BRAGG CENTRE FOR MATERIALS RESEARCH
ANNUAL REPORT

2022 - 2023

UNIVERSITY OF LEEDS

Contents

Vision:

“The Bragg Centre nurtures a vibrant and innovative materials research community to deliver the greatest impact across disciplinary boundaries.”

EDI Statement:

“The Bragg Centre is an inclusive, diverse and creative materials research community which attracts and develops students and staff of all identities, characteristics and backgrounds, valuing everyone’s contribution and supporting them to thrive.

The Bragg Centre is committed to continuous, ongoing action to improve everyone’s well-being and productivity.”

Our Capabilities

New ways of using energy: power efficiency, scavenging and biohybrid capture

- Engineering interfaces between electronic, magnetic, and photonic materials to deliver ultralow power electronics.
- Exploiting tribology, piezoelectric materials and thermal sources to develop energy scavenging systems for wearable textiles, robotics and self-powered devices.
- Creating biohybrid approaches to solar energy capture using bacteria, mitochondria and self-assembled systems – a "bionic leaf".

New approaches to personalised healthcare: model systems, diagnostics and interventions

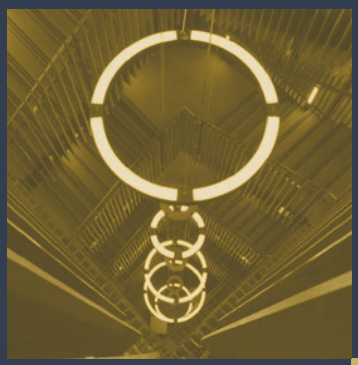
- Accelerating drug development, understanding disease, and reducing *in vivo* trials through developing model membrane and organ-on-chip systems.
- Developing new tools and approaches for precision diagnostics and treatment, including biosensors, smart materials, and cell enrichment.
- Designing new materials for delivery of bioactives, human tissue replacement and surgical lubrication.

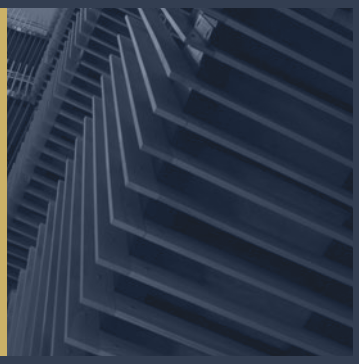
New ways of computing: architectures, algorithms and storage

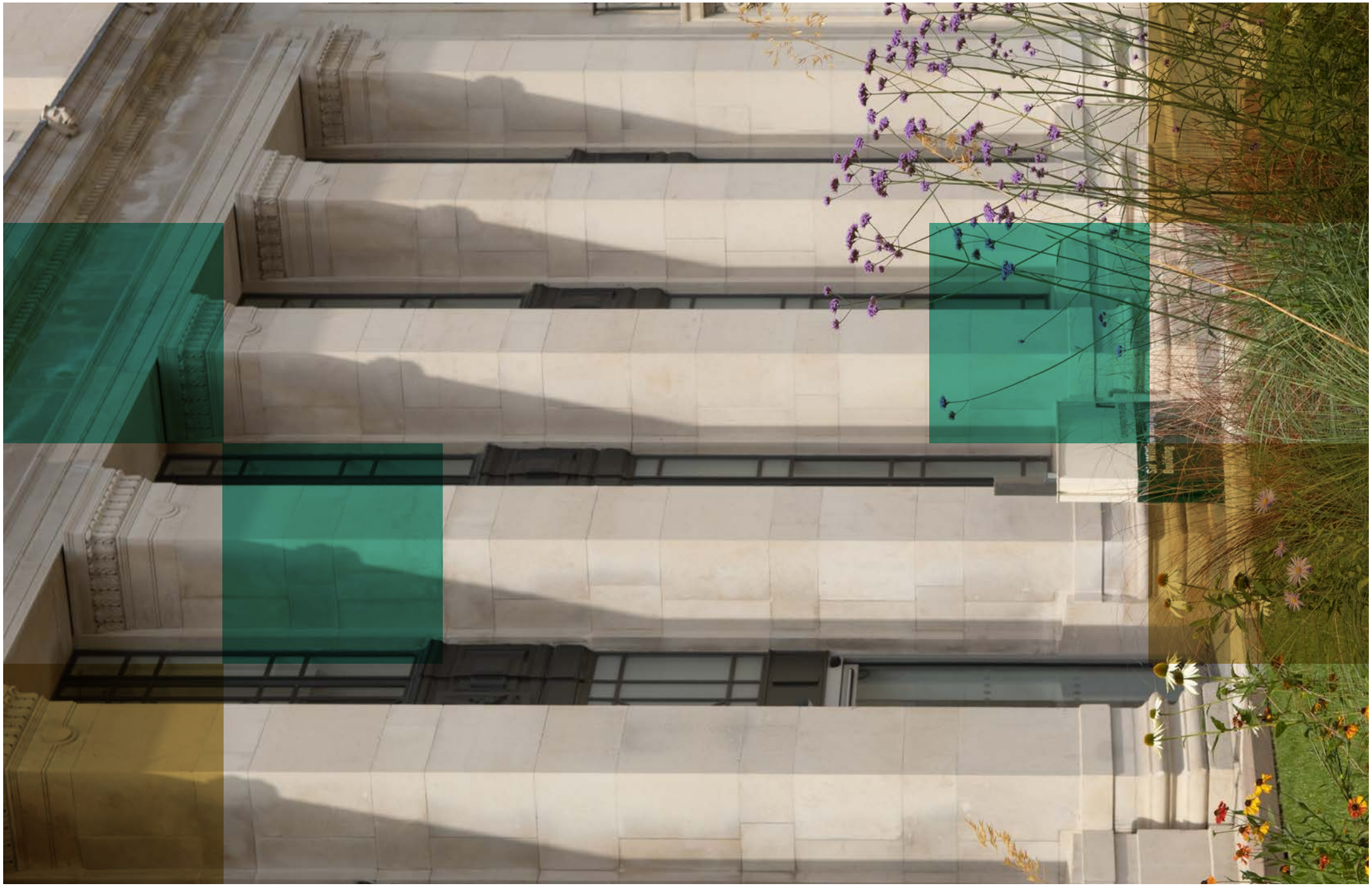
- Alternative computing methods (e.g. neuromorphic and quantum) providing energy efficient and secure architectures.
- Innovative computer algorithms for interpreting big data sets.
- Biological based approaches (e.g. DNA) for low energy archival data storage.

