materials Institute. Patent application number: ES2947809 A1 (May 2023). Inventors: F. Sket, J.I. Caballero, C. González, E. Menasalvas, C. Gonzalo. Patent granted.

3.4. International conferences. Invited and plenary talks

1. *Digital manufacturing and sustainability*, **Universidad Europea's Digital Business Week 2023,** Madrid, Spain. M.T. Pérez-Prado. March 2023.

2. *Atomic interactions of dislocations and twin boundaries with nanoscale precipitates in magnesium alloys,* **ACS Spring Meeting 2023**, Indianapolis, United States. D. Shi, C.M. Cepeda-Jiménez, M.T. Pérez-Prado. March 2023.
3. *PM Co base superalloys and PM HEAs: beyond Ni base superalloys for high temperature applications*, **TMS 2023, 152nd Annual Meeting and Exhibition**. San Diego, United States. J.M. Torralba, S.V. Kumaran, A. Mejía, A. Meza, A. Mohammadzadeh, D. Garbiec and M. Campos. March 2023.
4. *Multiscale modeling of Ni alloys laser powder-bed fusion*, **Japan Institute of Metals and Materials (JIM) Spring Meeting**, Tokyo, Japan. D. Tourret. March 2023.
5. *Understanding the interactions of dislocations and twins with grain boundaries in hexagonal metals,* **Symposium on Physics of Plasticity**, Cairo, Egypt. E. Nieto-Valeiras, M. Sarebanzadeh and J. LLorca. March 2023.
6. *3D printed composite bioabsorbable scaffolds for bone tissue engineering: mechanical, corrosion and biological performance,* **SAMPE Summit 32**, Paris, France. J. LLorca. April 2023.
7. *Past, present and future of Metallurgy: towards sustainable metallurgy*, **90th anniversary of the Danish Metallurgical Society**, Kolding, Denmark. J.M. Torralba. April 2023.
8. *Atomic scale engineering of dislocation slip and twinning in Mg alloys*, **MecaNano General Meeting**, Madrid, Spain. D. Shi, C. Wang, C.M. Cepeda-Jiménez and M.T. Pérez-Prado. April 2023.
9. *Effect of elastic strain engineering in the catalytic activity of transition metals and intermetallic compounds for the HER and the ORR*, **Euromech Colloquium on Modulation of Physico-Chemical Processes by Elastic Strain Engineering**, Besancon, France. C. Martínez-Alonso, V. Vassilev-Galindo, K. Winther, F. Abild-Pedersen, J. LLorca. May 2023.
10. *Tough as textiles, conductive as metals and processed like polymers*. **Carbon Hub Annual Technical Meeting**. Houston, United States. J.J. Vilatela. May 2023.
11. *Descriptors and structure-property models across families of porous materials and their applications*, **1st International Seminar on Modelling, Simulation and Machine Learning for the rapid development of porous materials**, Cologne, Germany. M. Haranczyk. May 2023.
12. *Formation of grain boundaries during polycrystalline solidification*, **Colloquium "La métallurgie, quel avenir!"**, Grenoble, France. D. Tourret. June 2023.
13. *Nanowire synthesis by FC-CVD and large-scale assembly as nanotextiles,* **23rd international conference on the Science and Applications of Nanotubes and Low-Dimensional Materials,** Arcachon, France. J.J. Vilatela. June 2023.
14. *Progress of flame-retardant technologies to electrolytes in lithium-ion battery: strategies and challenges*, **European meeting on fire retardant polymeric materials, FRPM23**, Zurich, Switzerland. D.Y. Wang. June 2023.
15. *Mg wires and 3D printed scaffolds for biomedical applications*, **Chinese Materials Conference 2022-2023**, Shenzhen, China. J. LLorca. July 2023.
16. *A multiscale modelling roadmap for virtual design of precipitation-hardened metallic alloys,* **Chinese Materials Conference 2022-2023**, Shenzhen, China. J. LLorca. July 2023.

17. *Sustainable flame-retardant strategies for polymers: State-of-the-art and future*, **14th National Conference on Fire Safety Materials**, Beijing, China. D.Y. Wang. July 2023.
18. *Non-Hermitian topological disclination defect in a valley-Hall sonic lattice*. **META 2023**, Paris, France. J. Iglesias, R. Pernas, P. Gao, M. Kadic, J. Christensen. July 2023.
19. *Topological Sonic defects*, **Progress in Electromagnetics Research Symposium (PIERS 2023)**, Prague, Czechia. J. Christensen. July 2023.
20. *Structed sonic tube with Carbon nanotube-like topological edge states,* **Progress in Electromagnetics Research Symposium (PIERS 2023)**, Prague, Czechia. Z. Zhang, P. Gao, J. Christensen. July 2023.
21. *Non-Hermitian topological whispering gallery*, **Progress in Electromagnetics Research Symposium (PIERS 2023)**, Prague, Czechia. B. Hu, Z. Zhang, J. Christensen. July 2023.
22. *Flame-retardant Technologies in Electric Vehicle: Opportunities and Challenges*, **The 6th National Flame Retardant Technology and Innovation Forum & 1st Sino-Spain Symposium for Flame-retardant Material Technology**, Shanghai, China. D.Y. Wang. August 2023.
23. *New Generation Fire-Safe Energy Storage Devices*, **55th assembly of the Advanced Materials Congress**, Stockholm, Sweden. D.Y. Wang. August 2023.
24. *Fire safety of electrolytes to lithium-ion battery and reinforced polymer composites*, **10th International Symposium on Engineering Plastics (EP'2023)**, Ningbo, China. D.Y. Wang. August 2023.
25. *Coupling microstructure and topology to produce robust Inconel718 lattices by additive manufacturing*, **FEMS-EUROMAT 2023**, Frankfurt, Germany. S. Banait, C. Liu, M. Campos, M.S. Pham, M.T. Pérez-Prado. September 2023.
26. *Altering twinning and dislocation slip by atomic scale engineering in magnesium alloys*, **Physical Metallurgy Gordon Research Conference**, Massachusetts, United States. X. Jin, C. Wang, I. Sabirov, S. Milenkovic, I. Beyerlein, M.T. Pérez-Prado. September 2023.
27. *Ultrafine Ti-Fe-based eutectics for additive manufacturing*. **E-MRS Fall 2023 meeting**. Warsaw, Poland. F. Sket, K. Bugelnig, J. Gussone, J. Haubrich, A.K. Pandey, P. Cloetens, U. Hecht, J.C. da Silva, M. Upadhyay, P.J. Withers, M. Easton, Y. Chen, A. Rack and G. Requena. September 2023.
28. *An FFT method for implicit dynamics in heterogeneous media: application to* polycrystals, **COMPLAS 202,** Barcelona, Spain. R. Sancoi, R. Lebensohn and J. Segurado. September 2023.
29. *Prediction of the impact behavior of composite plies from instrumented nano-impact tests*. **FEMS EUROMAT 23**, Frankfurt am Main, Germany. J.M. Molina-Aldareguia, M. Rueda, F. Gálvez, C. González and F. Sket. September 2023.
30. *4D Printing of metallic alloys: towards novel shape morphing of medical devices*, **Alloys for Additive Manufacturing Symposium 2023 (AAMS 2023)**, Madrid, Spain. J.M. Molina-Aldareguia. September 2023.
31. *Interactions of dislocations and twins with grain boundaries: unravelling the mechanisms of plastic deformation in polycrystals*, **XVII International Conference on Computational Plasticity COMPLAS 2023**, Madrid, Spain. J. LLorca. September 2023.

32. *Phase-field modeling of pitting and mechanically assisted corrosion of Mg alloys for biomedical applications*, **XVII International Conference on Computational Plasticity COMPLAS 2023,** Barcelona, Spain. S. Kovacevic, W. Ali, E. Martínez-Pañeda, J. LLorca. September 2023.
33. *Bayesian calibration of complex models. Application to elasto-plastic constitutive relations under high-strain rates and temperature*, **XVII International Conference on Computational Plasticity**. **Fundamentals and Applications. COMPLAS 2023**. Barcelona, Spain. Prof. I. Romero and Drs. J.L. de Pablos and I. Sabirov. September 2023.
34. *High-throughput strategies to discover catalysts based on first principles calculations, elastic strain engineering and machine learning*, **SEMTA-MECAMAT Colloquium**, Toledo, Spain. C. Martínez-Alonso, V. Vassilev-Galindo, J. LLorca. October 2023.
35. *Simulation of corrosion and mechanical degradation of bioabsorbable materials for biomedical applications*, **Computational Modelling of Complex Materials Across the Scales, CMCS2023, ECCOMAS**, Einhoven, The Netherlands. J. LLorca. October 2023.
36. *The use of SPS for sustainable development of high entropy alloys using pre-alloyed commodity powders*, **2nd Conference on FAST/SPS**, Warsaw, Poland. S.V. Kumaran, D. Garbiec and J.M. Torralba. October 2023.
37. *4D Printing of Metallic Alloys towards Novel Shape Morphing Medical Devices*. **7th International Congress on 3D Printing (Additive Manufacturing) Technologies and Digital Industry (3D-PTC2023)**, Istanbul, Türkiye. J.M. Molina-Aldareguia. October 2023.
38. *Topological Sonic Defects*, **Society of Engineering Science, 2023 SES Annual Technical Meeting**, Minnesota, United States. J. Christensen. October 2023.
39. *Phase-field insights into the selection of grain boundaries during polycrystalline solidification processes*, **3rd International Conference on Phase Field Simulation and Related Methods**, Hefei, China. D. Tourret. December 2023.
40. *Carbon Nanotube High-Performance Macromaterials: Progress in Assembly and Roadmap for Industrialisation*, **Indian Conference on Carbon Materials 2023**, Mumbai, India. J.J. Vilatela. December 2023.

3.5. Invited Seminars by IMDEA Materials Institute Researchers

1. *In quest of accurate modelling of complex potential-energy surfaces*, **IMDEA Materials Institute**, Madrid, Spain. V. Vassilev. January 2023.
2. *Swelling-Dependent Shape-Based Transformation of a Human Mesenchymal Stromal Cells-Laden 4D Bioprinted Construct for Cartilage Tissue Engineering*, **IMDEA Materials Institute**, Madrid, Spain. P.J. Díaz Payno. January 2023.
3. *From novice to ninja: Tools and techniques for a productive career in scientific computing*, **IMDEA Materials Institute**, Madrid, Spain. I. Romero. January 2023.
4. *Strategies for materials design from atomistic simulations*, **NOMATEN Center of Excellence**, **National Center for Nuclear Research**, Swierk, Poland. J. LLorca. February 2023.

