EXETER TECHNOLOGIES GROUP

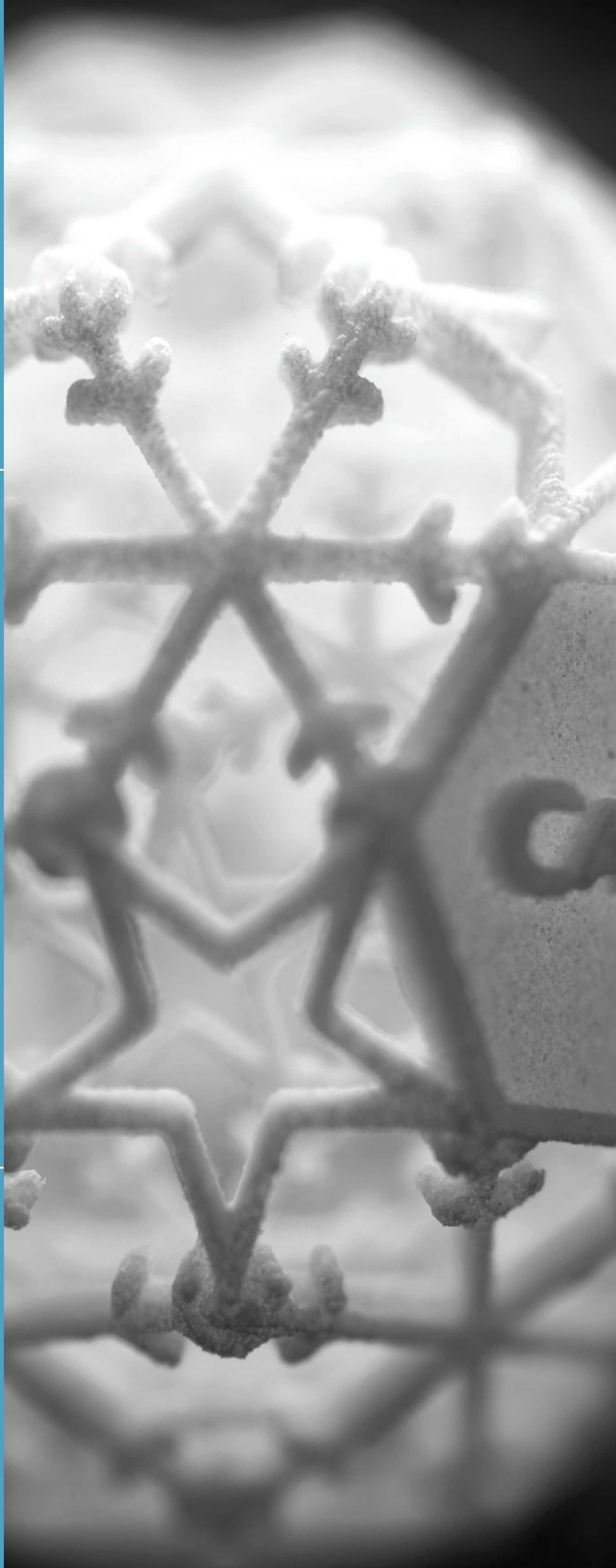
Centre for Additive Layer Manufacturing

RESEARCH AND DEVELOPMENT

Research and Development at CALM
(Centre for Additive Layer Manufacturing)

UNIVERSITY OF EXETER

contents



Cover image: EOSINT P 800 in action, manufacturing the PEK violin, as featured in the Economist.

CALM is the centre of excellence in Additive Manufacturing (AM) at the University of Exeter.

CALM is a leading research centre, working at multiple Technology Readiness Levels, on both fundamental and applied research. Our projects are funded through research councils (eg EPSRC), government organisations (eg Innovate UK and EU) or directly with industry partners through short and long term contract research. We aim to achieve maximum impact from our work and therefore collaborate with a wide range of organisations.

CALM offers independent research and technical support, working with both academia and industry worldwide, to develop the next generation of materials for engineering and high temperature polymers and composites.

With a background in material science and manufacturing, we are highly experienced in Additive Manufacturing (AM) materials research and development, from powder research, through to sintering and process investigation for part manufacture and analysis.

The Centre for Additive Layer Manufacturing (CALM)

Established in 2010, following significant investment from the EU, the University of Exeter and Airbus Group Innovations, CALM has supported hundreds of businesses in their quest to investigate and use AM.

We have an extensive research programme on materials for AM and offer contract research on all aspects of the technology, working in partnership with companies, other universities and government agencies.

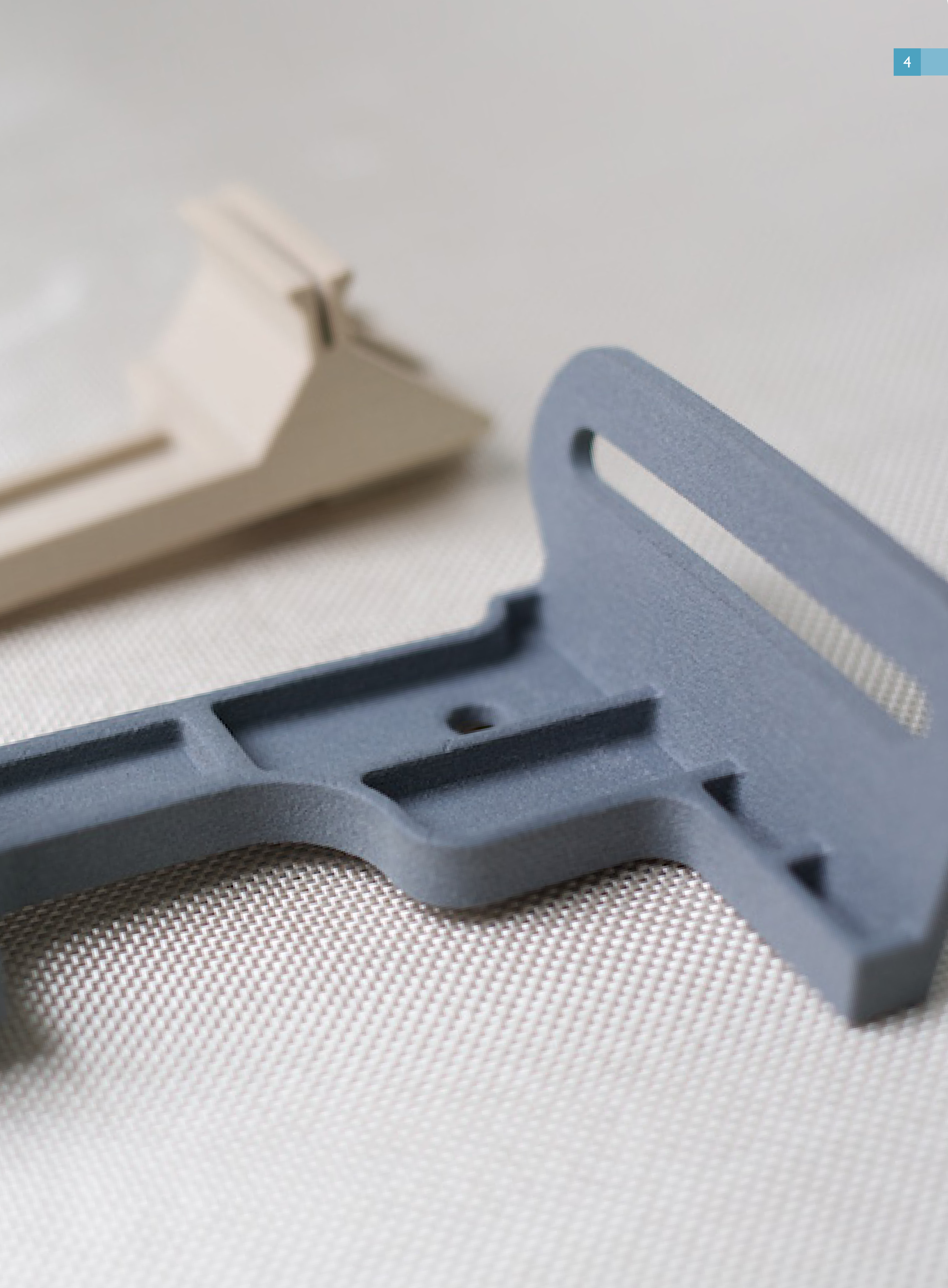
Understanding the relationship between microstructure, processing and parts performance is at the heart of materials and process development. Particularly focused on solving material issues in AM, we work together with our research partners at the cutting edge of current knowledge. We are working on projects that stretch and deepen our knowledge of AM for high value and high impact industrial applications, creating more functional and sustainable products and processes. We are the only independent centre worldwide researching laser sintering of high temperature and high performance engineering polymers and composites using both the commercial high temperature laser sintering platform EOSINT P 800 and the EOSINT P 810.