New approaches to materials design: prediction, mitigation and sustainability

- Multiscale characterisation, *in operando* analysis and simulation informing *in silico* prediction of materials properties from atoms and crystals to products and manufacturing.
- Developing resilient engineering mitigation strategies against wear, corrosion and failure based on predictive interface performance.
- Sustainable approaches to material synthesis from research to production, inspired by and using natural materials, and reducing waste.







Our Progress in Perspective

Director's Summary

Prof. Edmund Linfield,
Director of the Bragg Centre

Let me start by saying 'thank you' – it has been another fantastic year for the Bragg Centre.

Thank you first to you, our members, for making the Centre such a success, and to all of our Bragg Management Committee. Thank you as well to our External Advisory Board who have provided constant support and guidance, and especially to Dame Prof. Julia Higgins for expertly chairing our external advisory board from the inception of the Bragg Centre. Julia's guidance has been pivotal in shaping the Centre into the vibrant success it is today, and we look forward to working with our new Chair, Prof. Rob Hardeman, as we take the Bragg Centre into its next phase of development.

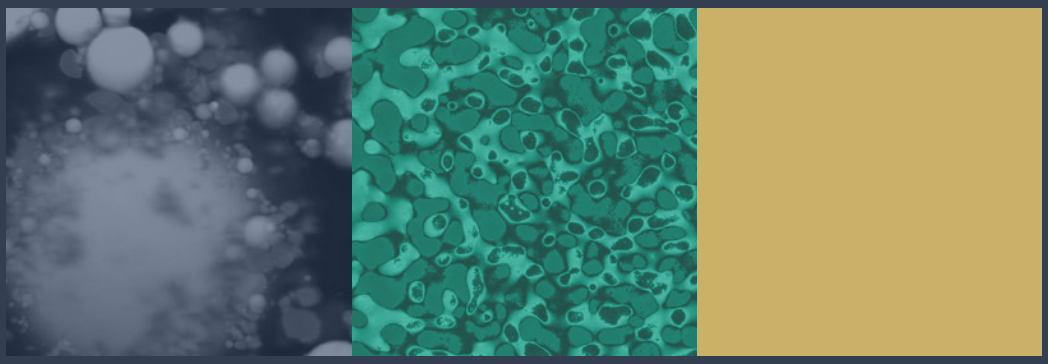
But, my biggest 'thank you' goes to Andy, Lucy, Helen and Dan – what has been achieved simply would not have been possible without you.

As I reflect back on the year, so much seems to have happened! We have showcased our facilities and expertise to industrial partners, MPs, international delegations and alumni, and to you, the University community, through our first facility open house event. We launched a new annual UK week-long cleanroom skills training course in conjunction with the Henry Royce Institute and the Universities of Cambridge and Swansea, in support of the UK Government's £1Bn semiconductor strategy. We have seen the community come together in great strength starting with the outstanding Bragg Exchange in January 2023, and especially over the early summer, we seemed to be hosting almost weekly user-group workshops – from surface science to epitaxial growth – together with networking meetings with funders and industry.

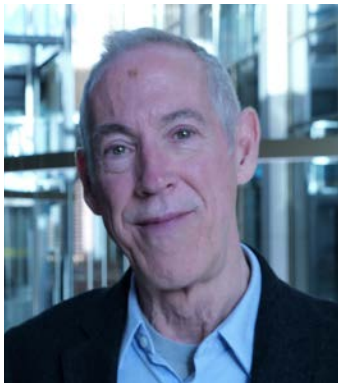
Throughout the year, we have been delighted to welcome new members, as the community has continued to grow and diversify – reaching more people than ever before through our events, publications, public engagement and communications. We have seen new Bragg PhD students, summer internship students, and increasing numbers of schools coming onto campus to understand the importance of 'materials'. Equally, we have been delighted by the significant increase in our industrial engagement, which has included QinetiQ now having a member of staff permanently embedded within the Bragg community.

So much has happened over the last year, and I can't wait to see what we will achieve in 2024.

Thank you everyone!



Observations from the External Advisory Board



Prof. Rob Hardeman MBE,

Chair of the Bragg Centre External Advisory Board

It was a pleasure working with Dame Prof. Julia Higgins during her term as Chair of the EAB. Her insights and approach made every meeting not only educational but also enjoyable. I only hope I can keep up her high standard as I take over her role.

Following the disruption of the COVID years, it has been pleasing to witness a huge range of benefits quickly accrue with a return to in-person interaction across the growing Bragg community.

New equipment, more students and staff, including an industrial secondee, moving into the Bragg Centre have meant a virtuous circle is clearly developing. The PhD students and early career researchers are now beginning to make a real impact in research and we look forward to many high quality publications that bolster the Centre's international reputation.

Over the next year it will be the EAB's priority to support the community to build on the strong portfolio of grant funding and industrial partnerships that have been secured. Academic partnerships with new areas across the University and with other leading institutions like Cambridge, Imperial, Manchester and UCL, to name just a few, highlight the range and reach of the work now being undertaken. Capitalising on these links and developing the strategic role of Bragg within the institution, and at a national level, will be critical as we see opportunities appear with evolving materials strategies in relevant areas in the next few years.

Impact Across the University

Prof. Nick Plant,

Deputy Vice-Chancellor: Research and Innovation

The University of Leeds produces high-quality, challenge led, interdisciplinary research, underpinned by our disciplinary fundamental research strengths and the Bragg Centre is a perfect example of how this is delivered. The Bragg Centre supports a broad remit of impactful research activity across 16 schools and five faculties through a substantive programme of events, education and training opportunities and industrial engagement.

In addition to enabling cross-school activities, the Bragg Centre develops challenge-led initiatives with its sister centres and institutes including the Centre for Healthtech Innovation to deliver new materials solutions for clinical problems and developing activities to support UKRI's Engineering Biology Strategy with the Astbury Centre. This helps develop new insights and solutions for innovative products, devices, and applications in support of our vision to work across disciplinary, institutional, and geographical boundaries to enable a sustainable, impact-focused research model for the future.

The Bragg Centre is committed to supporting the skills pipeline in materials research, delivering nationally acclaimed schools' outreach, undergraduate research internships, and funding PhD studentships. This year the Centre further extended its portfolio to include nationally important advanced skills training courses to meet the needs of the UK semiconductor industry, in support of the UK Government's £1bn semiconductor strategy.