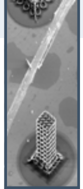
5. *3D printed multimaterial bioabsorbable scaffolds for bone tissue engineering: mechanical, corrosion and biological performance,* **Faculty of Materials Science and Engineering, Warsaw University of Technology**, Warsaw, Poland. J. LLorca. February 2023.
6. *Singularity theory for the design of thermoelastic metamaterials with shape memory*, **Institute for Computational Mechanics, Technical University of Munich**, Munich, Germany. I. Romero. March 2023.
7. *Additive manufacturing of energy-saving materials*, **Max-Planck Institute for Iron Research**, Düsseldorf, Germany. M.T. Pérez-Prado. March 2023.
8. *Microstructure selection in solidification of metallic alloys: Insights from multiscale modeling*, **University of Tokyo**, Tokyo, Japan. D. Tourret. March 2023.
9. *Microstructure selection in solidification of metallic alloys: Insights from multiscale modeling*, **Kyoto Institute of Technology**, Kyoto, Japan. D. Tourret. March 2023.
10. *Microstructure selection in solidification of metallic alloys: Insights from multiscale modeling*, **Kyoto University**, Kyoto, Japan. D. Tourret. March 2023.
11. *Microstructure selection in solidification of metallic alloys: Insights from multiscale modeling*, **Hokkaido University**, Sapporo, Japan. D. Tourret. March 2023.
12. *Multimaterial bioresorbable scaffolds manufactured by 3D printing for biomedical applications*, **POLYMAT, University of the Basque Country**, Donostia, Spain. J. LLorca. May 2023.
13. *Microstructure formation in solidification of metallic alloys*, **INSA Lyon** – **MATEIS**, Lyon, France. Dr. Tourret. June 2023.
14. *Past, present and future of metallurgy: toward sustainable metallurgy,* **IMDEA Materials Institute**, Madrid, Spain. J.M. Torralba. June 2023.
15. *Fire-safe Electrolytes to Lithium-ion Battery and some interesting fire-related topics*, **Beijing Institute of Technology**, Beijing, China. D.Y. Wang. July 2023.
16. *Nanoindentation at extreme conditions*, **MecaNano Summer School on Experimental Nano- and Micromechanics**, Rome, Italy. J.M. Molina-Aldareguia. July 2023.
17. *Assessment of deformation mechanisms in Mg alloys by means of advanced characterization techniques and machine learning*, **School of Materials Science and Engineering**, Shanghai, China. J. LLorca. July 2023.
18. *Multiscale modelling of metallic materials,* **State Key Laboratory of Metastable Materials Science and Technology, Yanshan University**, Qinhuangdao, China. J. LLorca. July 2023.
19. *High Temperature Materials*, **European Powder Metallurgy Association, Summer School**, Dresden, Germany. Prof. J.M. Torralba. 2023.
20. *Past, present and future of Metallurgy: towards sustainable Metallurgy*, **Orden dos Engenheiros**, Porto, Portugal. Prof. J.M. Torralba. 2023.
21. *Advance on fire-retarded polymer material and Fire-safe electrolytes to Lithium-ion battery*, **Ningbo Institute of Material Technology & Engineering, Chinese Academy of Sciences**, Ningbo, China. D.Y. Wang. August 2023.
22. *Advance on fire-retarded polymer material and Fire-safe electrolytes to Lithium-ion battery,* **China Jiliang University**, Hangzhou, China. D.Y. Wang. August 2023.

23. *Accurate prediction of phase diagrams of binary and ternary metallic alloys from first-principles calculations and statistical* mechanics, **Centre for Sustainable and Competitive Metallurgical and Manufacturing Industry, SINTEF/Norwegian University of Science and Technology**, Trondheim, Norway. J. LLorca. September 2023.
24. *Size effects in the deformation and fracture of nanolaminates*, **AFM User Meeting (Telstar)**, Cadiz University, Cadiz, Spain. Dr. J.M Molina-Aldareguia. November 2023.
25. *Additive manufacturing of energy-saving materials*, **Swiss Federal Institute of Technology Lausanne**, Lausanne, Switzerland. M.T. Pérez-Prado. November 2023.

3.6. Oral Talks by IMDEA Materials Institute Researchers

1. *Geometry and Topology Analysis of Characterization and Discovery of Porous Material Structures*, **SIAM Conference on Computational Science and Engineering (CSE23)**, Amsterdam, The Netherlands. M. Haranczyk. February 2023.
2. *Analysis of multicomponent alloy systems printed via Direct Energy Deposition using Thermodynamic Simulations*, **TMS 2023**, **152nd Annual Meeting and Exhibition**, San Diego, United States. J. Valilla, I. Sabirov and D. Tourret. March 2023.
3. *Enhancing the reliability of reconstruction for small grains using novel Laboratory Diffraction Contrast Tomography (LabDCT) acquisition and reconstruction approaches*, **TMS 2023, 152nd Annual Meeting and Exhibition**, San Diego, United States. E. Ganju, E. Nieto-Valeiras, J. LLorca and N. Chawla. March 2023.
4. *First principles calculation of phase diagrams including configurational and vibrational entropic contributions*, **TMS 2023, 152nd Annual Meeting and Exhibition**, San Diego, United States. W. Shao, S. Liu and J. LLorca. March 2023.
5. *Characterization of deformation mechanisms near grain boundaries in Mg alloys by means of in situ EBSD and high-resolution digital image correlation*, **TMS 2023, 152nd Annual Meeting and Exhibition**, San Diego, United States. B. Yang, M. Sarebanzadeh, E. Nieto-Valeiras, A. Orozco-Caballero and J. LLorca. March 2023.
6. *Manufacturing of Mg wires with optimized properties for biomedical applications*, **TMS 2023, 152nd Annual Meeting and Exhibition**, San Diego, United States. S.W. Ali Rizvi, L. Tillman, G. Domínguez, M. Li, M. Echeverry-Rendón, T. Mayer, C. González, J. LLorca and A. Kopp. March 2023.
7. *Modeling of location-specific microstructures in additive manufacturing of metallic alloys*, **TMS 2023**, **152nd Annual Meeting and Exhibition**, San Diego, United States. J. Mancias, R. Saunders, R. Arroyave and D. Tourret. March 2023.
8. *On the origin of grain boundaries during solidification processes*, **TMS 2023**, **152nd Annual Meeting and Exhibition**, San Diego, United States. J. Mancias, R. Saunders, R. Arroyave and D. Tourret. March 2023.
9. *Processing and properties of 3D printed bioabsorbable polymer-metal composites (PLDL/Mg and PLDL/Zn) for orthopaedic applications*, **TMS 2023, 152nd Annual Meeting and Exhibition**, San Diego, United States. C. Thompson, G. Domínguez, J. de la Vega, M. Echeverry-Rendón, C. González and J. LLorca. March 2023.

10. *Selective laser melting and characterization of a massive amorphous soft magnetic rotor for electric applications*, **TMS 2023, 152nd Annual Meeting and Exhibition**, San Diego, United States. A. Ghavimi, L. Thorsson, M. Unosson, M.T. Pérez-Prado, X. Jin, P. Tiberto, G. Barrera, B. Adam, N. Neuber, M. Frey, M. Rahimi Chegeni, R. Busch and I. Gallino. March 2023.
11. *Selective laser melting and characterization of a massive amorphous soft magnetic rotor for electric applications*, **TMS 2023, 152nd Annual Meeting and Exhibition**, San Diego, United States. C. Galera-Rueda, M.T. Pérez-Prado and J. LLorca. March 2023.
12. *Slip localization, slip transfer at grain boundaries and crack initiation during fatigue of solution-hardened Ni-based superalloys*, **TMS 2023, 152nd Annual Meeting and Exhibition**, San Diego, United States. I. Escobar-Moreno and J. LLorca. March 2023.
13. *Slip transfer at grain boundaries and intergranular fracture in Ti*, **TMS 2023, 152nd Annual Meeting and Exhibition**, San Diego, United States. E. Nieto-Valeiras, E. Ganju, N. Chawla and J. LLorca. March 2023.
14. *Solidification mechanisms during selective laser melting of binary Ni-Cu, Ni-Al and Ni-Zr alloys*, **TMS 2023, 152nd Annual Meeting and Exhibition**, San Diego, United States. C. Galera-Rueda, M.T. Pérez-Prado and J. LLorca. March 2023.
15. *Design of new low-density sintered cobalt-based superalloys*, **VIII Congreso Nacional y III Congreso Iberoamericano de Pulvimetalurgia**, San Sebastián, Spain. A. Mejía-Reinoso, B. Gault; J.M. Torralba and M. Campos. May 2023.
16. *High entropy alloys developed by metal injection moulding*, **VIII Congreso Nacional y III Congreso Iberoamericano de Pulvimetalurgia**, San Sebastián, Spain. A. Meza, A. Barbosa, E. Tabares and J.M. Torralba. May 2023.
17. *New alumina-forming martensitic steels for power generation*, **VIII Congreso Nacional y III Congreso Iberoamericano de Pulvimetalurgia**, San Sebastián, Spain. S.V. Kumaran, B. Malladi, E. Hryha and J.M. Torralba. May 2023.
18. *Optimization of manufacturing parameters for CoCrMo aamples using composite extrusion modelling*, **VIII Congreso Nacional y III Congreso Iberoamericano de Pulvimetalurgia**, San Sebastián, Spain. L. García de la Cruz, P. Alvaredo, J.M. Torralba and M. Campos. May 2023.
19. *Spark plasma sintering of novel CoNi based high entropy superalloy (HESA)*, **VIII Congreso Nacional y III Congreso Iberoamericano de Pulvimetalurgia**, San Sebastián, Spain. A. Mohammadzdeh, A. De Nardi, D. Garbiec, J. Valilla, D. Tourret and J.M. Torralba. May 2023.
20. *Polymer-like toughness enabling recycling of CNT fabrics*, **Multifunctional Nanocarbon Fibre Workshop**, Jeonbuk, South Korea. J.J. Vilatela. May 2023.
21. *Elastic interactions in Object kinetic Monte Carlo for defect evolution using a FFT approach*, **14th International Symposium on Continuum Models and Discrete Systems 14 (CMDS14)**, Pari, France. J. Segurado, C. Ortiz, R. Santos-Güemez and G. Álvarez. June 2023.