As the leading centre of excellence in the high temperature AM sector, CALM is conducting pioneering research on AM techniques, examining how it can enable and speed-up the widespread adoption and use of AM technologies in industrial production.

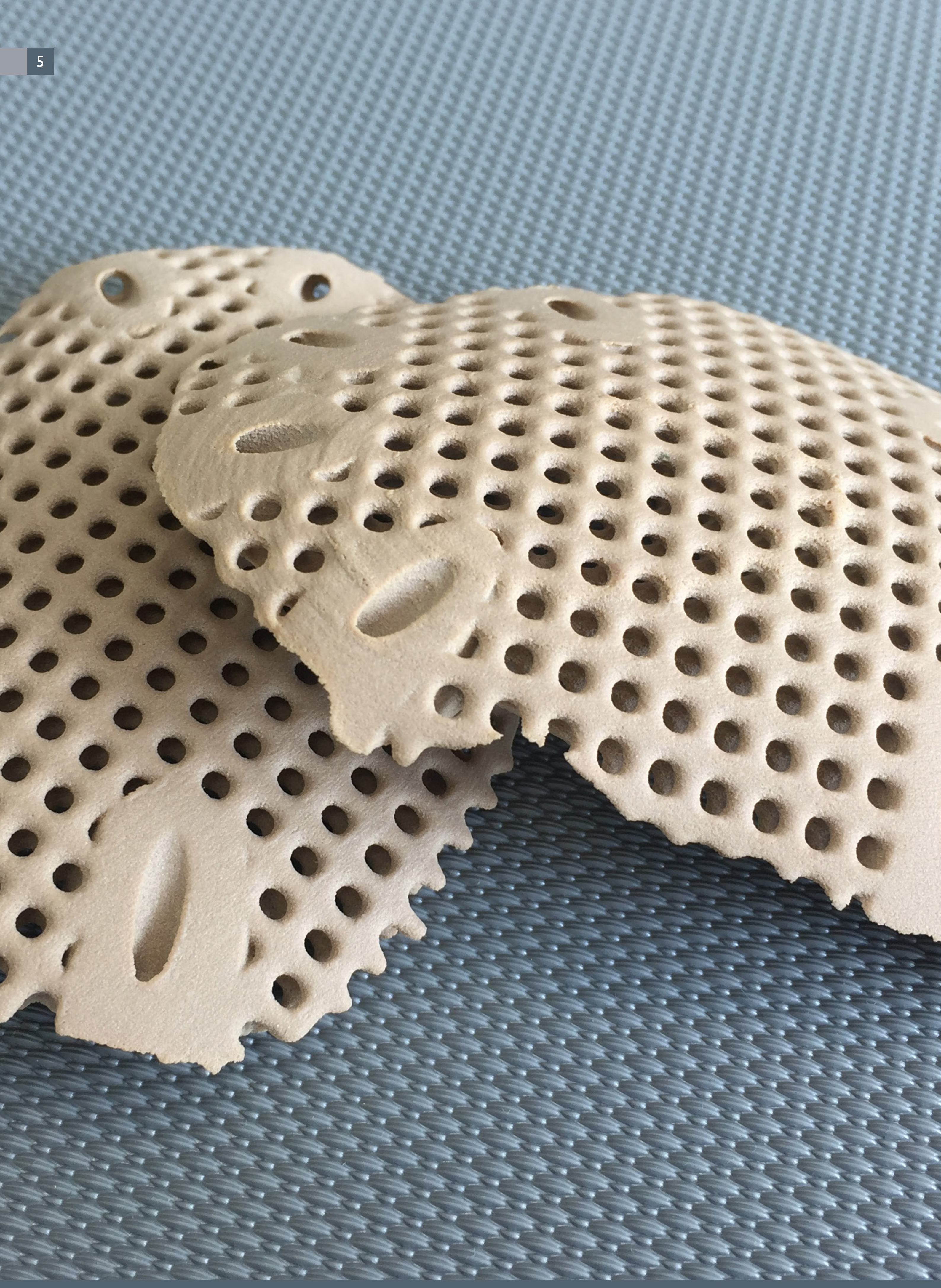
With an extensive suite of high temperature laser sintering (including both the EOS P 800 and P 810) and material extrusion/FFF equipment, CALM is helping to tailor existing materials and develop new ones.

These include high temperature PAEK varieties and fluoropolymers, and high performance composites incorporating carbon fillers (graphite, carbon black), glass and carbon fibre reinforcement, carbon nanotubes (CNT), graphene, boron nitride and ceramic particles (WS_2).