In previous years, the Bragg Centre has focussed on growing its post graduate community, providing career development opportunities and connections to industry. This year the University has welcomed the Centre's efforts to champion its research technical professional (RTP) community. The Centre has helped bring awareness to the vital role that RTPs play in the research community and how this underpins our high-quality research and innovation. It has provided a forum to emphasise the need for active career development, reward and recognition for these important members of our research community. This has influenced new policies such as the Fair Attributions Policy, which ensures that all the people whose work contributes to research and innovation are recognised, valued and supported, in line with our Fairer Future for All initiative.

The Bragg Centre continues to bring discipline-specific experts together, across interdisciplinary portfolios, to create new solutions to major societal challenges. This will support the University to continue to deliver transformative, high impact research, and through interdisciplinary global collaboration will help tackle inequalities, to benefit society and drive change. I look forward to seeing how the Bragg Centre continues to grow in the coming year.

Our Governance

Research Theme Leads

Prof. Rik Drummond-Brydson
Analytical Science

Prof. Christoph Wälti
Bionanotechnology

Prof. Christopher Marrows
Electronic & Photonic Materials

Prof. Ardian Morina
Functional Surfaces

Prof. Fiona Meldrum
Multiscale Materials

Position Vacant
Soft Matter

Prof. Edmund Linfield
Centre Director

Bragg Centre Team

Dr Andrew Lee
Centre Manager

Ms Lucy Leonard
Research & Innovation Development Officer

Daniel Paterson
Research & Innovation Development Officer

Ms Helen Walters
Research & Events Administrator

Ex Officio Members

- **Dr Oliver Harlen,** Pro Dean for Research & Innovation
- **Prof. Giles Davies,** Deputy Executive Dean, Faculty of Engineering and Physical Sciences

Management Committee Members by Application

To ensure that the management committee continues to represent a balanced view of the community, members are appointed by application to sit for a two-year term. This year the Centre broadened the terms of reference to draw in the critical voice of research technical professional (RTP) colleagues, as well as advancing the recruitment timeline to ensure overlap between outgoing and incoming members for continuity of discussion.

Term: October 2021 – September 2023

- **Dr Almut Beige,** School of Physics & Astronomy
- **Prof. Robert Kay,** School of Mechanical Engineering
- **Prof. Anwesha Sarkar,** School of Food Science & Nutrition
- **Dr Philippa Shepley,** School of Physics & Astronomy
- **Ms Rachel Bocking**, School of Chemistry (Student representative)

Term: October 2022 – September 2024

- **Dr Razan Aboljadayel,** School of Physics & Astronomy (EDI representative)
- **Dr Andrew Burnett,** School of Chemistry
- **Dr Robert Davies,** School of Dentistry
- **Dr Timothy Moorsom,** School of Chemical & Process Engineering

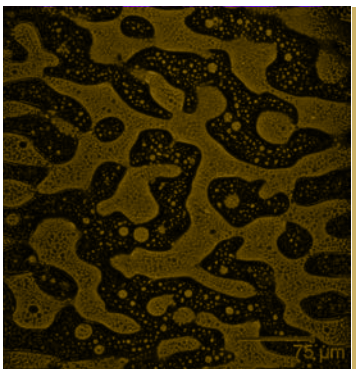
Term: September 2023 – September 2025

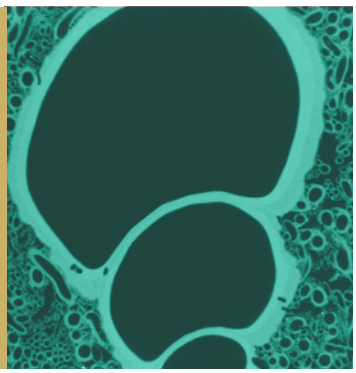
- **Dr Richard Walshaw,** School of Earth & Environment
- **Mr Rob Simpson,** School of Chemical & Process (RTP)
- **Dr Joshua Owen,** School of Mechanical Engineering
- **Dr Alice Macente,** School of Civil Engineering
- **Ms Victoria Haines-Woolley,** School of Mechanical Engineering (Student representative)

External Advisory Board

Our external advisory board helps to shape the strategic direction of the Bragg Centre. Drawn from academia and industry, they continue to support the growth of the Centre and its international reputation for materials research. This year saw substantial changes to the board with the departure of Dame Prof. Julia Higgins following four years as Chair, with longstanding board member Prof. Rob Hardeman MBE taking over at the helm. In addition, the Centre appointed Dr Charles Footer, Dr Charles Bragg and Dr Linda Pravinata to support expansion of the Centre's activities in new strategic directions.

- **Chair:**
  Outgoing: **Dame Prof. Julia Higgins DBE FRS FREng,** Imperial College London (Stepped down January 2023)
  Incoming: **Prof. Rob Hardeman MBE,** Independent Technology Consultant
- **Prof. Jeremy Baumberg FRS FRSC,** Director of the Nanophotonics Centre, University of Cambridge
- **Dr Mark Hampden-Smith,** Vice President Business and Technology Strategy (Ceramics), Saint-Gobain
- **Prof. Peter Dowding**, Infineum UK
- **Dr Sheetal Handa,** Materials Science Advisor, BP
- **Prof. Mary Ryan CBE FREng,** Vice Provost for Research and Enterprise, Imperial College London
- **Prof. Jim De Yoreo,** Chief Scientist for Materials Synthesis and Simulation Across Scales, Pacific Northwest National Laboratory
- **Dr Charles Footer,** Head of Products, QinetiQ (Joined January 2023)
- **Dr Charles Bragg,** Non-Executive Director and Deputy Chair, Centre for Process Innovation (Joined January 2023)
- **Dr Linda Pravinata,** Lead Scientist, Marlow Ingredients (Joined June 2023)