22. *Elastic interactions in object kinetic Monte Carlo for defect evolution using a FFT approach*, **14th International Symposium on Continuum Models and Discrete Systems 14 (CMDS14)**, Paris, France. J. Segurado, C. Ortiz, R. Santos-Güemez and G. Álvarez. June 2023.
23. *Buoyancy-induced oscillatory instability during directional solidification of alloys*, **16th International Conference on Modelling of Casting, Welding, and Advanced Solidification Processes**, Banff, Canada. J.M. Barbera, T. Isensee and D. Tourret. June 2023.
24. *Computational study of polycrystalline growth during melt pool solidification*, **16th International Conference on Modelling of Casting, Welding, and Advanced Solidification Processes**, Banff, Canada. R. Tavakoli, M. Elahi and D. Tourret. June 2023.
25. *Role of Al mixing to prepare feedstocks for PBF-LB/M to develop new HEAs via in-situ alloying*, **AMPM (Additive Manufacturing Powder Metallurgy) 2023**, Las Vegas, United States. S.V. Kumaran, B. Malladi, E. Hryha and J.M. Torralba. June 2023.
26. *Development of PM CoNi-based high entropy superalloy for sustainable manufacturing technologies*, **PowderMet2023 International Conference on Powder Metallugy & Particulate Materials**, Las Vegas, United States. A. Mohammadzadeh, A. De Nardi and J.M. Torralba. June 2023.
27. *Cold-forming of quenched and partitioned martensitic stainless steels: from Nakajima to simulation*, **The 7th International Conference of Engineering against Failure**, Spetses Island, Greece. A. Sierra-Soraluce, J.L. de Pablos, A. Smith, M. Muratori and I. Sabirov. June 2023.
28. *Fatigue behaviour of advanced high strength steels*, **The 7th International Conference of Engineering against Failure**, Spetses Island, Greece. A. Sierra-Soraluce, A. Gómez-Fernández, A. Banis, R. Petrov, J.M. Molina-Aldareguia and I. Sabirov. June 2023.
29. *The effect of aging treatments on the microstructure and mechanical properties of Fe-Mn-Al-C lightweight steels on macro- and mircoscale,* **The 7th International Conference of Engineering against Failure**, Spetses Island, Greece. A. Gómez-Fernández, I. Sabirov, M. Monclus, M. Avella, A. Dutta and J.M. Molina-Aldareguia. June 2023.
30. *Nanowire synthesis by FC-CVD and large-scale assembly as nanotextiles*, **Cambridge Particle Meeting**, Cambridge, UK. J.J. Vilatela. June 2023.
31. *Fatigue behaviour of a fully austenitic Fe-30Mn-9Al-1C* steel, **International Conference THERMEC**, Vienna, Austria. A. Gómez Fernández, M. Avella, J.M. Molina-Aldareguia, A. Dutta and I. Sabirov. July 2023.
32. *Microstructure, mechanical properties and corrosion behaviour of Mg and Zn alloys manufactured by LPBF for biomedical applications*, **15th Biodegradable Metals Conference**, Cetraro, Italy. M. Li and J.M. Molina-Aldareguia. August 2023.
33. *Material acceleration platform for the design of sustainable multifunctional nanocomposites*, **2023 ACCELERATE CONFERENCE**, Toronto, Canada. M. Haranczyk. August 2023.
34. *Composite extrusion modeling, a promising tool to manufacture a FeCrAlMoTiNi high entropy alloy,* **Alloys for Additive Manufacturing Symposium (AAMS2023)**, Madrid, Spain. L. García de la Cruz, M. Lagos, P. Alvaredo, J.M. Torralba and M. Campos. September 2023.

35. *Laser powder bed fusion of soft magnetic bulk metallic glasses,* **Alloys for Additive Manufacturing Symposium (AAMS2023)**, Madrid, Spain. M. Rodríguez-Sánchez, S. Sadanand, A. Ghavimi, R. Busch, I. Gallino, P.M. Tiberto, E. Ferrara, G. Barrera and M.T. Pérez-Prado. September 2023.
36. *Microstructural grading through laser scanning parameter modification for L-PBFed IN939*, **Alloys for Additive Manufacturing Symposium (AAMS2023)**, Madrid, Spain. I. Rodríguez-Barber, M.T. Pérez-Prado and S. Milenkovic. September 2023.
37. *Role of manufacturing routes on microstructural features of CoNi-based high entropy superalloy*, **Alloys for Additive Manufacturing Symposium (AAMS2023)**, Madrid, Spain. A. Mohammadzadeh, A. De Nardi, A. Mostafaei, D. Garbiec, J. Valilla, D. Tourret, E. Hryha and J.M. Torralba. September 2023.
38. *Selective laser melting of bulk metallic glasses for energy applications*, **Alloys for Additive Manufacturing Symposium (AAMS2023)**, Madrid, Spain. S. Sadanand, M. Rodríguez-Sánchez, A. Ghavimi, R. Busch, I. Gallino, P.M. Tiberto, E. Ferrara, G. Barrera, T. Choma, L. Zrodowski and M.T. Pérez-Prado. September 2023.
39. *Using powder mixtures to develop high entropy alloys via in-situ alloying in PBF-LB/M and studying its phase evolution by annealing*, **Alloys for Additive Manufacturing Symposium (AAMS2023)**, Madrid, Spain. S.V. Kumaran, S. Bala, A. Malladi, E. Hryha and J. M. Torralba. September 2023.
40. *Computational thermodynamic analysis applied to multicomponent alloy design*, **FEMS EUROMAT 2023**, Frankfurt am Main, Germany. J. Valilla, A. Mohammadzadeh, I. Sabirov, J.M. Torralba and D. Tourret. September 2023.
41. *Design and characterization of a FeNiCrMn-Al High Entropy Alloy*, **FEMS EUROMAT 2023**, Frankfurt am Main, Germany. R. Castellote-Alvarez, D. San-Martín, S. Milenkovic, J.M. Molina-Aldareguia and I. Toda-Caballero. September 2023.
42. *Effect of aging on microstructure and mechanical properties of Fe-30Mn-9Al-1C steel on macro- and microscales*, **FEMS EUROMAT 2023**, Frankfurt am Main, Germany. A. Gómez-Fernández, A. Dutta, J.M. Molina-Aldareguia, M. Monclús, M. Avella and I. Sabirov. September 2023.
43. *Effect of surface properties on the vascular biocompatibility of 3D-printed shape memory alloys for the development of smart cardiovascular implants*, **33rd Annual Conference of the European Society for Biomaterials**, Davos, Switzerland. J. Ordoño, O. Contreras-Almengor, J.M. Molina-Aldareguia, M. Echeverry-Rendón. September 2023.
44. *In situ synchrotron multi-resolution characterization of the mechanical and degradation performance of SLM WE43 scaffolds for bone regeneration systems*, **FEMS EUROMAT 2023**, Frankfurt am Main, Germany. M.D. Martín-Alonso, F. Benn, A. Kopp, M. Majkut, J. Villanova, J.M. Molina-Aldareguia and F. Sket. September 2023.
45. *Modeling of location-specific microstructures in AM of metallic alloys*, **FEMS EUROMAT 2023**, Frankfurt am Main, Germany. J. Mancias, R. Saunders, R. Arroyave and D. Tourret. September 2023.
46. *Microstructure evolution during martensite decomposition in additively manufactured Ti-6Al-4V: In-situ characterization and phase-field modelling*, **FEMS EUROMAT 2023**,

Frankfurt am Main, Germany. A. Boccardo, Z. Zou, M. Simonelli, M. Tong, J. Segurado, S. Leen and D. Tourret. September 2023.

47. *Microstructure and mechanical properties of NiTi shape memory alloys manufactured by LPBF for biomedical applications*, **FEMS EUROMAT 2023**, Frankfurt am Main, Germany. M. Li, O. Contreras, A. Díaz-Lantada and J.M. Molina-Aldareguia. September 2023.
48. *Phase-Field Study of Rapid Solidification in Laser Powder-Bed Fusion Additive Manufacturing*, **FEMS EUROMAT 2023**, Frankfurt am Main, Germany. R. Tavakoli and D. Tourret. September 2023.
49. *Surface modification of nitinol parts manufactured by LPBF*, **FEMS EUROMAT 2023**, Frankfurt am Main, Germany. O. Contreras-Almengor, J. Ordoño, M. Echeverry-Rendón, M. Li, A. Díaz-Lantada and J.M. Molina-Aldareguia. September 2023.
50. *Application of Exponential Integrators for a Phase-Field Dendritic Crystal Growth Model*, **International Association for Mathematics and Computers in Simulation (IMACS) World Congress**, Rome, Italy. R. Tavakoli and D. Tourret. September 2023.
51. *Additively Manufactured Novel CoNi-based High Entropy Superalloy*, **EUROPM2023**, Lisbon, Portugal. A. Mohammadzadeh, A. De Nardi, F. Omidbakhsh, A. Mostafaei and J.M. Torralba. October 2023.
52. *Developing CoCrFeNiMox high entropy alloys using commodity powders by powder injection moulding*, **EUROPM2023**, Lisbon, Portugal. A. Meza, A. Barbosa, X. Yang, E. Tabares and J.M. Torralba. October 2023.
53. *Effect of process parameters and heat treatments on non-equiatomic CoCrFeNiMoxAly HEAs manufactured by PBF-LB/M via in-situ alloying*, **EUROPM2023**, Lisbon, Portugal. S.V. Kumaran, S. Bala, A. Malladi, E. Hryha and J.M. Torralba. October 2023.
54. *Electrical resistance sintering: a promising tool to process CoCrMo alloy samples with exceptional mechanical properties*, **EUROPM2023**, Lisbon, Portugal. L. Garcia de la Cruz, M. Lagos, P. Alvaredo, J.M. Torralba and M. Campos. October 2023.
55. *Role of Al Mixing to Prepare Feedstocks for PBF-LB/M to Develop New HEAs via In-Situ Alloying Additive Manufacturing with Powder Metallurgy*, **AMPM 2024**, Las Vegas, United States. S.V. Kumaran, B. Malladi, E. Hryha and J.M. Torralba. November 2023.
56. *Development of PM CoNi-Based High Entropy Superalloy for Sustainable Manufacturing Technologies*, **International Conference on Powder Metallurgy and Particulate Materials, PowderMet 2023**, Las Vegas, United States. A. Mohammadzadeh, A. De Nardi and J.M. Torralba. November 2023.