We have the experience and capabilities required to run and compare new manufacturing technologies with established, conventional processes (eg extrusion, compression and injection moulding), and simulate manufacturing processes in thermal profiles and gas atmospheres.



CNT/PEEK bracket for improved light weighting and performance.



Customised PEEK cranial implant geometries manufactured with laser sintering.

AM challenges

AM is an enabling manufacturing technology and a catalyst for opening up new markets in customised products (for example patient specific surgical implants, or bespoke production equipment and tooling).

AM offers tantalising prospects for better designed, more cost effective and sustainable products. Material developments have come a long way over the last decade and more grades have appeared, particularly with regards to filament-based options. However, there are still significant challenges, such as:

- The need for better control and to monitor materials and systems in process
- The requirement for qualification of material properties across a range of production systems
- The need to better understand the relationships between material, process and properties, including shrinkage, warpage and distortion, as well as how the microstructure of materials affects the printing and part performance
- The need for better prediction and modelling to aid material/design selection for the required application

Robust AM manufacturing will only become widely adopted when material properties are known and understood at all levels – from molecular to macroscopic structures.

Our mission is to provide evidence-based solutions to the material challenges facing AM.

Multifunctionality and Powder Processing

Demands for greater functionality from parts and materials is being met with innovation in powder and material production.

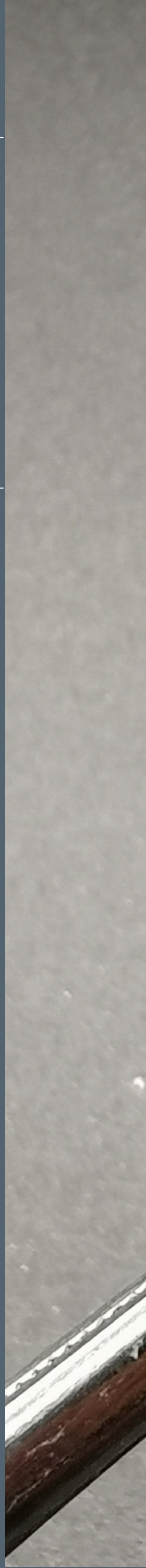
As the range of materials is expanding, end users and product designers are now seeking greater design freedom in their materials looking to build functionality into the part through enhanced material properties.

There are demands for electrical and electromagnetic conductivity and insulation, adsorption properties and mechanical reinforcements.

CALM has worked with partners on industrial and government funded projects to develop new, safe methods for incorporating nanoparticles and fibres into AM powders, and optimise powder flow and the printing process.

Examples of methods include:
1. Mechanofusion^{TM} process available from Hosokawa - During the Innovate UK funded project (F4 PAEK) (see page 22), the technology was used to achieve suitable nanocomposites, for producing parts with improved mechanical or conductivity performance.

2. Core-shell encapsulation – A unique (patented) method for encapsulating nano-particles such as MOFs (Metal Organic Frameworks) directly onto the polymer matrix (patented). CALM has developed a range of MOF coated polymeric powders for AM with benefits such as CO_2 adsorbtion and H_2 storage capacity (such as ZIF-67, ZIF-8, MIL-125, HKUST-1, MOF-74 on PAEKs and PA12).