Innovate

Strategic and Industrial Engagement

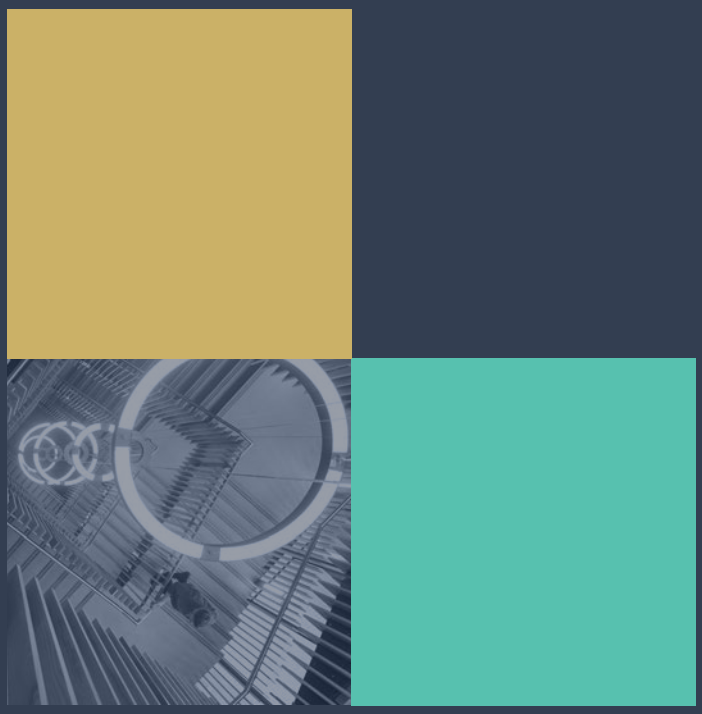
This year, the Bragg Centre has seen a significant rise in its engagement with industry, with a total of 60 direct enquires and a conversion rate of 15% to active work including facility access, collaborative bids and direct industrial funding.

Furthermore, over the year, the Centre hosted 10 strategic industrial, ministerial, and international visits. These include:

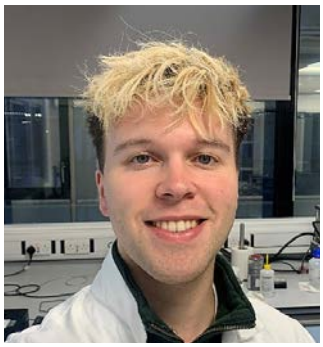
- Prof. Paul Monks, Chief Scientific Officer Department for Energy Security and Net Zero,
- Paul Scully MP, Parliamentary Under Secretary of State & Minister for Tech and the Digital Economy,
- A delegation from the South Carolina Department of Commerce, as part of a West Yorkshire Combined Authority (WYCA) engagement programme,
- A delegation of 23 local business and civic leaders as part of the West Yorkshire Combined Authority (WYCA) manufacturing task force,
- A delegation of five leaders from the Advanced Manufacturing Research catapult,
- Alongside strategic visits from the EPSRC and BBSRC.

In addition, the Bragg Centre celebrated the awarding of a number of collaborative proposals with industrial partners, these include:

- A **£340k** Innovate UK Knowledge Transfer Partnership (KTP) led by Prof. Stephen Evans (School of Physics & Astronomy) in partnership with SureScreen Diagnostics.
- Northern Gritstone invested **£2M** seed funding in spinout company LC AuxeTec, led by Prof. Helen Gleeson (School of Physics & Astronomy).
- A **£457k** Innovate UK funded proposal to engage, inspire and train a new generation of students, as well as upskilling and re-skilling employees to meeting the shortage of skilled workers in the UK semiconductor industry. The project titled “Skills, Talent, And Re-education Training for Semiconductors” (START-SEMI) is led by Dr Chris Wood (School of Electronic & Electrical Engineering).
- Inclusion, along with 10 other Universities and three companies, as part of a successful Royce-led bid to the Defence Science and Technology Laboratory (DSTL) Advanced Materials S&T Programme to establish a Centre of Excellence for Materials in Extreme Physical Environments. The Leeds portion of the bid is led by Prof. Richard Barker (School of Mechanical Engineering), with the total consortium worth **£40M**.



Just Add Water!



Dr Ben Kew
Post Doctoral Research Fellow
School of Food Science & Nutrition

Understanding the lubrication properties of more sustainable plant proteins is emerging as an important strategy to increase the palatability, use and replacement of animal protein in our diet.

A shift towards more sustainable plant-based ingredients is seen as an increasingly necessary step to achieve the UK's net zero emissions goal by 2050. It is estimated that animal-based foods can have as much as 50 times greater environmental impact per gram of protein, contributing approximately 18 gigatonnes of CO_2 equivalent emissions per year. This is roughly one third of all human generated greenhouse emissions globally.

Plant-based proteins are often touted as a sustainable alternative, however the astringent sensation of these proteins has limited their significant adoption to date. These unpleasant characteristics are linked to the low lubrication properties of the plant proteins which tend to aggregate and exclude water leading to increased friction between the food and the mouth's surfaces. Now work in the Bragg Centre, as part of its Soft Matter theme, has developed an approach to tune the lubrication properties of plant proteins, changing the experience from one that is dry to one that is juicy and fat-like.

Work by Dr Ben Kew, as part of his PhD in the group of in the group of Prof. Anwesha Sarkar (School of Food Science & Nutrition), converted native plant proteins into highly hydrated and non-aggregated ultra-lubricating microgels. To do this, the plant proteins are simply placed in water and heated to denature them. This alters the structure of the protein molecules which subsequently come together to form an interconnected network, or gel, that is capable of trapping water. The resultant gel is then homogenised, which fragments the protein network into a microgel. When placed under pressure, as would be the case when these microgels are being eaten, they ooze water which creates a lubricity akin to that of single cream. When reflecting on this, Ben noted:

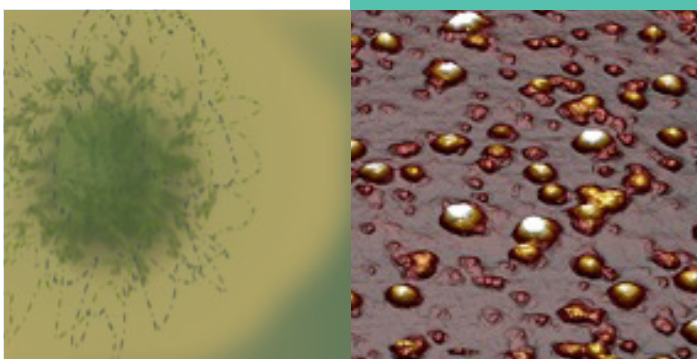
> ***This is quite a remarkable finding. It is striking that, without adding a drop of fat, the microgels have the lubricity of a 20% fat emulsion, which we are the first to report.***

Ongoing work with Innocent Drinks, as part of an Innovate UK funded project, aims to apply this technology to real food matrices, with implications for future sustainability and health as a new class of fat mimetic ingredients.