3.7. Invited Seminars Hosted by IMDEA Materials Institute

1. *Data mesh refinement*, Dr. J.G. Suárez, **Swiss Federal Institute of Technology**, Switzerland. January 2023.
2. *Multiscale modeling of laser-powder bed fusion additive manufacturing*, Dr. C.A. Gandin, **CNRS and Mines Paris PSL**, France. January 2023.

3. *Recent progress in voltage control of magnetism using magneto-ionics and strain: fundamental aspects and prospective applications*, Prof. J. Sort, **University of Barcelona**, Spain. February 2023.
4. *Physically guided neural networks with internal variables: from material unravelling to applications in biomedical engineering,* Dr. J. Ayensa, **Tissue MicroEnvironment Laboratory**, Zaragoza. February 2023.
5. *Large strain crystal plasticity gradient model based on FFTs: Formulation, Implementation and Application*, Dr. M. Zezevic, **Los Alamos National Laboratory**, United States. March 2023.
6. *Topological signatures of porosity*, Dr. P. Dlutko, **Institute of Mathematics of the Polish Academy of Sciences**, Poland. April 2023.
7. *Growth functions of periodic space tessellations*, Dr. B. Naskrecki, **Institute of Mathematics of the Polish Academy of Sciences**, Poland. April 2023.
8. *Design of polymer hydrogels as biomaterial inks for 3D extrusion printing,* Dr. R. Hernández, **Institute of Polymer Science (CSIC)**, Spain. April 2023.
9. *Using radio frequency fields for heating, curing, welding and 3D printing,* Prof. M. Green, **Texas A&M University**, United States. May 2023.
10. *Multiscale Performance Characterization of PMCs and AM-PMC*, Dr. M. Flores, **Air Force Research Laboratory, Wright-Patterson AFB**, United States. May 2023.
11. *Laser synthesized nanoparticles to enhance additive manufacturing materials: from ODS steels to plasmonic and magnetic polymers*, Dr. C. Doñate, **University of Wuppertal**, Germany. June 2023.
12. *Research & Development of biodegradable Mg-based vascular stent*, Dr. G. Yuan, **Shanghai Jiao Tong University**, China. June 2023.
13. *Deep generative models for biomolecular engineering*, Prof. R. Mercado, **Chalmers University**, Sweden. June 2023.
14. *Electrical properties of nanocarbon-based composites 3D printed by digital light processing*, Dr. D. Tilve, Paul Pascal Research Centre, **French National Research Center (CNRS)** and **Bordeaux University**, France. July 2023.
15. *Perspectives on composite sustainability*, Dr. D. Tilbrook, **Hexcel**. July 2023.
16. *How defect interactions between dislocation and grain boundaries affect the inside of the grain*, Prof. Y. Shibutani, **Osaka University**, Japan. August 2023.
17. *The amazing world of 2D materials,* Prof. H.T. Maldonado, **Rensselaer Polytechnic Institute**, United States. September 2023.
18. *Computational description of aerogels and the challenges posed in obtaining 3D visualizations of their mesoporous nanostructures*, Prof. A. Rege, **German Aerospace Centre (DLR)** and **Keele University**, Germany. September 2023.
19. *Developing next-generation alloys for powder bed fusion additive manufacturing*, Dr. Federico Bosio, **Technology Innovation Institute**, United Arab Emirates. September 2023.
20. *New insights into the relationships between microstructure and mechanical properties in Titanium (Ti) alloys*, Prof. S. Hémery, Pprime, **ISAE-ENSMA, Université de Poitiers**, France. October 2023.

21. *Complex flow phenomena in composite processing: experimental evidence and modelling,* Prof. C. Binetruy, **Nantes University**, France. October 2023.
22. *Unraveling the construction of honeycomb in the Apis mellifera using time-resolved X-ray microscopy*, Prof. N. Chawla, **Purdue University**, United States. October 2023.
23. *Overcoming the adhesion paradox with shape memory polymers,* Prof. K.J. Hsia, **Nanyang Technological University**, China. October 2023.
24. *Molecular biophysics of biomaterials at the respiratory surface, in Health and Disease*, Prof. J. Gil, **Complutense University of Madrid**, Spain. November 2023.
25. *Measuring twinning stress of CoCrFeNiMn high entropy alloy by in situ micromechanical testing*, C.A. Teixeira, **Karlsruher Institute of Technology**, Germany. November 2023.
26. *Microstructurally defect induced inelastic and fracture modes in crystalline materiales,* Prof. M. Zikry, **North Carolina State University**, United States. December 2023.

3.8. International Conferences. Membership in Organising Committees

1. **Frontiers in Solidification: An MPMD Symposium Honoring Jonathan A. Dantzig Symposium TMS 2023**, San Diego, United States. A. Phillion, M. Rappaz, M. Serefoglu and D. Tourret (Symposium Organiser). March 2023.
2. **Computational Thermodynamics and Kinetics Symposium TMS 2023**, San Diego, United States. H. Askari, E. Zarkadoula, E. Martinez Saez, F. Soisson, F. Abdeljawad, Z. Hou and D. Tourret (Symposium Organiser). March 2023.
3. **Congreso Español e Iberoamericano de Pulvimetalurgia**, San Sebastián, Spain. J.M. Torralba (Technical Programme Committee). May 2023.
4. **Multifunctional Nanocarbon Fibre Workshop**, Jeonbuk, South Korea. J.J.Vilatela (International Workshop Organiser). May 2023.
5. **Modulation of Physico-Chemical Processes by Elastic Strain Engineering, EuroMech Colloquium 636**, Besancon, France. F. Amiot and J. LLorca. May 2023.
6. **PowderMet2023/AMPM2023 Congress**, Las Vegas, United States. J.M. Torralba (Technical Programme Committee). June 2023.
7. **META 2023: 13th International Conference on Metamaterials**, Paris, France. J. Christensen (Technical Program Committee). July 2023.
8. **EUROMAT International Conference**, Frankfurt, Germany. A. Malakizadi, B.X. Xu and D. Tourret (Symposium Organisers). September 2023.
9. **Plasticity and Damage at The Microscale: COMPLAS 2023**, Barcelona, Spain. S. Forest, J. Marian and J. Segurado (Symposium Organisers). September 2023.
10. **Alloys for Additive Manufacturing Symposium, AAMS2023**, Madrid, Spain. J.M. Torralba, J.M. Molina-Aldareguia, D. Tourret, J. Segurado (Local Organising Committee). September 2023.
11. **HSS-23 International Workshop on High Strength Steels International Workshop**, Bergamo, Italy. E. Anelli and I. Sabirov (Workshop Organisers). October 2023.

12. **European Powder Metallurgy Congress EUROPM2023 Congress**, Lisbon, Portugal. J.M. Torralba (Technical Programme Committee), October 2023.

3.9. Researcher and Institutional Awards

1. ***Human Resources Excellence in Research Award***, European Commission, IMDEA Materials Institute. January 2023.
2. ***Consolidation of Research Activity Award***, Technical University of Madrid, Prof. J. Segurado. January 2023.
3. ***SMD Distinguished Scientist/Engineer Award***, Minerals, Metals and Materials Society (TMS), Prof. J. LLorca. March 2023.
4. ***Young Scholars Award***, Minerals Metals and Materials Society (TMS), Dr. D. Tourret. April 2023.
5. ***Public Choice Award***, Falling Walls Lab Madrid, Dr. P.J. Navarrete Segado. May 2023.
6. ***AMES-Joan Antoni Bas Prize***, Congreso Español Iberoamericano de Pulvimetalurgia, Dr. S.V. Kumaran. May 2023.
7. ***Honorary Professorship***, Yanshan University, Prof. J. LLorca. July 2023.
8. ***Plastometrex 2023 Research Competition***, Plastometrex, Dr. I. Sabirov. July 2023.
9. ***National Research Prize Leonardo Torres Quevedo in Engineering and Architecture***, Spanish Ministry of Science and Innovation, Prof. J. LLorca. September 2023.
10. ***World's Most Influential Scientists***, Stanford University, Profs. J. LLorca, J.M. Torralba, C. González and J. Segurado and Drs. D.Y. Wang, M.T. Pérez-Prado, I. Sabirov, M. Haranczyk, J. Christensen and R. Tavakoli. October 2023.
11. ***2023 Keynote Paper Award***, Powder Metallurgy 2023 – European Congress & Exhibition, Dr. S.V. Kumaran. October 2023.
12. ***International Magnesium Award for Innovative Process of the Year***, International Magnesium Society, Dr. S.W. Ali Rizvi. December 2023.
13. ***Outstanding Thesis Award in Materials Science and Engineering***, Carlos III University of Madrid, Dr. S.W. Ali Rizvi. December 2023.
14. ***Outstanding Thesis Award in Materials Science and Engineering***, Carlos III University of Madrid, Dr. A. Fernández. December 2023.
15. ***Extraordinary Thesis Award***, Technical University of Madrid, Dr. A. Yusuf. December 2023.

4. Technology Offer

IMDEA Materials Institute is constantly developing new technologies and inventions based on the results of our R&D projects. Here you can find a listing of our technological offers ready to be transferred to industry, other research institutions, investors or entrepreneurs.