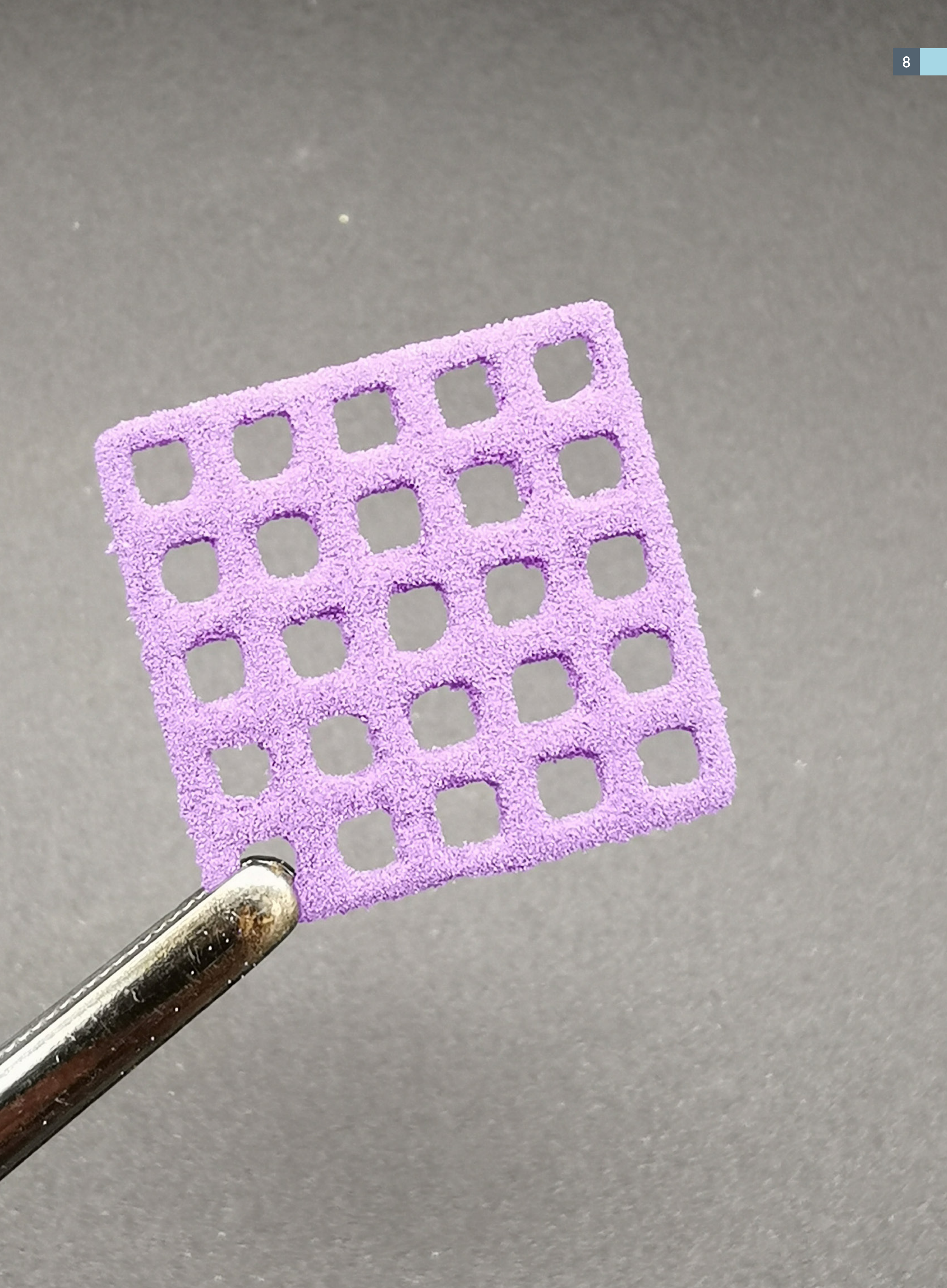
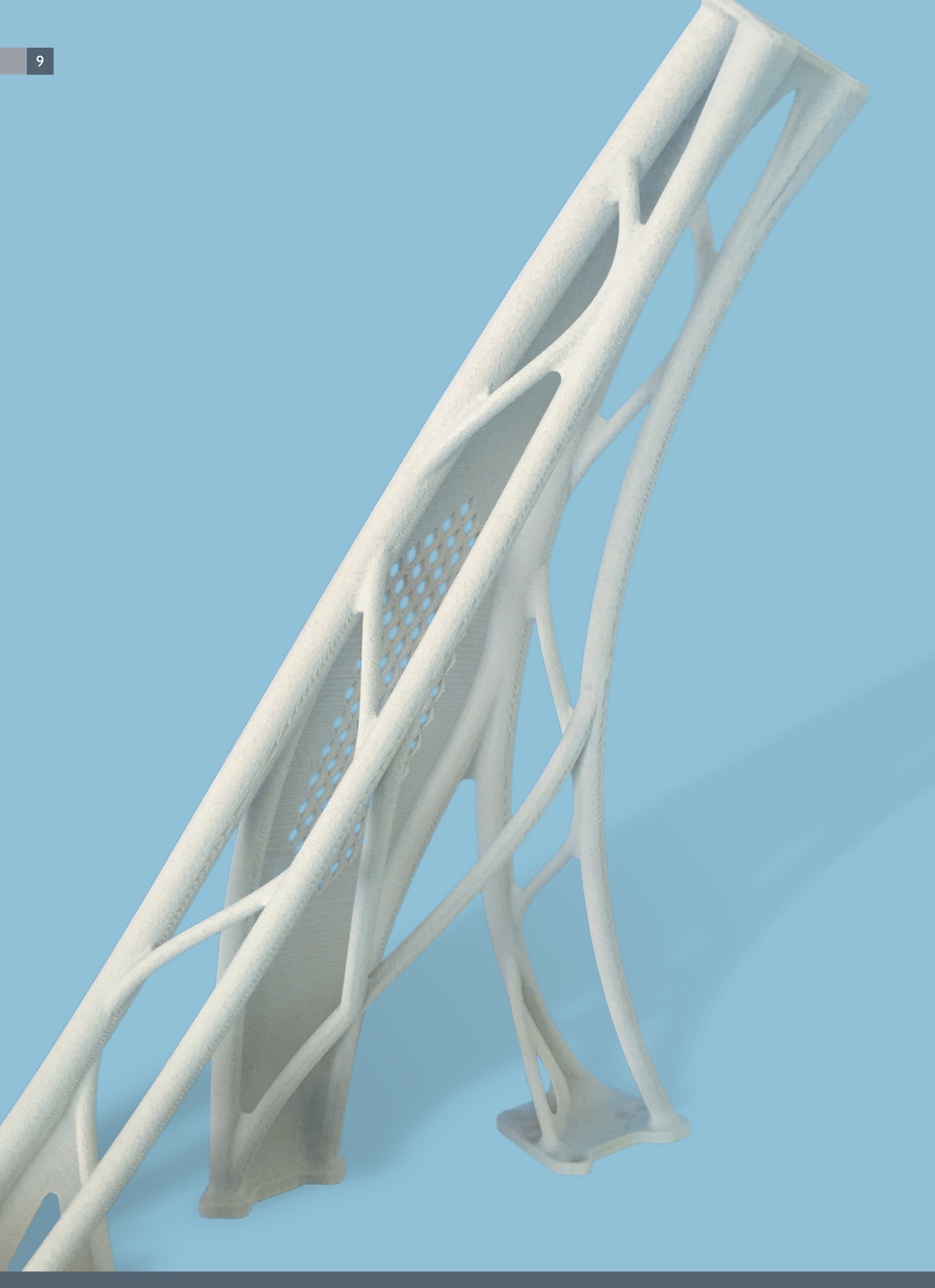


Image: Laser sintered Metal Organic Frameworks (MOF)/PA12 structure. The MOF is Zeolite Imidazolate Frameworks (ZIF-67)



Topologically optimised demonstrator bracket made of experimental Victrex PAEK material. Design owned by 3T RPD Ltd., who reserves all rights to it.

Expanding knowledge of AM materials

As AM moves from development into full-scale production, material understanding remains essential.

CALM is a global leader in materials research for high temperature laser sintering, publishing data that is independent from powder suppliers and machine manufacturers. **For recent publications see page 29.**

Despite laser sintering being one of the most cost-effective and robust AM production methods, the range of commercially available materials that can be used in the process is still limited.

CALM is working with its partners to develop new high performance polymers. Using in-house designed methodologies and tests we investigate how the size and morphology of particles and subtle changes in chemical structures influence powder flow, spreadability and sintering. This is combined with statistical and mathematical methods to predict powder properties and performance.

Through this work we are developing ways of improving key component properties and adding multi-functionality to parts. This includes introducing a range of glass, carbon fillers and nano-materials to create composite materials, providing new opportunities for the manufacture of lightweight and functional components.

Using in-house compounders, extruders and mixers, we manufacture and test novel AM composite powders at low and medium batch sizes.

In process knowledge is vital in AM

CALM is one of only a few organisations worldwide able to make high performing polymeric structures with the commercially available high temperature laser sintering EOSINT P 800 and the EOSINT P 810 machines.

Using in-depth microstructure testing and analysis combined with modelling, we can predict and control the variability of components manufactured within the same build chamber, and also components manufactured on a range of different machine systems by different suppliers.

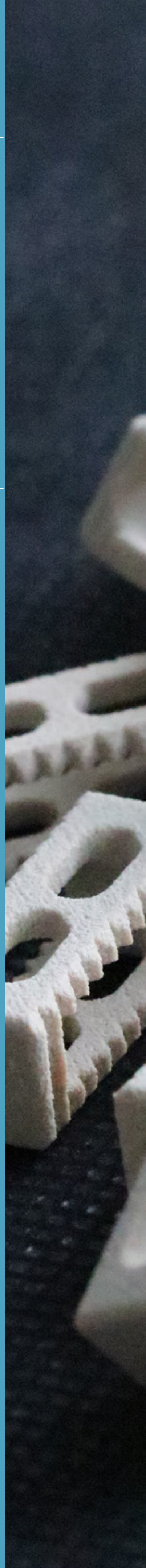
Process control based on in-depth material investigations is vital for AM to become an accepted production tool.