The Bragg Centre played a pivotal role in this breakthrough by enabling a new interdisciplinary collaboration to be ignited following discussions at the Bragg Exchange 2022, where Ben's work received the 1st place poster prize. This new partnership allowed Ben to experimentally validate his theoretical models of the plant-protein microgel morphology, viscosity and friction regime using the equipment and expertise in the Centre's atomic force microscopy facility. When considering the enabling role of the Centre, Ben highlighted that:

> ***Bragg allows for interdisciplinary networking and collaborating that expedites cutting-edge research to take place.***

Now having completed his PhD, Ben's journey was inspired by his own personal experience with childhood obesity which has driven him to develop healthier and more sustainable food materials, authoring six publications to date.



Persistence Beats Resistance

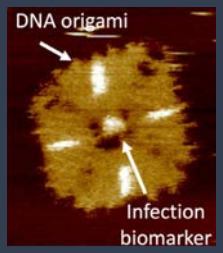
Dr Paolo Actis
Associate Professor
School of Electronic & Electrical Engineering

The rise of antimicrobial resistance (AMR) is one of the biggest threats to global health, food security and development today. AMR is a naturally occurring process whereby bacteria develop the ability to defeat the drugs, also known as antibiotics, designed to kill them. These bacteria may infect humans and animals, and the infections they cause are therefore much harder to treat than those caused by non-resistant bacteria. This rapid increase in AMR is frightening, with over 1 million deaths being directly attributed to antibiotic-resistant infections globally in 2019 and predicted to rise to up to 10 million deaths annually by 2050. Without urgent action, we are heading for a post-antibiotic era, in which common infections and minor injuries can once again kill.

A large part of the problem is the way in which the world over-uses antibiotics, which are often prescribed by de facto against infections that are caused by fungi, viruses and bacteria. However, where antibiotics are erroneously taken to combat a viral infection, they will provide no benefit for the patient, but will enable naturally resident bacteria to evolve resistance to the drug. It is well recognised that this is a very significant driver of AMR and that new diagnostics, which can identify the type of an infection rapidly and accurately, are an urgent piece of this puzzle.

To combat this problem, Dr Paolo Actis is leading the development of a point of care device that can determine the difference between bacterial and viral infections on the spot, enabling a more appropriate and controlled use of antibiotics.

Paolo's work, which is primarily aligned with the Bragg Centre's Bionanotechnology theme, combines DNA nanotechnology with ultra-fine glass capillaries to create a device that can detect specific infection biomarkers in blood within minutes. This system is based on monitoring the minute changes in electrical current as a molecule translocates through a nanopore, following a similar principle to the nanopore-based sequencing approach of industry leader, Oxford Nanopore Technologies. The basic principle requires an electrolytic solution separated into two chambers with only a small connecting channel, the nanopore. Where a constant voltage is applied across the chambers, an electric field is induced that drives a flow of ions through the nanopore. Molecules of interest can be detected as they pass through the nanopore, partially restricting the flow of ions, which creates a detectable drop in current. Molecules can therefore be characterised based on the change in magnitude of the ionic current and the duration of the translocation.



To be effective, the size of the nanopore needs to match the size of the molecules of interest. As such, in order to detect protein markers of infection a nanopore would need a typical diameter of less than 10 nm and be tailored specifically to each protein of interest. This creates significant manufacturing challenges.

The breakthrough from Paolo's team was to combine the nanopore detection approach with DNA-based nanostructures that could act as carriers to bind the specific protein of interest. This approach confers several distinct advantages including reducing the dependency on small nanopore sizes and therefore manufacturing cost; providing an improved signal to noise ratio with a binary on or off detection mechanism; and enabling the possibility of detecting multiple different proteins from the same mixture through a single nanopore.

The work, which included experimental and theoretical aspects, was a collaborative effort between the PhD students and Postdoctoral associates across the groups of Dr Actis and Prof. Christoph Wälti (School of Electronic & Electrical Engineering), including Dr Mukhil Raveendran, Dr Chalmers Chau, Gayathri Mohanan, Dr Samuel Confederat, Tim Peace, Dr Fabio Marcuccio and Dr Dimitrios Soulias. More recently, the group has worked closely with Prof. Martin Edwards (University of Arkansas, USA) to develop a multiphysics model that provides mechanistic insights into the experimental system, enabling further optimisation. Looking towards the future, Paolo and his collaborators are currently working with the sector leader, **Oxford Nanopore Technologies**, to commercialise their technology with a provisional patent currently under assessment.

When commenting on the impact that the Bragg Centre has had on his work, Paolo said:

> ***The Bragg community is a great pull to hire and retain talent. The facilities are world class and the Centre is managed extremely well with lots of diverse activities to support staff development and knowledge exchange.***

Paolo trained as a materials scientist, before undertaking a postdoc in bionanotechnology at the University of California, Santa Cruz in 2008. He started working with nanopores for single molecule analysis and manipulation during a second postdoc at Imperial College London, followed by a brief stint as an industrial consultant in the Bionanotechnology space. This industrial perspective has been key for Paolo, ensuring that he always identifies a commercial pathway to ensure the impact of his blue-sky research.

Welcoming a New Cheney Fellow

Prof. Nicholas A. Kotov
Professor, Chemical Engineering,
University of Michigan
&
Cheney Fellow,
School of Physics & Astronomy, University of Leeds

This year the Bragg Centre was pleased to welcome Prof. Nicholas Kotov to the University of Leeds as a prestigious Cheney Fellow.

A globally renowned academic in the nanoscience and nanotechnology communities, Prof. Kotov joins Leeds from the Chemical Engineering Department at the University of Michigan for a two-year visiting appointment. Whilst he holds many distinguished awards in science and engineering, including the Irving Langmuir Distinguished University Professor of Chemical Sciences and Engineering, he also boasts a world-class publication and citation record. In addition to his research contributions, Prof. Kotov also serves as an Associate Editor for ACS Nano and as a member of the Advisory Boards of several nanotechnology and materials journals.

Prof. Kotov's research interests include multifunctional composites for biomedical implants, biosensors, and artificial organs. His more recent activity developing nanoparticles for drug delivery and biomedical imaging, as well as the structural design of nanomaterials to combat drug-resistant bacteria and biofilms, significantly overlaps with the Bragg Centre's remit.