Materials Science and Engineering technology, which is available for licensing:

Title: *Device for detecting movement and/or pressure force of a first element relative to a second element*
Description: A device for detecting long and short duration and frequency movements, for identifying waveforms of velocity, acceleration and external excitation forces and for detecting the spectrum of oscillating motion energies.
Opportunity: Technology License

Title: *Spark ablation device, a method for generating nanoparticles by means of said device, and associate uses thereof*
Description: Spark ablation device used for generating large concentrations (108 particles/cm3) of very small conductive nanoparticles (<5 nm geometric mean size).
Opportunity: Technology License

Title: *Mechanical testing device attachable to a cone calorimeter (Utility Model)*
Description: Mechanical testing device attachable to a cone colorimeter configured to perform tests for safety design and to test mechanical properties under load and under extreme thermal conditions.
Opportunity: Technology License

Title: *Portable, communicating impact detection and wearer condition monitoring device and system comprising the device*
Description: A device capable of identifying impacts, their magnitude and location, as well as a person’s vital signs if applied as a wearable and transmitting these parameters via the internet.
Opportunity: Technology License

Title: *PLA aerogel-based phase-change composites for thermal energy storage and heat management*
Description: Shape-stabilised composite phase-change material (PCM), physically stable and with high phase change enthalpy. The material is suitable for thermal management applications in electronics, power electronics, solar energy, batteries, or construction.
Opportunity: Technology License

Title: *Recyclable and bendable vitrimer core resins for shapeable sandwich structures*
Description: Vitrimer-based syntactic foams with application in recyclable and curved lightweight sandwich composites manufactured by hot-press, for flexible interiors in the transportation, aerospace and defense industries, as well as in construction.
Opportunity: Technology License

Title: *ML-based porosity inspection method for composite materials*
Description: Non-destructive machine learning-based methodology capable of improving porosity estimation and types of porosity on composite materials.
Opportunity: Technology License

Title: *Smart mask that monitors breath rhythm*
Description: Smart face mask with self-powered sensors capable of monitoring vital parameters such as respiration rate and characteristics of respiration pulses that wirelessly transmits them through IoT protocols to a telemedicine platform.
Opportunity: Technology License

Title: *Seismic detection system*
Description: Sensor device that allows the detection of seismic waves and plenty of physical magnitudes characteristic of them, through a wide range of frequencies, capable of communicating data signals in real time. The device is also mechanically robust and capable of withstanding extreme environmental conditions.
Opportunity: Technology License

Title: *Energy Storage in multifunctional structural composite material*
Description: Laminar composite material simultaneously having excellent structural properties and high energy storage efficiency.
Opportunity: Technology License

Title: *Electrode for capacitive deionization*
Description: Electrode for capacitive deionization in which the active phase and the current collector are included in a single element, i.e. a composite material.
Opportunity: Technology License

Title: *Multifunctional sensor for composite materials*
Description: Thin sensor laid between dry fabric layers and connected to a simple electrical power meter, that provides real-time information about the resin flow and the gel point during resin infusion and curing, remains embedded in the composite and can be used for structural health monitoring (SHM) and damage detection.
Opportunity: Technology License

Title: *Resistive curing of polymers and composite materials*
Description: Resistive heating of polymer formulations with a very small fraction of conductive nanocarbon materials. Processing of the polymer can be carried out with conventional power supplies, either with AC or DC.
Opportunity: Technology License

Title: *A halogen free flame-retardant epoxy resin composition*
Description: New halogen free flame-retardant epoxy resin with excellent mechanical properties, thermal resistance, low smoke release and good processability, which can also be used as adhesive.
Opportunity: Technology License

Software

Title: *CAPSUL*
Description: CAPSUL is a package of crystal plasticity and polycrystalline homogenization simulation tools.
Opportunity: Software License

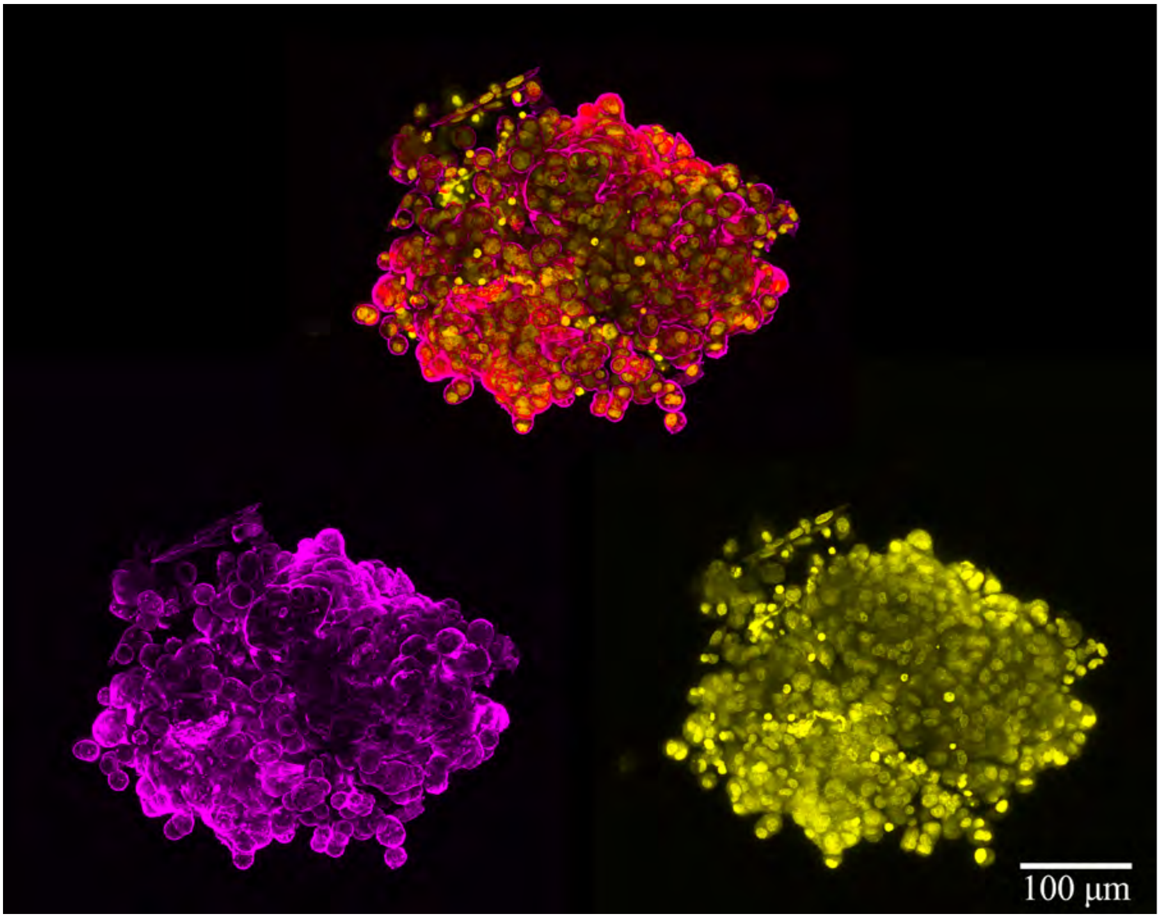
Title: *FFTMAD (Fast Fourier Transform Based Homogenisation Code, MADrid)*
Description: FFT-based simulation tool developed by IMDEA Materials for computational homogenisation of any heterogeneous material, such as composites, polycrystals or celular materials, by simulating the behaviour of a Representative Volume Element of the microstructure.
Opportunity: Software License

Title: *MULTIFOAM*
Description: Simulation tool developed within the framework of computational micromechanics by IMDEA Materials to predict the mechanical behaviour of low to medium density foams with open and closed-cell microstructure
Opportunity: Software License

Title: *VIPER (VIrtual Ply PropERty)*
Description: Simulation tool developed by IMDEA Materials to predict ply properties of fibre-reinforced composite materials from the properties and spatial distribution of the different phases and interfaces in the composite.
Opportunity: Software License

Title: *IRIS*
Description: IRIS is an object oriented, general purpose, parallel code for computational mechanics in solid, fluid, and structural applications. It has finite element and meshless capabilities, a wide range of material models, and solvers for linear and nonlinear, stationary and transient simulations.
Opportunity: Software License

Title: *MUESLI*
Description: MUESLI, a Material UnivErSal LIbrary, is a collection of C++ classes and functions designed to model material behavior at the continuum level. It is available to the material science and computational mechanics community as a suite of standard models and as a platform for developing new ones.
Opportunity: Software License



A549 Spheroid in Focus. IMDEA Materials Imaging Contest 2024. Materials Characterisation Category.
Taken by: Dr. P.J. Navarrete Segado.

5. Training, Internships and Visiting Researchers

5.1. PhD Theses

1. **Title:** *Multiscale modeling of dendritic growth kinetics with liquid convection*
   Student: T. Isensee
   Supervisor: Dr. D. Tourret and Prof. J. LLorca
   Date: January 18, 2023

2. **Title:** *Microstructure sensitive simulation framework for additive manufactured Hastelloy-X*
   Student: C. Pilgar
   Supervisor: Prof. J. Segurado
   Date: February 24, 2023

3. **Title:** *Effect of microstructure on architecture materials fabricated by additive manufacturing*
   Student: S. Banait
   Supervisor: Dr. M.T. Pérez-Prado and Prof. M. Campos Gómez
   Date: June 8, 2023

4. **Title:** *Facilitating development of special clays by incorporation of machine learning techniques*
   Student: G. Lo Dico
   Supervisor: Drs. M. Haranczyk and V. Carelén
   Date: June 12, 2023

5. **Title***: Fatigue behaviour and fatigue crack initiation micromechanisms of rolled AZ31 Mg alloy*
   Student: S.A. Jamali
   Supervisor: Prof. J. LLorca and Dr. A. Ma
   Date: July 19, 2023

6. **Title:** *Bioabsorbable composite laminates of PLA reinforced with surface-modified Mg wires for orthopedic implant applications*
   Student: S.W. Ali Rizvi
   Supervisor: Profs. C. González and J. LLorca
   Date: July 24, 2023

7. **Title:** *Development and experimental correlation of machine learning models for diagnosis of processing disturbances in liquid molding of structural composites*
   Student: K. Keramati
   Supervisor: Prof. C. González
   Date: September 15, 2023

8. **Title:** *Development of Ti-Fe-based powders for laser additive manufacturing of ultrafine lamellar eutectics*
   Student: A. Kumar
   Supervisor: Drs. F. Sket and Srdjan Milenkovic
   Date: September 14, 2023

9. **Title:** *Binder Jetting: a microstructural perspective*
   Student: S. Bafaluy
   Supervisor: Drs. M.T. Pérez-Prado, F. Sket and R. Muñoz Moreno
   Date: September 22, 2023

10. **Title:** *Advanced deep learning technologies for the smart manufacturing of structural composites*
    Student: J. Fernández
    Supervisor: Profs. L. Baumela and C. González
    Date: October 4, 2023

5.2. Master's and Bachelor's Degree Research

1. *Development of high entropy alloys (HEAs) through metal injection moulding (MIM)*
   Student: A.B. Cantú
   Advisor: Prof. J.M. Torralba
   Visiting student from: Carlos III University of Madrid
   Period: November 2022 – September 2023

2. *Development of CoNi-based High Entropy Superalloys*
   Student: A. De Nardi
   Advisor: Prof. J.M. Torralba
   Visiting student from: Technical University of Torino
   Period: November 2022 – July 2023

3. *Tool life studies of PVD coated tools in micro-milling operations on titanium alloys of titanium alloys*
   Student: D.S. Plano
   Advisor: Dr. J.M. Molina-Aldareguia
   Visiting student from: Technical University of Madrid
   Period: October 2023 – February 2024

4. *Analysis of 3D Printed Carbon Strands as Deformation Sensors*
   Student: M.H. Yagües
   Advisor: Prof. C. González
   Visiting student from: Carlos III University of Madrid
   Period: September 2022 – March 2023