Our work is rooted in realistic applications and production scenarios.

We use our knowledge to develop production-friendly ways of inspecting AM components.

For example, we have designed a potentially non-destructive test, using Raman spectroscopy, which quickly determines the surface roughness of AM components and relates it to laser sintering manufacturing parameters.

Investigating fully manufactured components only tells us half of the story. Using specific sensor technologies, we determine what happens to materials during manufacture. For example, the need for continuous in-line material monitoring led us to use optical fibre sensors for process improvement.



ASTM spinal cage geometries manufactured with laser sintered PAEK.

A selection of equipment available within the CALM facilities.

World-leading facilities

CALM has an extensive suite of high temperature powder bed and material extrusion (known as fused filament fabrication (FFF)) equipment, and latest material characterisation instrumentation.

Together with our partners we have invested in our equipment and facilities to ensure we are at the cutting-edge of research developments.

Alongside testing and developing materials on the latest equipment, we are pushing the knowledge boundaries of materials characterisation. A comprehensive set of methodologies allows us to predict powder flow and material performance in the lab before scaling up for printing.

Powder Bed Fusion – CALM's focus on high temperature systems means we have both the EOS P 800 and EOS P 810 systems available for research studies, whilst other technologies such as the EOS P 100 and Sharebot SnowWhite extend the research across the polymeric landscape.

Material Extrusion – We continue to invest in the latest 3D printing equipment with offerings from 3D Gence, Intamsys, Minifactory, Mark Forged and others, all available at CALM, allowing us to validate materials across a range of hardware and temperature environment options.

Particle and powder flow analysis, material characterisation and polymer melt rheology – Understanding particle flow is vital to understanding printing performance. Combining a unique knowledge in modelling and a wide range of powder data gathered from equipment such as the particle size analyser, FT4 powder rheometer and rotary powder analyser, with thermal characterisation, imagery and other bespoke processes, we can define material and process requirements.

Improving knowledge and design of AM components

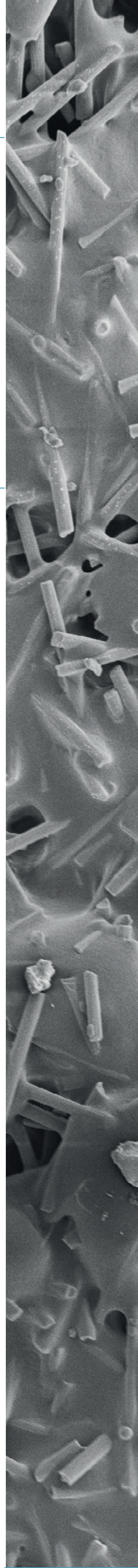
Quantifying key bulk properties using standard techniques is just the beginning of our investigations.

With an array of specialised tests, ranging from thermal and optical imaging techniques through to rheology and mechanical, we thoroughly investigate and scrutinise components. This helps us define component microstructure.

We identify how microstructure affects important macroscopic properties, helping us to predict how AM components will behave when in use. Materials and parts characterisation allows us to define the material-process-properties relationship and define design guidelines as a function of material or equipment used. Different techniques offer different resolution and different levels of design freedom. We are able to advise and assess full parameters and equipment capabilities.

In addition, we are determined to understand and provide solutions to outstanding issues still concerning the AM processes including:

- Improving strength in the z-direction
- Developing new methods to fabricate composite materials to both reinforce components and add functionality
- Matching the performance of parts manufactured using conventional techniques
- Comparisons of AM technologies for specific applications
- Supporting the development of standards
- Collation of datasets and development of statistical and modelling solutions



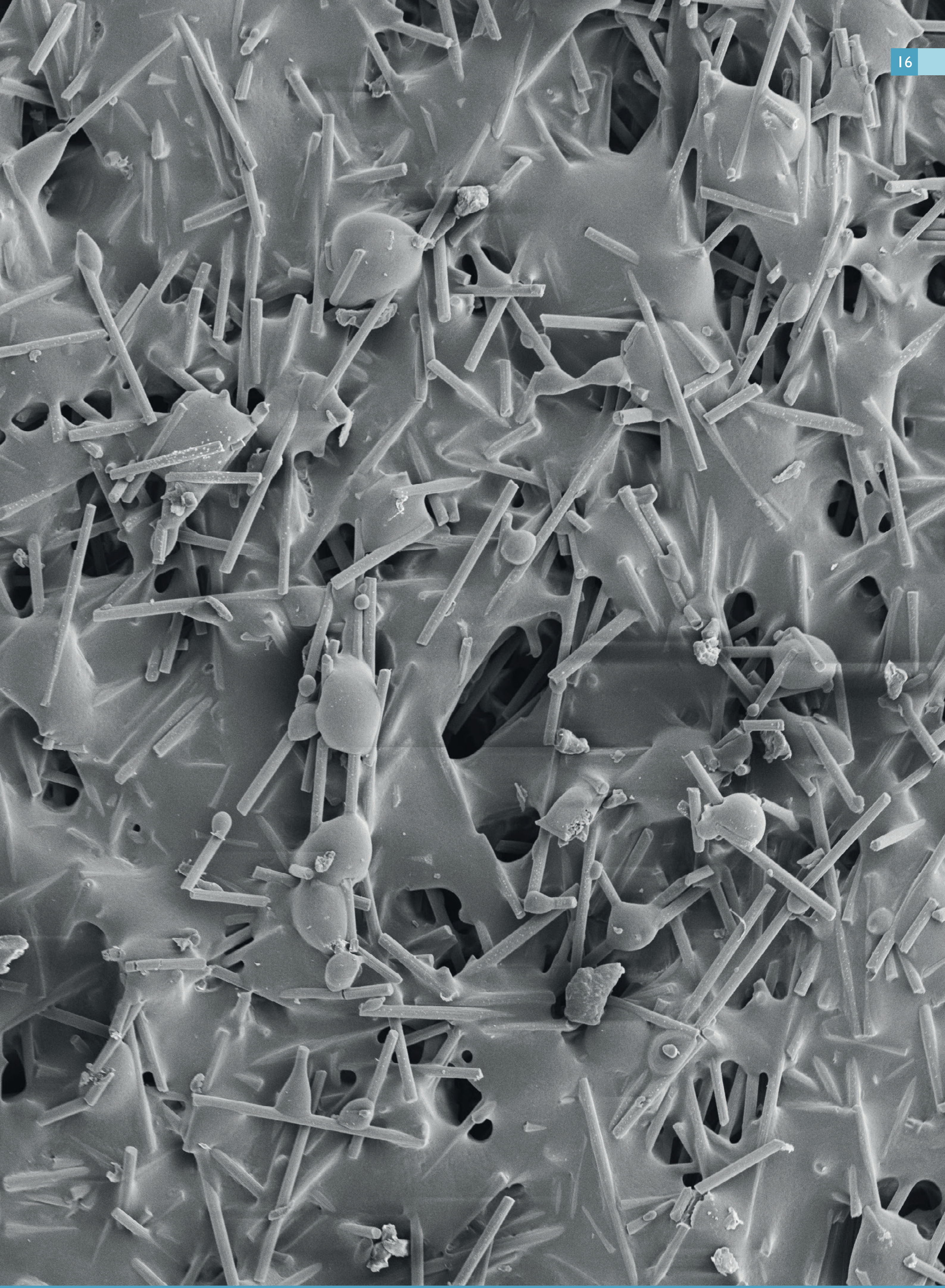


Image of a sintered layer of carbon fibre reinforced PAEK.