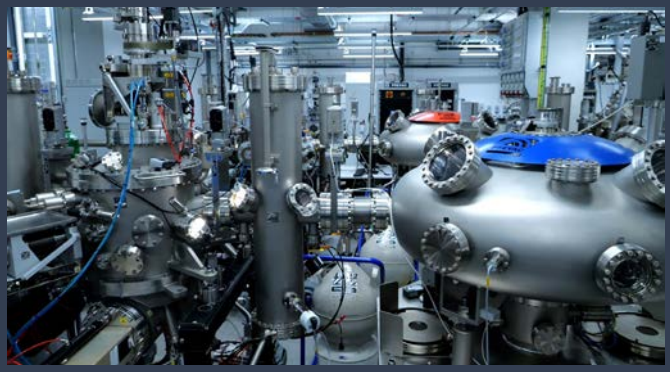
Throughout his time in Leeds, Prof. Kotov is expected to be an inspirational new member in the Bragg community due to his track record of recognising novel opportunities and developing ideas from fundamental science through to commercialisation.

He is currently exploring the use of graph theory to understand the assembly of chiral nanoparticles into superstructures. In other words, he is developing an understanding of the fundamental assembly rules of nanoparticles based on their shape, size, and chirality. Based on this work, Prof. Kotov has been awarded a $30M grant from the National Science Federation (NSF) to establish the 'Science and Technology Centre on Complex Particle Systems' between the University of Michigan and other Universities in the USA.

Prof. Kotov's fellowship began with a workshop, enabling the Cheney fellow to meet with academics engaged in nanoscience from across the University of Leeds. The meeting demonstrated that Leeds has exceptional capability and talent, with Prof. Kotov noting that the facilities and strength of research rivalled the best nanoscience research institutions in the world. The Bragg Centre is excited to support Prof. Kotov's collaboration with Leeds in the coming months.

It's All Coming Together

In March 2023, the separate parts of the Royce deposition system made their final move into the Sir William Henry Bragg building and were fully integrated together within a new dedicated space. This pivotal moment combined the four chambers of the £2.2M deposition system together for the first time, marking a step change in the Bragg Centre's thin film growth capability.



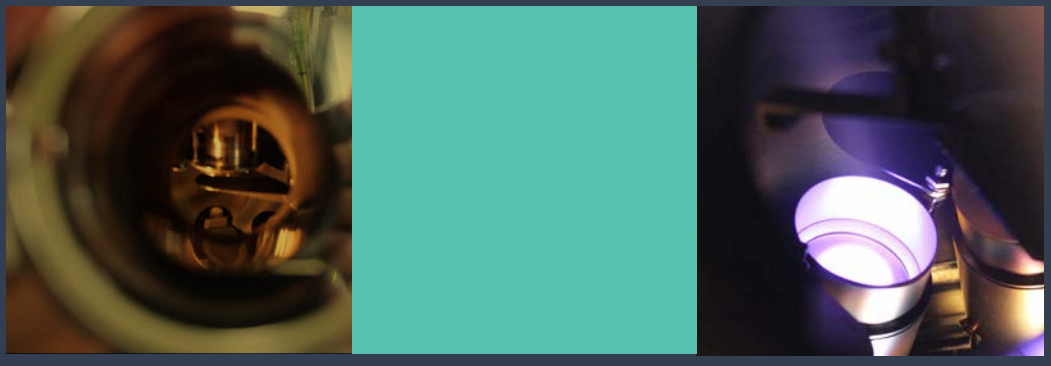
The Royce deposition system combines several deposition techniques together in a continuous vacuum system and includes:

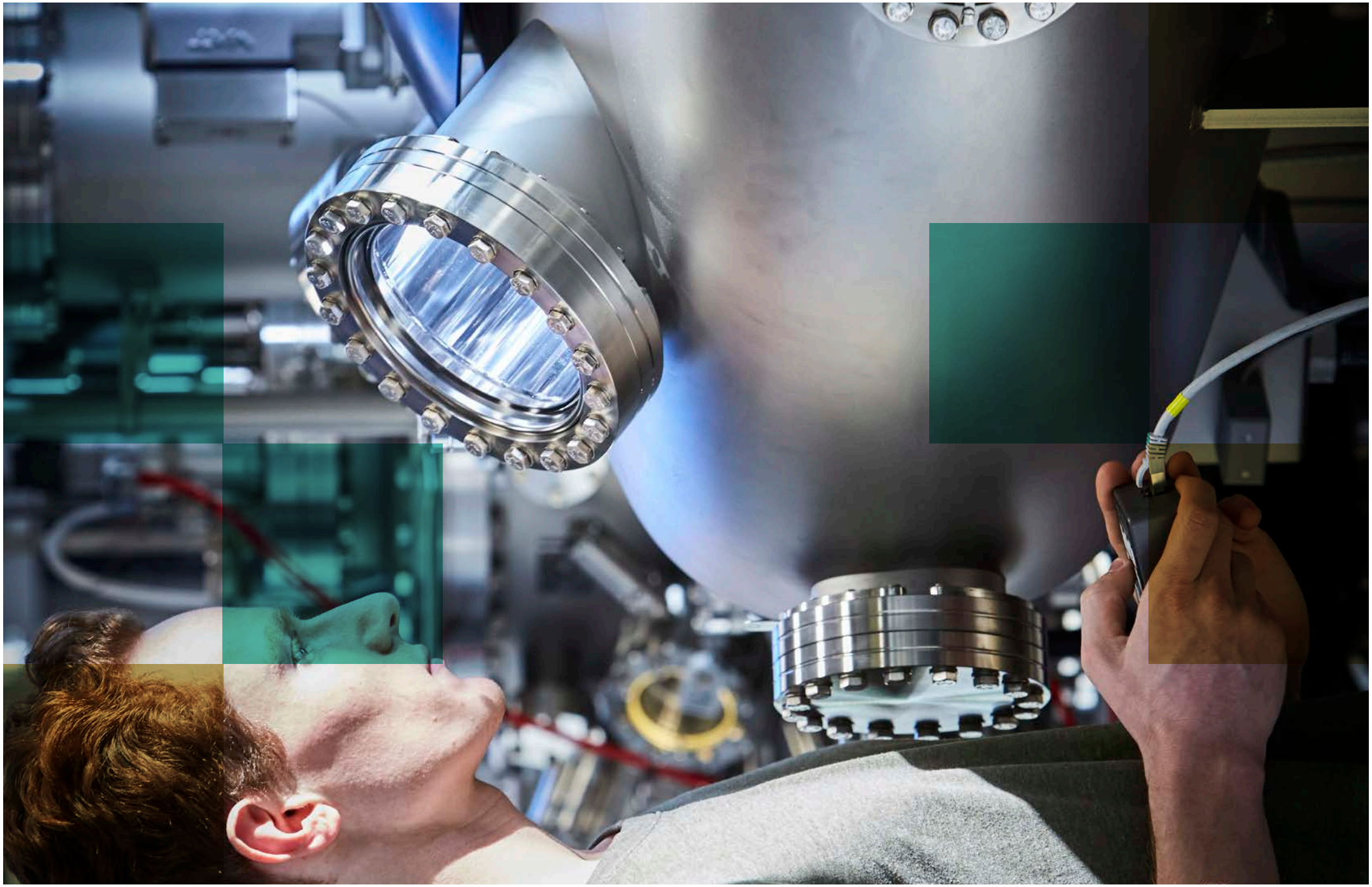
- **Molecular Beam Epitaxy (MBE)** for epitaxial growth of thin film topological materials.
- **Pulsed Laser Deposition** for the growth of complex oxides, including dielectrics, ferroelectrics and multiferroics.
- **Sputtering** for the growth of magnetic and non-magnetic materials, as well as magnetic oxides (e.g. yttrium iron garnet).
- **Organic Deposition** of molecular and organic materials such as fullerenes, metallo-fullerenes, thalocyanines and quinolines.