5. *Study of the mechanical behavior and degradation/regeneration of bioabsorbable structures of composite materials with Mg and Zn fabricated with a multi-material 3D printer*
   Student: P.B. Estrada
   Advisor: Prof. J. LLorca
   Visiting student from: Technical University of Madrid
   Period: October 2022 – January 2023

6. *The effect of sulfur on the morphology of carbon nanotubes and its relation to 2D Peak*
   Student: R. Fernández-Torres
   Advisor: Prof. J.J. Vilatela
   Visiting student from: Carlos III University of Madrid
   Period: December 2022 – June 2023

5.3. Visiting researchers, internships and students

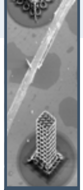
1. *Bio-based, smart and fire safe polymeric materials*
   Name: Dr. G. Yin
   Advisor: Dr. D.Y. Wang
   Position: Visiting Adjunct Researcher
   Period: March 2022 – March 2025

2. *Combined phase field and mechanical modelling for solid-state transformations in AM Ti6Al4V alloy*
   Name: A. Dante Boccardo
   Advisor: Dr. D. Tourret
   Position: Visiting Research Associate
   Period: June 2021 – January 2023

3. *Design and Simulation of Composite Structures*
   Name: A. Fernández Gorgojo
   Advisor: Dr. J.M Molina-Aldareguia
   Position: Visiting Research Associate
   Period: April 2022 – April 2025

4. *Development of antibacterial polymer-based textiles*
   Name: Dr. A. Vázquez López
   Advisor: Dr. D.Y. Wang
   Position: Visiting Research Associate
   Period: November 2022 – October 2024

5. *Powder metallurgy*
   Name: A. Páez Pavón
   Advisor: Prof. J.M. Torralba.
   Position: Visiting Research Associate
   Period: April 2022 – July 2023



6. *Micro- and nano-mechanics*
   Name: A. Orozco Caballero
   Advisor: Prof. J. LLorca
   Position: Visiting Research Associate
   Period: September 2022 – December 2024

7. *Micro- and nano-mechanics*
   Name: J.J. Hernández Rueda
   Advisor: Dr. J.M. Molina-Aldareguia (in colaboration with Dr. M. Monclús)
   Position: Visiting Research Associate
   Period: March 2018 – September 2023

8. *Micro- and nano-mechanics and high-performance polymers and fire retardants*
   Name: Dr. J. Sánchez del Río Sáez
   Advisor: Dr. J.M. Molina-Aldareguia and Dr. D.Y. Wang
   Position: Visiting Research Associate
   Period: April 2021 to May 2025

9. *Additive manufacturing of metallic materials*
   Name: M.S. Flores Vidal
   Advisor: Dr. M.T. Pérez-Prado
   Position: Visiting Research Associate
   Period: January 2023 – April 2023

10. *High-performance polymers and fire retardants*
    Name: Dr. R. Sánchez Díaz
    Advisor: Dr. D.Y. Wang
    Position: Visiting Research Associate
    Period: February 2023 to February 2024

11. *Physical simulation*
    Name: Z. Ye
    Advisor: Dr. I. Sabirov
    Position: Visiting Research Associate
    Period: October 2023 to June 2024

12. *Electro-momentum coupling in piezoelectric heterostructures*
    Name: Dr. R. Pernas Salomón
    Advisor: Dr. J. Christensen
    Position: Visiting Research Associate
    Period: December 2022 – November 2024

13. *Multifunctional Nanocomposites*
    Name: A. Álvarez Gómez
    Advisor: Dr. J.P. Fernández
    Position: Visiting Research Assistant
    Period: September 2022 – January 2023

14. *Characterisation of 3D printed biodegradable metal scaffolds*
    Name: A. Leo Bakke
    Advisor: Dr. J. Patterson
    Position: Visiting Research Assistant
    Period: June 2023 – August 2023

15. *Development of new martensitic stainless steels*
    Name: A. Sierra Soraluce
    Advisor: Dr. I. Sabirov
    Position: Visiting Research Assistant
    Period: September 2023 – June 2024

16. *Design and fabrication of multimaterial bioresorbable scaffolds by 3D printing for osteochondral tissue regeneration*
    Name: A.G. de la Camacha Díaz
    Advisor: Prof. J. LLorca and Dr. J. Sánchez del Río Sáez
    Position: Visiting Research Assistant
    Period: September 2023 – August 2025

17. *Micro- and nano-mechanics*
    Name: C. Aguiar Teixeira
    Advisor: Dr. J.M. Molina-Aldareguia
    Position: Visiting Research Assistant
    Period: November 2023 – December 2023

18. *Micro- and nano mechanics*
    Name: C. Aguilar Vega
    Advisor: Dr. J.M. Molina-Aldareguia
    Position: Visiting Research Assistant
    Period: November 2022 – June 2024

19. *Study on the effect of polymeric structure on 3D printing.*
    Name: C. Martín Pérez
    Advisor: Dr. J.P. Fernández
    Position: Visiting Research Assistant
    Period: November 2023 – December 2023

20. *Mechanics of materials and structural composite materials*
Name: Dr. C. Thompson
Advisor: Prof. J. LLorca and Prof. C. González
Position: Visiting Research Assistant
Period: November 2023 – February 2024

21. *Multifunctional nanocomposites*
Name: C. Giudici
Advisor: Dr. J.J. Vilatela
Position: Visiting Research Assistant
Period: October 2023 – June 2024

22. *Synthesis and characterisation of polymeric resins for applications in spheroid generation*
Name: C.M. Wasick
Advisor: Dr. J. Patterson
Position: Visiting Research Assistant
Period: June 2023 – August 2023

23. *Micro- and nano-mechanics*
Name: D.A. García Carrero
Advisor: Dr. J.M. Molina-Aldareguia
Position: Visiting Research Assistant
Period: December 2022 – November 2025

24. *Solid-state processing*
Name: F. Tomás Masari
Advisor: Dr. J.A. Meza
Position: Visiting Research Assistant
Period: May 2021 – December 2024

25. *Multiscale materials modelling*
Name: G. Zarzoso Bueno
Advisor: Prof. J. Segurado
Position: Visiting Research Assistant
Period: January 2023 – April 2023

26. *Micro- and nano-mechanics*
Name: G. Ortiz Pérez
Advisor: Dr. J.M. Molina-Aldareguia
Position: Visiting Research Assistant
Period: June 2020 – April 2023

27. *Structural composite materials*
Name: I. Lizerralde Delgado
Advisor: Prof. C. González
Position: Visiting Research Assistant
Period: March 2022 – April 2024

28. *Fabrication, processing, testing and characterization (structural, physicochemical and electrical) of carbon nanotube-based fibers and devices.*
Name: I. Gómez Palos
Advisor: Dr. J.J. Vilatela
Position: Visiting Research Assistant
Period: May 2021 – August 2024

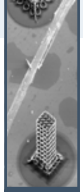
29. *High performance polymers and fire retardants*
Name: J. Xu
Advisor: Dr. De-Yi Wang
Position: Visiting Research Assistant
Period: October 2022 – October 2023

30. *Solid computational mechanics*
Name: L. Koerkemeier
Advisor: Prof. I. Romero
Position: Visiting Research Assistant
Period: April 2023 – November 2023

31. *Study of materials based on CNT fibers as possible soft sensors*
Name: L.K. Mena López
Advisor: Dr. A. Mikhalchan
Position: Visiting Research Assistant
Period: November 2023 to December 2023

32. *Preparation and characterisation of nanocomposite materials*
Name: M.C. Gaunt
Advisor: Dr. M. Haranczyk
Position: Visiting Research Assistant
Period: June 2023 – August 2023

33. *Mechanics of materials*
Name: M. Sarebenzadeh
Advisor: Prof. J. LLorca
Position: Visiting Research Assistant
Period: December 2020 – November 2024



34. *Alumina-forming steels*
Name: C. del Castillo Montull
Advisor: Prof. J.M. Torralba
Position: Visiting Research Assistant
Period: October 2023 – October 2023

35. *Structural composite materials*
Name: C. Pereira Lobato Costa
Advisor: Prof. J. LLorca and Prof. C. González
Position: Visiting Research Assistant
Period: November 2023 – May 2024

36. *Multifunctional Nanocomposites*
Name: J.I. Delgado Castaño
Advisor: Dr. J.P. Fernández
Position: Visiting Research Assistant
Period: January 2023 – January 2026

37. *Computational design of metallic alloys for additive manufacturing*
Name: J. Macías
Advisor: D. Tourret
Position: Visiting Research Assistant
Period: November 2023 – October 2024

38. *Bio-based epoxi resins*
Name: M. Zhou
Advisor: Dr. D.Y. Wang
Position: Visiting Research Assistant
Period: May 2023 – August 2023

39. *COCINET - Optimal design of mechanical metamaterials with phase transitions in the elastic regime*
Name: N.O. Rossi Cabral
Advisor: Prof. I. Romero
Position: Visiting Research Assistant
Period: November 2022 – January 2023

40. *Multifunctional nanocomposites*
Name: R.J. Morrin Ellingham
Advisor: Dr. J.J. Vilatela
Position: Visiting Research Assistant
Period: November 2022 to February 2023

41. *High-performance polymers and fire retardants*
Name: R. Crouse
Advisor: Dr. D.Y. Wang
Position: Visiting Research Assistant
Period: June 2023 – August 2023

42. *Micro- and nano-mechanics*
Name: R. Zapata Martínez
Advisor: Dr. J.M. Molina-Aldareguia
Position: Visiting Research Assistant
Period: November 2022 to June 2024

43. *Micro- and nano-mechanics and solidification processing and engineering*
Name: R. Castellote Álvarez
Advisor: Dr. J.M. Molina-Aldareguia
Position: Visiting Research Assistant
Period: May 2021 to December 2024

44. *In-situ processing and mechanical characterization of materials*
Name: S. Bafaluy Ojea
Advisor: Dr. M.T. Pérez-Prado and Dr. F. Sket
Position: Visiting Research Assistant
Period: January 2020 – January 2023

45. *Improvement of the 3D Metal Jet Part Quality through print mode development supported by the HR-XCT characterization of the printed parts*
Name: S. Bafaluy Ojea
Advisor: Dr. M.T. Pérez-Prado and Dr. F. Sket
Position: Visiting Research Assistant
Period: February 2023 – October 2023

46. *Development and characterization of High Entropy Alloys resistant to Hydrogen Embrittlement by Selective Laser Melting*
Name: S. Arenas
Advisor: Prof. J.M. Torralba
Position: Visiting Research Assistant
Period: June 2023 – August 2023