Victrex – University of Exeter Partnership

Victrex and the University of Exeter are committed to a research partnership to progress Additive Manufacturing to the next level. The multi-million pound collaboration is designed to exploit the full potential of high-performance PAEK polymers in Additive Manufacturing.

The aim is to further develop the next generation of PAEK polymers for Additive Manufacturing (AM) and commercialise novel material solutions throughout the supply chain (materials, processes, design, parts). It will also seek to develop a broader platform for new and existing AM technologies, to enhance the speed at which products can be prototyped and brought to market, and reduce waste levels involved in some of the current processes.

The partnership continues to progress cutting edge polymeric research for Additive Manufacturing, building up an extensive database of new insight and data which can be used to model and tailor new development grades.

Some of the successes to date include:

1.The launch of the new VICTREX AM™200 filament – a new, high performance polymer optimised and successfully implemented on over ten platforms with global resellers, including Intamsys, 3DGence, 3NTR, Aon3D, and Stratasys.

2. New knowledge and methodologies for powder development, including new developmental grades, accurate prediction of powder flow performance and optimised manufacturing and pre-treatment processes.

3. World leading facilities – through combined investment the facilities at CALM are now world leading for research into high performance polymers for AM, both in terms of characterisation and manufacturing options. Both partners are keen to open up these facilities to more partners, strengthening collaborations and accelerating developments.

4. Materials database – the knowledge gained from analysing multiple materials has resulted in an extensive database of parameters which can be used for prediction, statistical analysis and modelling opportunities. By comparing results against this benchmark data a thorough understanding of the properties of new materials can be gathered and the materials quickly modified as required to optimise their function.

5. Robust fundamental knowledge in crystallisation kinetics, melt rheology and shrinkage form the foundations of our work.

The partnership continues to thrive with innovation and collaboration at the heart of all operations and new developments to be announced in the coming years. Both partners Victrex and CALM are open to the integration of new partners into this successful partnership.

Funded by: Victrex plc and the University of Exeter

Innovate UK 10004428 Overprinting with high-performance polymers – OverHiPP

OverHiPP will develop and optimise a new hybrid manufacturing technique for overprinting features, inserts and conductive materials onto thermoformed organo-sheets and other components.

The solution will utilise 5-axis 3D printing technology and optimise existing and new high performance materials, providing a new manufacturing process for low-medium volume requirements, with improved design flexibility and efficiency savings.

The consortium, led by the LEHVOSS UK and formed by CALM, Victrex, FDM Digital Solutions, Q5D Technology and GRM Consulting, is targeting an advisory board formed by automotive, aerospace, medical technology, and defence companies; with applications including electronic components, sensors, structural components and medical instruments and aids.

Expected results from this project are new material combinations and improved processes for overprinting, new applications, unique hardware for printing high-performance polymers onto non-planar surfaces, new software for the optimal positioning and orientation of materials and parts, as well as demonstrator components.

Funded by: Innovate UK

Partners: LehVoss UK ltd, Victrex Manufacturing Ltd, G.R.M. Consulting Ltd, Q5D Technologies Ltd, FDM Digital Solutions Ltd,

Research projects

Sartorius Stedim Knowledge Transfer Partnership (KTP)

A 2 year programme of work aims to embed knowledge within the AM team at Sartorius Stedim, to enhance its material characterisation and materials development knowledge for AM.

The primary goal of the project being to develop polymeric powder materials optimised for AM for the biopharma industry.

Funded by: Innovate UK
Partners: Sartorius Stedim

EPSRC Researcher in Residence (RiR) at the Manufacturing Technology Centre(MTC)

In 2019, The National Centre for Additive Manufacturing (NCAM) at the Manufacturing Technology Centre (MTC) signed a Memorandum of Understanding with the University of Exeter to support and collaborate in the development of high performance polymer components using additive manufacturing.

This was further built on with the appointment of Professor Oana Ghita as the Researcher in Residence for polymeric AM. Working in partnership the Centres sought out organisations with interest and opportunities in using HPPs with AM and worked with them to further develop these ideas.

Funded by: EPSRC
Partners: The Manufacturing Technology Centre (MTC)

Reaching the PEEK in Additive Manufacturing – An application case study in partnership with Thales and MTC.

The CALM team at the University of Exeter worked with the MTC and Thales UK, to showcase how AM can be used with high performance polymers such as PEEK, to produce production parts for high value applications.

This case study attempted to showcase some of the steps required to design and build these components, whilst providing a brief overview of the technologies available.

This case study contributed towards the evaluation of high performance polymeric AM technologies within Thales, guiding engineers in their choice of materials and AM processes which will help define the next generation of products and manufacturing processes.

Through discussions the team was able to identify a suitable product to investigate and from this, all partners worked together to develop a new design, before printing the part in Exeter's EOS P 800 system. The study was carried out using Victrex 450PEEK grade, a well know PEEK grade used extensively for machining, as well as injection and compression moulding, but not optimised for AM. This provided a good comparison for Thales with a material grade used by the teams and well understood.

This case study contributed towards the evaluation of high performance polymeric AM technologies within Thales, guiding engineers in their choice of materials and AM processes which will help define the next generation of products and manufacturing processes.

The final parts were inspected by the Thales team and they confirmed the expected benefits had been successfully realised, including 1) elimination of the assembly stage – the original design was based on four parts and, 2) the creation of a lighter part with less material wastage.

The full case study was presented at the TCT show 2021 and published in the TCT magazine:

www.tctmagazine.com/additive-manufacturing-3d-printing-industry-insights/reaching-the-peek-in-additive-manufacturing/

Funded by: EPSRC
Partners: The Manufacturing Technology Centre (MTC), Thales UK Ltd

A selection of facilities available within the CALM laboratory

Innovate UK 391 – Multifunctional PAEK nanocomposites for Additive Manufacturing (F4 PAEK)

Combining nano-particles with PAEK polymers, this project looked to develop new bespoke lightweight multifunctional materials that could be 3D printed using powder bed fusion technology and material extrusion/FFF. PAEK polymers are temperature resistant, tough and corrosion resistant. They are increasingly being used as a metal replacement within aviation and military applications.