The Royce deposition system is an integral technology platform of the Royce 'Atoms to Devices' theme, co-led by the University of Leeds, and is allowing the exploration of new physical phenomena, and the development of next-generation electronic and spintronic devices. Already the system is leading to a breadth of new national and international collaborations. Research programmes include:

- The **£6.5M** EPSRC **Combining Advanced Materials for Interface Engineering (CAMIE) Programme** grant [EP/X027074/1] led by Prof. Bryan Hickey at the University of Leeds, in partnership with Imperial College London and Queen's University Belfast. This programme is developing fundamentally new ways to store, manipulate and transport information, based on materials integration and interface control, through the development of spintronic devices.
- The **£7.7M** EPSRC **Nanoscale Advanced Materials Engineering (NAME)** Programme Grant [EP/V001914/1], led by the University of Manchester in partnership with the University of Leeds (led by Prof. Edmund Linfield) and Imperial College London. This brings together new approaches to deliver material functionalisation based on nanoscale materials engineering, and enables control of, for example, spin and topological surface states, with potential long-term applications in quantum computing.
- The **€3.6M** EC Horizon 2020 **Extreme Optical Nonlinearities in 2D materials for Far Infrared Photonics (EXTREME-IR)** research and innovation programme (964735), led by the Laboratoire de Physique de l'Ecole Normale Superieure (France), in partnership with the University of Leeds (led by Dr Joshua Freeman), the Consiglio Nazionale delle Ricerche (Italy), École Polytechnique Fédérale de Lausanne (Switzerland), Bielefeld University (Germany), and mirSense (France). This is realising functionalised, compact and coherent, solid state-based far-infrared light sources, based on, for example, harmonic generation in topological materials.

These exemplar programmes are supported by a breadth of collaborations with industry, including QinetiQ, Seagate Technology, the South Wales Compound Semiconductor Centre, Hitachi, Intel, and IBM, and with national laboratories such as the National Physical Laboratory, the Tyndall National Institute, the Diamond Light Source, the Lawrence Berkeley National Laboratory, and the Paul Scherrer Institute.





Expanding Our Capabilities

A Flourishing Partnership with TESCAN

This year, the Bragg Centre was pleased to welcome new capability to its portfolio with significant investments into the Leeds electron microscopy & spectroscopy (LEMAS) centre.

The development began with the addition of a TESCAN AmberX cryo-plasma focused ion beam & scanning electron microscope (cryo-FIBSEM) coupled with time-of-flight secondary ion mass spectrometry (ToFSIMS). This unique combination enables large area – greater than 100 microns - cross-sections to be milled from both hard and soft materials; with the accompanying X-ray emission and mass spectrometry techniques allowing for the *in situ* analysis of chemical composition alongside the crystal structure and morphology taken through the cross section. This instrument was successfully secured with an award from the EPSRC [EP/V028855/1] and was installed directly into the Sir William Henry Bragg Building.

LEMAS further strengthened its partnership with TESCAN via a **£1.75M** collaboration agreement focusing on a new dedicated TENSOR scanning transmission electron microscope with the addition of scanning diffraction capabilities (4D-STEM). This system was commissioned in July 2023 within dedicated space in the Sir William Henry Bragg Building and is one of only two such systems in the world. Through the agreement, the Bragg Centre and LEMAS will act as a beta test site for TESCAN, alongside the other instrument installed in the world leading Ernst Ruska Centre in Jülich, Germany.

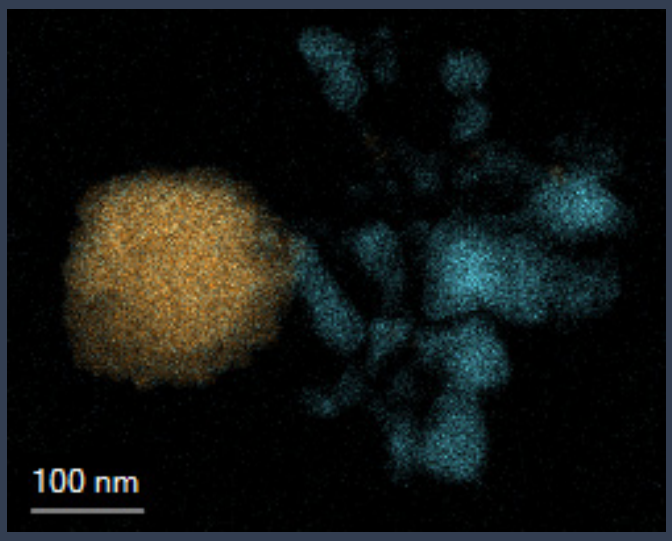
This new type of electron microscope allows the detailed correlated imaging and mapping of crystal structure and strain – as measured by electron diffraction - and its relationship to variations in chemical composition – as measured by X-ray spectroscopy - in nanostructured materials. With this information it will be possible to understand how the fabrication and subsequent processing of materials is linked to their functional properties.

At Leeds the new TENSOR 4D-STEM and cryo-FIBSEM systems will be optimised for low electron dose analysis of sensitive materials. This strategic partnership with the manufacturer TESCAN has attracted further funding from the EPSRC [EP/X040992/1] with **£1.5M** awarded over four years to provide a dedicated staff resource to optimise this suite of instrumentation. This investment in expertise will enable a step-change in analytical capability for the Bragg Centre community based around the discovery, formulation & manufacture of complex chemical products.