47. *Multifunctional nanocomposites*
Name: S. Tahsin Upama
Advisor: Dr. J.J. Vilatela
Position: Visiting Research Assistant
Period: August 2023 – May 2025

48. *Mechanics of materials*
Name: S.W. Ali Rizvi
Advisor: Prof. J. LLorca
Position: Visiting Research Assistant
Period: August 2023 – November 2023

49. *Mechanics of materials*
Name: V. Hernández Montes
Advisor: Prof. J. LLorca
Position: Visiting Research Assistant
Period: September 2022 to February 2023

50. *Mechanics of materials*
Name: V.A. Tucker
Advisor: Prof. J. LLorca and Dr. I. Sabirov
Position: Visiting Research Assistant
Period: September 2023 to February 2024

51. *Mechanics of materials*
Name: W. Shao
Advisor: Prof. J. LLorca
Position: Visiting Research Assistant
Period: December 2021 to December 2024

52. *Preparation of temperature-sensitive surfaces for cell sheet engineering*
Name: Y. Estela Olivas Biddle
Advisor: Dr. J. Patterson
Position: Visiting Research Assistant
Period: June 2023 to August 2023

53. *Modeling and Simulation of Materials Processing*
Name: Z. Thune
Advisor: Dr. D. Tourret
Position: Visiting Research Assistant
Period: June 2023 to August 2023

54. *Porous Hierarchical Nanofibers for Electrochemical Applications*
Name: Z.P. Shen Lin
Advisor: Dr. J.P. Fernández
Position: Visiting research assistant
Period: February 2023 to December 2024

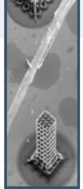
55. *Acoustic coherent perfect absorption based on flexible manipulation of system exceptional point*
Name: Z. Xu
Advisor: Dr. J. Christensen
Position: Visiting research assistant
Period: October 2023 to December 2023

56. *Processing and characterisation of High Entropy Alloys*
Name: A. Barbosa Cantú
Advisor: Prof. J.M. Torralba
Position: Student (Research Initiation Fellowship)
Period: June 2023 – September 2023

57. *Multiscale modeling of microstructure development in solidification processing*
Name: A. Montanero Lacharro
Advisor: Dr. D. Tourret
Position: Student (Research Initiation Fellowship)
Period: July 2023 – September 2023

58. *Sustainable Powder Technologies*
Name: A. De Nardi
Advisor: Prof. J.M. Torralba
Position: Student (Research Initiation Fellowship)
Period: November 2022 – July 2023

59. *High-throughput computational strategy based on first principles calculations and artificial intelligence tools to discover new catalysts for the hydrogen economy*
Name: D. Schaefer Dalmau
Advisor: Prof. J. LLorca
Position: Student (Research Initiation Fellowship)
Period: September 2023 – November 2023



60. *Fire safety and fire-mechanical survivability of structural polymer composites*
Name: G. Guerrero Muñoz
Advisor: D.Y. Wang
Position: Student (Research Initiation Fellowship)
Period: July 2023 - October 2023

61. *Recyclable composites*
Name: K.L. Hernández Gil
Advisor: Dr. J.J. Vilatela
Position: Student (Research Initiation Fellowship)
Period: June 2023 – September 2023

62. *Autonomous and Data-driven Nanocomposite Materials Discovery*
Name: E. Dios Lázaro
Advisor: Dr. M. Haranczyk
Position: Student (Research Initiation Fellowship)
Period: June 2023 – September 2023

63. *Physical and chemical characterization of biodegradable metal alloys or polymers for applications as implants or cell culture substrates*
Name: M.F. Melero
Advisor: Dr. J. Patterson
Position: Student (Research Initiation Fellowship)
Period: July 2023 – September 2023

64. *Development of high entropy alloys by advanced fabrication techniques*
Name: A. Cotobal Gómez (Student)
Advisor: Prof. J.M. Torralba
Position: Student
Period: July 2023 – September 2023

65. *Microscale fatigue behaviour of martensitic stainless steels*
Name: A. Ricciardi Lara
Advisor: Dr. I. Sabirov
Position: Student
Period: March 2023 – May 2023

66. *Additive manufacturing of medical devices with nitinol*
Name: A. De Blas de Miguel
Advisor: Dr. J.M. Molina-Aldareguia
Position: Student
Period: October 2023 – October 2023

67. *Recycling and revalorisation of waste for its application as a functional additive in biodegradable polymers*
Name: A. Guillén García
Advisor: Dr. D. Wang
Position: Student
Period: March 2023 – June 2023

68. *High entropy alloy components prepared from commodity alloys and Metal Injection moulding techniques*
Name: A. Alonso Romero
Advisor: Prof. J.M. Torralba
Position: Student
Period: October 2023 – May 2024

69. *Optimization of a Modified H13 Tool Steel for Manufacturing by Metal Injection Molding and 3D Printing*
Name: A. Martín Martín
Advisor: Dr. J.A. Meza
Position: Student
Period: December 2023 – March 2024

70. *Technical and research support*
Name: A. Clemot Medina
Advisor: J. de la Vega
Position: Student
Period: March 2023 – June 2023

71. *Title: Technical and research support*
Name: A. Guillén
Advisor: J. de la Vega
Position: Student
Period: March 2023 – June 2023

72. *Technical and research support*
Name: M. Bergaño Guzmán
Advisor: J. de la Vega
Position: Student
Period: September 2023 – May 2024

73. *Study on the effect of polymer structure on 3D printing*
Name: C. Martín Pérez
Advisor: Dr. J.P. Fernández
Position: Student
Period: January 2023 – September 2023

74. *Mechanical and Microstructural Characterisation of 3D Printed PA12 and TPU: Effect of Ageing*
Name: C. Cantador Flores
Advisor: Dr. M. Monclús
Position: Student
Period: November 2023 – June 2024

75. *Use of Machine Learning for Pulvimetallurgy Applications*
Name: D. de la Brena Fernández
Advisor: Prof. J.M. Torralba
Position: Student
Period: June 2023 – August 2023

76. *Characterization of wear of hard coatings under service conditions*
Name: D. Sanmartín Plano
Advisor: Dr. M. Monclús
Position: Student
Period: October 2023 – February 2024

77. *Study of fatigue crack propagation in advanced steels*
Name: D. Vaquero Cerezo
Advisor: Dr. I. Sabirov
Position: Student
Period: February 2023 – May 2023

78. *Solid-state processing*
Name: D. Iriarte Hernández
Advisor: Prof. J.M. Torralba
Position: Student
Period: February 2023 – April 2023

79. *Preparation and characterization of polyurethane elastomeric substrates for scaffold-free cell-based regenerative medicine therapy*
Name: E. de la Luz Bellido González
Advisor: Dr. J. Patterson
Position: Student
Period: February 2023 – May 2023

80. *Information Technology*
Name: G. Montoro Álvarez
Advisor: D. González
Position: Student
Period: April 2023 – June 2023

81. *Development of batteries and electrodes for the DITTCe project*
Name: I. de Loyola **Pérez del Val**
Advisor: Prof. J. LLorca
Position: Student
Period: June 2023 – July 2023

82. *Finance and administration*
Name: I.M. Urbina Urbina
Advisor: M. García
Position: Student
Period: June 2023 – April 2024

83. *Autonomous data-based materials design*
Name: J. Rubio Romero
Advisor: Dr. M. Haranczyk
Position: Student
Period: January 2023 – June 2023

84. *Development of autonomous laboratory for nanocomposite materials*
Name: J.J. Ilarraza Zuazo
Advisor: Dr. M. Haranczyk
Position: Student
Period: May 2023 – August 2023

85. *Role of grain boundaries in plastic deformation in pure Titanium*
Name: J. Morales Bustos
Advisor: Prof. J. LLorca
Position: Student
Period: February 2023 – August 2023

86. *Development of the robot lab*
Name: J. Audoux
Advisor: M. Haranczyk
Position: Student
Period: March 2023 – June 2023

87. *Additive manufacturing of recycled carbon fiber composite materials with chain extenders to improve adhesion*
Name: J. San Román de la Morena
Advisor: Dr. J.M. Molina-Aldareguia
Position: Student
Period: March 2023 – July 2023

88. *High-performance polymers and fire retardants*
Name: L. Arranz Marcos.
Advisor: Dr. D.Y. Wang
Position: Student
Period: September 2022 – January 2023

89. *Study of the evolution of the microstructure of metallic glasses manufactured by selective laser melting (SLM)*
Name: M. del Carmen Garrote Junco
Advisor: M. Rodríguez
Position: Student
Period: September 2023 – February 2024

90. *Technical support*
Name: M. Tararukhina
Advisor: A. San Román
Position: Student
Period: March 2023 – June 2023

91. *Analysis of 3D-printed carbon strands as deformation sensors*
Name: M. Herrerías Yagües
Advisor: Prof. C. González
Position: Student
Period: September 2022 – March 2023

92. *Micro- and nano-mechanics*
Name: M. Huete Aimen
Advisor: Dr. Muzi Li
Position: Student
Period: February 2023 – September 2023

93. *Finances and administration*
Name: P. Silva Freire
Advisor: M. Huerta
Position: Student
Period: September 2023 – May 2024

94. *Study of the mechanical behaviour and degradation/regeneration of bioabsorbable Mg and Zn composite structures fabricated with a multi-material 3D printer*
Name: P. Bardisa Estrada
Advisor: Dr. J. Sánchez del Río Sáez and Dr. C. Thompson
Position: Student
Period: October 2022 – January

95. *Supra-reticular fibers of carbon nanotubes*
Name: R. Fernández Torres
Advisor: Dr. J.J. Vilatela
Position: Student
Period: April 2022 – June 2023

96. *Fatigue and fracture behaviour of advanced high-strength steels*
Name: S. Mallet
Advisor: Dr. I. Sabirov
Position: Student
Period: April 2023 to July 2023

97. *Multifunctional nanocomposites*
Name: S. Cano Santigosa
Advisor: Dr. J.J. Vilatela
Position: Student
Period: October 2023 – January 2024

98. *3D printing and CAD designs for the electronics laboratory*
Name: S. Vela Bolado
Advisor: V. López
Position: Student
Period: July 2023 to July 2023

99. *Flame-retardant polymer composites*
Name: W. Tang
Advisor: Dr. D.Y. Wang
Position: Student
Period: December 2023 to November 2023