Boron nitride and graphene were selected as the nano-materials most suited for the intended applications here. These new materials offer multifunctional capabilities including lightweighting, thermal and electro-magnetic properties.

The project studied the surface chemistry of the nanoparticles for good interface bonding with PAEK; fabrication of the composite powder (encapsulation of the nanoparticles either on the surface or within the bulk of the PAEK particles) and laser sintering of these new powders. Powder properties (bulk density, compaction, shape – roundness and circularity, aspect ratio, viscosity, surface tension) are key parameters for a good sintering process.

Incorporation of nanomaterials with different particle sizes and shape, significantly affect powder flow, polymer viscosity and subsequently sintering mechanisms. New techniques were developed and materials optimised for both the material extrusion and laser sintering processes.

Funded by: Innovate UK

Partners: Qioptiq, Thales UK Ltd, Victrex Manufacturing Ltd, Hosokawa Micron Ltd, Airbus Operations Ltd, 2-DTech Ltd, Haydale Ltd

Innovate UK 102362 – High temperature affordable polymer composites for aerospace applications

High performance mouldable plastics like PEEK and others in the polyaryletherketone family (PAEK), and their engineered composites are materials of the future and of particular interest to airframe makers as a metal replacement, being 40-70% lighter than steel, titanium or aluminium. PAEK composites are also highly corrosion resistant, heat tolerant to 250°C+, possess outstanding flame, smoke, and toxicity performance, and can compete mechanically.

CALM was part of a consortium of eight organisations, led by Victrex, an innovative world leader in high-performance PAEK/PEEK polymer solutions headquartered in the UK, to develop PAEK for various 3D printing processes. This initiative brought together the entire materials and processing supply chain, including polymer makers/ suppliers, through to parts manufacturers, post-processors and end users.

As a result of this large collaboration, Victrex is preparing newly developed materials for Additive Manufacturing (AM). The first of these is a high strength material for laser sintering (LS) which attains lower refresh rates, resulting in improved recycling for unsintered powder. The second is a filament with better Z-strength than existing PAEK materials and better printability for filament fusion (FF).

“These next-generation VICTREX PAEK materials for Additive Manufacturing mark a decisive step forward, having potential to transform multiple applications, including Aerospace and Medical. The exciting progress is based on continued intense R&D at Victrex and excellent collaboration within the Victrex led consortium of companies and institutions pursuing innovation in Additive Manufacturing. Through this consortium we’re already seeing demonstrator parts that show how AM processes, coupled with high-performance materials, transform thinking to create truly innovative parts based on increased design possibilities.”

Jakob Sigurdsson, Victrex CEO

The new VICTREX PAEK filament and powder tie in with technologies developed by other members of this Innovate UK project. EOS has recently released a new automation-ready manufacturing platform for laser sintering of plastic parts on an industrial scale (EOS P 500) with the capability to print high-performance polymers at high temperatures. Selected materials of the consortium are evaluated at EOS R&D facilities for processability on current EOS systems as well as for use with the EOS P 500 platforms. Victrex is planning to continue pre-commercial testing of a new PAEK Filament product in conjunction with consortium partner E3D, who has recently commercially released a new water-cooled filament extruder head especially optimised for this new PAEK filament.

In parallel with the material developments and process optimisation, South West Metal Finishing Ltd (SWMF), a specialist in surface treatment of aerospace components and part of the consortium, developed the first known surface treatment process, which enhances all surfaces of Additive Manufactured PAEK components by chemically dissolving the material to remove semi-sintered powder particles and large undulations, leading to smoothing of the surfaces.

CALM has also strengthened its methodologies and procedures of testing and analysis of PAEK HPP powders for AM, by creating rigorous protocols, ready to be used in new material developments.

This project was conceived and the team established following the first conference on European Strategy for Additive Manufacturing with High Temperature Polymers, held by the University of Exeter in 2014.

Funded by: Innovate UK (Aerospace Technology Institute)

Partners: Victrex Manufacturing Limited, University of Exeter, E3D-Online Ltd, South West Metal Finishing Limited, Airbus Group Limited, 3T-RPD Ltd, EOS, HiETA Technologies

EPSRC EP/R00478I/I - TEAM-A: The tailored electromagnetic and acoustic materials accelerator

CALM is a partner in a five-year Prosperity Partnership programme with QinetiQ together with other research groups across the College of Engineering Mathematics and Physical Sciences.

The partnership is focused on developing advanced matenals that can be used to control and manipulate the propagation of electromagnetic and acoustic energy in a highly tailored, bespoke fashion, and develop innovative techniques for their cost-effective manufacture.

Materials that have the ability to fully control and manipulate tho flow of electromagnetic (eg radiated heat. light. radiowaves) and acoustic (eg sound, vibration, shock) energy have the potential to transform, and enable, a large and diverse range of technologies. Exeter and QinetiQ have long been at the forefront of the science and engineering of such materials, with recent examples being: the modification of wind turbines to reduce their Interference with meteorological and aviation radar systoms. where half of the viable wind-farm sites In the UK arc currendy blocked for this reason, and the development of new optoelectronic materials for the realisation of beyond ultra-high definition displays.

However, there are still slgniftcant challenges prohibiting the widespread take up of these new materials in applications. In particular, concepts developed in the laboratory are often incompatible with commercial manufacture, due to their complexity and the nature of the constituent parts. Instead, the basic science that describes the behaviour of these new materials needs to be combined with a detailed understanding of how such materials could be manufactured, so that now materials can be designed and engineered to tackle specific technological challenges using commercially viable approaches.

The full programme will develop advanced materials that can be used to control and manipulate the propagation of electromagnetic and acoustic energy in a highly tailored, bespoke fashion, and develop innovative techniques for their cost-effective manufacture.

Funded by: EPSRC
Patners: QinenQ

Arkema & CALM PhD

Arkema and CALM worked together on optimising Poly Ether Ketone Ketones (PEKK) for the EOSINT P 800 powder bed process.

Arkema is a French chemical company leader in the field of high performance polymer materials, one of which is PEKK, invented in the 1960s as part of the Apollo space program.

PEKK Kepstan®, PEKK from Arkema, has a very high melting point (300°C to 360°C depending on the grade) and provides excellent mechanical properties, excellent resistance to chemicals and abrasion. Reinforced with carbon fibres, it is as rigid as some metals, but very much lighter and it is non-flammable without releasing any toxic fumes.

The PhD aimed to gain a deep understanding of the material at the microstructure level in order to optimise it for the manufacturing process.

Funded by: University of Exeter and Arkema

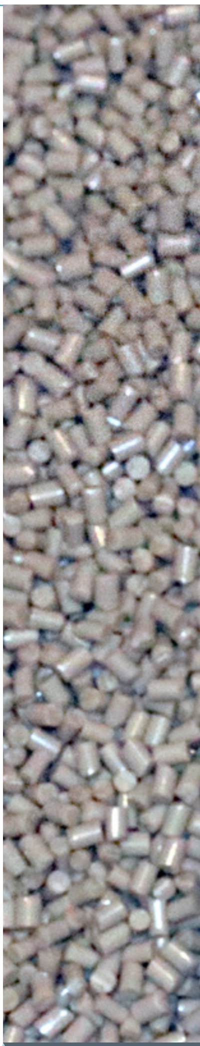
Research projects

Bond High Performance 3D & CALM PhD

CALM in partnership with Bond 3D co-funded a PhD studentship seeking to investigate polymer behaviour and performance of Poly Ether Ether Ketone (PEEK) polymers. Bond 3D is a fast growing, young and entrepreneurial company based in the Netherlands who are developing a novel, ultra-performance Free Form Fabrication (FFF) printer for printing high performance polymers such as PEEK.

CALM is pleased to provide research support for the PhD programme which focused on understanding the polymer behaviour from molecular scale to macro-scale performance throughout the new manufacturing process. Aspects such as crystal structure, size, amorphous and crystalline behaviour, layer-to-layer bonding, degradation effects, mechanical performance and design considerations formed part of the PhD study.

Funded by: University of Exeter and Bond High Performance 3D



EPSRC EP/N034627/1 – Novel high performance polymeric composite materials for additive manufacturing of multifunctional components

The aim of the project was to develop novel high performance, nanocomposite feedstock powder materials and filament for two processes: Laser Sintering and Fused Deposition Modelling (FDM). It examined the potential use of inorganic fullerene-like tungsten disulfide (WS_2) as nanofillers for high value, PAEK (Poly Aryl Ether Ketone) based products.

The incorporation of these nanomaterials has been shown to improve thermal, mechanical and tribological properties of various thermoplastic polymers. It reduces wear and the coefficient of friction as well as offering processability benefits with dispersion characteristics that are superior to 1D and 2D nanoparticles. They are also the best shock absorbing cage structures known to mankind and importantly, they are non-toxic, and thermally stable.

Prof Yanqiu Zhu's group has carried out extensive research on WS_2 inorganic fullerenes and their applications in nanocomposites using conventional fabrication techniques and has recently invented a new rotary manufacturing technology for the continuous production of WS_2 inorganic fullerenes.

Funded by: EPSRC
Partners: University of Exeter and Ulster University Supported by: Victrex Polymer Solutions, Laser Prototype Europe Ltd – LPE, Bombardier Aerospace, Daido Metals Co. Ltd

The CALM laboratory' and 'PEEK granules'

Research projects

EPSRC EP/L017318/1 – Particle shape and flow behaviour in Laser Sintering: from modelling to experimental validation

This project investigated the way the polymeric powders of different shapes and sizes flow, interact and sinter in the laser sintering process, through modelling and experimental validation. The spreading and compaction of the powder is an important part of the LS process. A non-uniform layer of powder leads to high porosity and weaker bonding between layers and therefore a structure with poor mechanical performance. Similarly, the size and shape of particles can change the sintering process. Larger contact areas between particles lead to a good sintering profile and ultimately to a high density part and good mechanical properties. Surface area of particles, polymer viscosity and surface tension were characteristics which were investigated when modelling the flow and sintering process.

It was a highly innovative project and its findings have the potential to help unlock the materials limitations for polymeric laser sintering. This allows rapid expansion into a wider range of higher value applications due to lower powders costs, wider choices and better understanding of their behaviour within the manufacturing process.

Funded by: EPSRC
Partners: University of Exeter and University of Edinburgh
Supported by: Victrex Manufacturing Limited and 3T RPD

Poly Ether Ether Ketone (PEEK) polymers for high temperature laser sintering (HTLS)

With the limited range of materials available for HTLS, this jointly funded PhD focused on the investigation of a new medical grade of PEEK. The study examined some of the key requirements needed for the successful development of new materials in LS processes at experimental and theoretical levels. This was the first study on a medical PEEK grade on a powder bed system.

Two medical grades of PEEK, 150PF and 450PF (OPTIMA LT3 and LT1), have been quantitatively investigated in parallel with well-established LS polymers in terms of particle size, particle morphology and flow behaviour. A calculation of the inter-particle interactions has been evaluated for all the materials proposed. These analyses, coupled with two strategies for the improvement of powder flowability, have formed a systematic and fundamental approach for studying powders in LS.

PEEK OPTIMA® LT1grade was selected for optimisation into the HTLS system, EOSINT P 800. The HTLS processing parameters and their effect on the mechanical characteristics of the laser sintered units were investigated and optimised. New insights into the HTLS mechanisms and functionalities of the EOSINT P 800 system were provided. The investigation also resulted in the proposal of a technique for the prediction of one of the HTLS processing temperatures from the powder properties as well as assessing a formula for linking material properties to processing parameters. Lastly, two case studies were performed with two long term medical implants manufactured utilising PEEK OPTIMA® LT1, and then tested.

Funded by: University of Exeter (PhD studentship) and Victrex (materials)
Partners: University of Exeter and Victrex

Research projects

Additional related research projects

CDE 31809 - Development of CNT/PEEK structures using AM, for lightweight, high performance and multifunctional applications.

- UTOPIUM – Ultimate Toughness and Other Properties by Ultimate Materials
- CDE 36453 – High temperature additive manufacturing for rapid manufacture and adaption of bespoke military equipment
- CDE100404 – High temperature additive manufacturing with embedded fibre optic sensors
- DSTL/AGR/00249/01 – Cost-benefit analysis (to the supply chain) of additive manufacturing
- EPSRC EP/M01777X/1 – Re-Distributed Manufacturing and the Resilient, Sustainable City (ReDReSC)

PhD Opportunities

CALM has regular PhD opportunities available to students across a range of AM and material characterization topics. Get in touch to find out about latest offerings.

Furthermore, it has been shown as an excellent way to work with industrial partners to get a deep understanding about materials and processes.

For those organisations interested, PhDs can be arranged directly with one company or in collaboration with 2 or more industry partners, depending on the scope of the project.

Contact our team to find out how your organisation can work with us on new PhD, or other funding opportunities.

Publications

2022

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