100. *High-performance polymers and fire retardants*
Name: Y.S. Mohamed
Advisor: Dr. R. Sánchez Díaz
Position: Student
Period: October 2023 to November 2023

5.4. Teaching in Masters

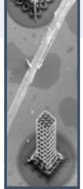
1. *Nanocomposites and nanostructured hybrid materials*
   Materials Engineering Master, Technical University of Madrid
   Dr. M. Echeverry-Rendón
   2023 - 2026

2. *Structural Design*
   Materials Engineering Master, Technical University of Madrid
   Dr. D. Mocerino
   2023 - 2024

3. *Nanocomposites and nanostructured hybrid materials*
   Materials Engineering Master, Technical University of Madrid
   Dr. D. Tilve Martínez
   2023 - 2024

5.5. Institutional activities

1. Member of the European Technology Platform for Advanced Engineering Materials and Technologies (EUMAT)
2. Member of the European Materials Characterization Council (EMCC)
3. Member of the European Aeronautics Science Network (EASN)
4. Member of the European Energy Research Alliance (EERA)
5. Member of the Batteries European Partnership Association (BEPA)
6. Member of the European Technology and Innovation Platform Batteries Europe
7. Member of the Royal Society of Chemistry
8. Member of the European Mechanics Society (EUROMECH)
9. Member of the Spanish Association of Composite Materials (AEMAC)
10. Technical Secretariat of the Spanish Technological Platform of Advanced Materials and Nanomaterials (MATERPLAT)
11. Member of the Spanish Aerospace Platform (PAE)
12. Member of the Spanish Technological Platform for Advanced Manufacturing (MANUKET)
13. Member of the Spanish Railway Technological Platform (PTFE)
14. Member of the Spanish Energy Storage Technological Platform (BatteryPlat)
15. Member of the Spanish Ceramics and Glass Society (SECV)
16. Member of the Spanish Society of Numerical Methods in Engineering (SEMNI)
17. Member of the Spanish Materials Society (SOCIEMAT)
18. Member of the Spanish Society of Theoretical and Applied Mechanics (SEMTA)
19. Member of the Spanish Catalysis Society (SECAT)
20. Member of the Spanish Royal Society of Chemistry (RSEQ)
21. Member of the Madrid Aerospace Cluster (MAC)
22. Member of the Severo Ochoa Centres and María de Maetzu Units Alliance (SOMMA)
23. Local Contact Point of the EURAXESS network
24. Member of the Spanish Association of Foundations (AFE)
25. Member of the Network of Research Laboratories of Comunidad de Madrid (REDLAB)



5.6. Training Courses Provided to Researchers and Staff

1. **Scientific entrepreneurship**. Delivered by: M.A.L. Trujillo, BA International Partners. January 2023.
2. **Workshop on atomistic modelling**. Delivered by: Prof. D. Spearot and Dr. Carlos Ruestes from IMDEA Materials Institute and the University of Florida. March 2023.
3. **Oral presentations: beyond slides.** Delivered by: L. Saemisch and G. Lucas from The PaperMill. May 2023.
4. **Creating your own career path and job search strategy**. Delivered by: M. Escobar from Carreras Científicas Alternativas. October 2023.
5. **Time and stress management**. Delivered by: U. Schubert. November 2023.

6. Communication, Outreach and Events

6.1. Organisation of Scientific/Industrial Events

1. **Winter Metals Meeting**. IMDEA Materials Institute. L. Martín, S.W. Ali Rizvi, E. Nieto, Dr. A. Boccardo, I. Rodríguez, J. Valilla, A. Sierra Soraluce, A. Gómez, M. Rodríguez Sánchez, S. Sadanand, S.V. Kumaran and A. De Nardi. Organised by Dr. I. Sabirov. February 2023.
2. **4th annual Open PhD Day**. IMDEA Materials Institute. April 2023.
3. **1st annual meeting of the European Network for the Mechanics of Matter at the Nanoscale**, IMDEA Materials Institute. April 2023.
4. **2nd annual Three Minute Thesis Talk (3MT).** IMDEA Materials Institute. Dr. X. Ao, J. de la Vega, S. Du, S. Sadanand, M. Zhang, S. Upama, Y. Liu, A. Sierra Soraluce, M. Castillon, L. Cobian and X. Li.
5. **6th International Advisory Board meeting.** IMDEA Materials Institute. July 2023.
6. **6th annual Symposium on Alloys for Additive Manufacturing (AAMS).** Organised by: Dr. M.T. Pérez-Prado. Carlos III University of Madrid. October 2023.
7. **User Conference for Hexagon Manufacturing Intelligence Iberia.** IMDEA Materials Institute. October 2023.

6.2. Participation in scientific/industrial events

1. **City and Science Biennial**. Organised by the Spanish Foundation for Science and Technology (FECYT) and the Círculo de Bellas Artes. Madrid. J. Valilla, J. García, D. Mocerino, J. de la Vega, J. León, J. Hobson, P. Paramio, C. Corchado, C. Costa, E. Nieto. February 2023.

2. **13th annual 'Madrid is Science' Fair**. Organised by the Madrid Regional Government and madri+d. Dr. X. Ao, Dr. D. Mocerino, Dr. P.J Navarrete Segado, J. García, A. Castro, A. Sierra Soraluce, V. Sevositanova, V. López, I. Escobar, J. León, D. Aveiga, P. Paramio, B. Limones, J.G. Pérez, C. Pereira, C. Corchado, J. Hobson, C. Martínez Alonso, M. Sales, M. Zarzoso and J. de la Vega.
3. **Falling Walls Lab Madrid 2023**. Madrid. Dr. P.J. Navarrete Segado, 'Breaking the wall of cardiac regeneration', May 2023.
4. **European Researchers' Night**. Madrid. Dr. M. de Nicolás Morillas and Prof. J.M. Torralba. September 2023.
5. **Madrid's Science and Innovation Week**. Organised by the Regional Madrid Government and madri+d. Madrid. Drs. M. Monclús, R. Sánchez, M. Islam, A. Boccardo, and L. Cobian and Y. Sbihi. November 2023.
6. **Transfiere 2023.** Málaga. M.A. Rodiel and E. Troche
7. **Patents for Innovation (P4I).** Madrid. M.A Rodiel and E. Troche
8. **3rd Meeting of the European Lightweighting Network (ELN).** Stockholm. M.A. Rodiel

6.3. School and university visits

1. *CASVI Villaviciosa de Odón*. Students in attendance: 40. February 22, 2023.
2. *University of Navarra*. Students in attendance: 60. February 24, 2023.
3. *Orvalle School*. Students in attendance: 60. March 6, 2023.
4. *4ESO + Empresa*. Students in attendance: 6. March 27-28, 2023.
5. *IES Antonio Fraguas Forges*. Students in attendance: 40. April 20, 2023.
6. *Carlos III University of Madrid.* Students in attendance. 30. June 7, 2023.
7. *Virgen de Europa School*. Students in attendance: 65. October 10, 2023.
8. *Complutense University of Madrid.* Students in attendance: 9. November 15, 2023.
9. *Retamar School.* Students in attendance: 20. November 20, 2023.

6.4. Highlighted media appearances

1. New Cheap and Durable Seismic Detector. **Ciencia Contada en Español (Agencia SINC)**: January 16, 2023.
2. Changing the world's most resource-intensive industry with metal 3D printing. **3D Printing Industry**. February 1, 2023.
3. Artificial intelligence and robots to design the next generation of customized materials. **ABC**. February 5, 2023.
4. IMDEA Materials studies how to stop tumour growth with cerebral implant. **CadenaSER.**
5. Safer helmets and more durable running shoes, made in Madrid. **TeleMadrid**. February 21, 2023.
6. Floatech, the Madrid-based startup eyes industrial-scale manufacturing of silicon anodes with its first pilot plant. **Batteries News**. March 30, 2023.
7. Researchers developing portable device that improves circulation. **CadenaSER.** April 10, 2023.
8. The Spanish startup that is already defining the next generation of batteries. **ABC**. April 17, 2023.
9. First scalable and continuous surface modification process for magnesium alloy wires. **SURFAS**. April 25, 2023.
10. Madrid studies the creation of stronger and more affordable bone implants. **ConSalud**. August 28, 2023.
11. IMDEA Materials researcher how to create heart tissue to improve recovery for heart attack patients. **El Mundo**. August 28, 2023.

12. IMDEA investigates how to use artificial intelligence to produce steel more efficiently. **Acermetal.** September 20, 2023.
13. IMDEA Materials Institute's Scientific Director receives national prize from the Ministry of Science and Innovation. **CadenaSER**. September 27, 2023.
14. IMDEA Materials and the UC3M present a new testing method for 3D-printed metal structures. **3D Printr.** November 17, 2023.
15. IMDEA Materials seeks to resolve a major recycling problem in the aeronautical industry, **Actualidad Aeroespacial**. December 1, 2023.

6.5. Researcher articles featured in The Conversation

1. 1. The materials that convert a Formula 1 car into the safest and fastest machine possible. **Prof. J.M. Torralba**. January 3, 2023.
2. 2. Nuclear fusion: what material can contain a star on Earth? **Dr. C. Ruestes** and **Prof. J. Segurado**. January 25, 2023.
3. 3. Mount Everest, runway of technical fashion: from wool and leather to Gore-Tex **L. Martín**. February 28, 2023.
4. 4. The secret of Damascus swords. **Prof. J.M. Torralba** and **Dr. I. Sabirov.** April 9, 2023.
5. 5. Silence in the city: the new wave of topological materials. **Dr. J. Christensen.** July 10, 2023.
6. 6. Do we have enough materials to make an energy transition actually possible? **M.A. Rodiel and Prof. J.M. Torralba.** September 21, 2023.
7. 7. What is the most used yet least studied material on the planet? **Prof. J.M. Torralba.** October 10, 2023.
8. 8. Fire converts nightclubs and homes into death traps: how to avoid it without replacing flammable materials?. **Dr. D.Y. Wang**. November 9, 2023.
9. 9. The most impressive experiments carried out on the International Space Station. **Dr. J. Ordoño**. November 20, 2023.
10. 10. An imaginative proposal to recycle all the world's electronic waste. **Drs. A. Meza** and **D. Tourret** and **Prof. J.M. Torralba.** December 6, 2023.

6.6. Researcher courses featured in Amautas

1. Materials that save lives. **Dr. M. Echeverry-Rendón.** March 2023.
2. Science and art. **C. Martínez Alonso**. November 2023.
3. Understanding catalysis. **C. Martínez Alonso.** December 2023.

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