By developing expertise to harness the new electron & focused ion beam microscopes, LEMAS will design new methodologies to understand the role of critical packing, defects and interfaces of atoms, molecules and crystals that limit chemical product performance. These insights will potentially offer insights across a range of sectors including Healthcare, Pharmaceuticals, Agrochemicals and new materials for Energy Production and Storage.

The remainder of the LEMAS instrumentation will be fully re-located to the Bragg Centre by February 2024. This purpose-built microscopy environment in the basement of the Sir William Henry Bragg Building maintains strict environmental control of temperature and electromagnetic fields for optimum instrument performance, in addition to enabling remote instrument operation.

LEMAS has over forty years' experience in transmission and scanning electron, as well as focused ion beam microscopies of both hard & soft materials. The facility is supported by five permanent research technical professional (RTP) staff John Harrington, Stuart Micklethwaite, Dr Zabeada Aslam, Dr Richard Walshaw and Macauley Hough; and is guided by the combined expertise of Prof. Andy Brown, Dr Nicole Hondow, Dr Sean Collins, Prof. Sandra Piazolo & Prof Rik Drummond-Brydson.



Elevating West Yorkshire's Ability to See Structures Big and Small

This year, a new suite of state-of-the-art X-ray scattering techniques was added to the Bragg Centre's portfolio of capability, available to a wide range of partners including industry. These analytical techniques measure the angular distribution and intensities of X-rays scattered by a sample to reveal internal microstructures; which allows the characterisation of structure, order, shape, size distribution, dispersion, and phase behaviour of materials ranging from nanoparticles to liquid crystalline materials.

This **£400,000 investment** in Small and Wide Angle X-ray Scattering (SAXS/WAXS) equipment was secured by Bragg Centre members Dr Johan Mattsson and Dr Devesh Mistry, based in the School of Physics & Astronomy, as part of a successful **£1.2M** EPSRC Core Equipment bid [EP/X034801/1]. The instrument, an Anton Paar SAXSpoint 5.0, is one of only a handful of similar systems in the UK and provides an on-site laboratory-scale equivalent to a National Synchrotron facility. This exciting new X-Ray scattering system is equipped with a detector which translates in three dimensions providing access across both the WAXS and SAXS Q-ranges (49.3 and 0.01 nm-1) which enables the resolution of structures ranging from 300 to 0.06 nm in size.

The new SAXSPoint 5.0 is a point-focus system, which enables study of both isotropic and anisotropic materials. It is complemented by the School of Food Science & Nutrition's existing line-focused Anton-Paar SAXSSpace, which is particularly suited to isotropic food and biological samples. Now co-located together as part of the Bragg Centre capability, this laboratory provides a unique single location with expertise for SAXS and WAXS characterisation across a broad range of materials, including polymers, composites, colloids, lipids, liquid crystals, and supramolecular systems.

Collectively, these systems offer a variety of sample environments, including a -20 to 120°C Peltier controlled stage for studying solids, powders, pastes, gels, and liquids; and a grazing-incidence stage for studying thin film materials and devices. However, by far the standout feature is the unique integration of an Anton Paar DSC 502 Rheometer in to the SAXSPoint 5.0 system, providing the simultaneous study of the evolution of structure and rheology in response to applied mechanical deformations. This ability, to link structure and thermo-mechanical response to applied deformations, is critical for developing better processing technologies for functionalised and sustainable polymers, new domestic product formulations, food technologies, or engineered biological hydrogels.

On-going work in the Bragg Centre, which is now strongly benefitting from this equipment, includes the characterisation of mesophases and nanostructures in liquid crystalline elastomers and block copolymers for soft robotics; the characterisation and optimisation of industrially relevant semi-crystalline co-polymer systems for energy applications; and the development of sustainable cellulose-based biopolymer composite systems. In addition, the new in-house facility will allow users to acquire high quality preliminary and feasibility data to support competitive proposals to national and international facilities. With this equipment being of use to researchers across the full breadth of the Bragg Centre's remit, the centre is excited to support and promote its use across the University and beyond with Industry.

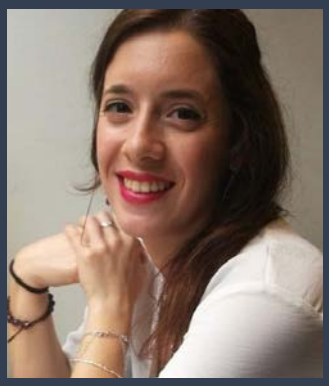
Find out more information:
https://smp.leeds.ac.uk/facilities/x-ray-scattering/

Imaging with X-rays

XCT is a non-destructive imaging technique that uses X-rays to penetrate through the object and create a three-dimensional density map of the internal structure. This is similar in approach to the more commonly recognised medical "CT scanner" which reveals internal structures of the human body. The technique stacks multiple two-dimensional radiographs while the sample is rotated, or slices through an object, to digitally recreate a three-dimensional density map of the sample.

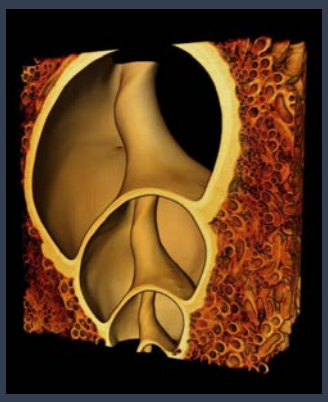
XCT is applicable to a wide range of materials and is particularly favoured with rare and sensitive samples due to its non-destructive imaging approach and minimal sample preparation requirements which leave the sample unharmed. The technique allows for the quantification of various properties in three-dimensions including identifying materials within mixtures, structural phases, porosity, defects, cracks and much more. These properties can be characterised in terms of volume, but also size distribution, orientation, shape and many other parameters. When combined with *in-situ* rigs, XCT allows imaging, monitoring, and quantification of material behaviour at the micro-scale over time and under changing conditions including temperature, pressure, and humidity.

The Bragg Centre's XCT capability is provided through the School of Civil Engineering which hosts a Zeiss Versa Xradia 410 with unique environmental control. This system is capable of operating at a maximum 150kV/30W power enabling fast scanning for large samples, and features five optical lenses reaching an outstanding maximum voxel size of 0.7 µm. Whilst the current setup features a Deben TEC 5kN cell which allows for tensile, compression, freezing and thawing studies during imaging; a new *in situ* reaction cell will be available from 2024 enabling imaging of samples under different gas mixtures and controlled humidity. The Centre is excited to support and promote this outstanding capability as part of its portfolio, enabling access to industry and external partnerships.



Dr Alice Macente
XCT Facility Manager
School of Civil Engineering

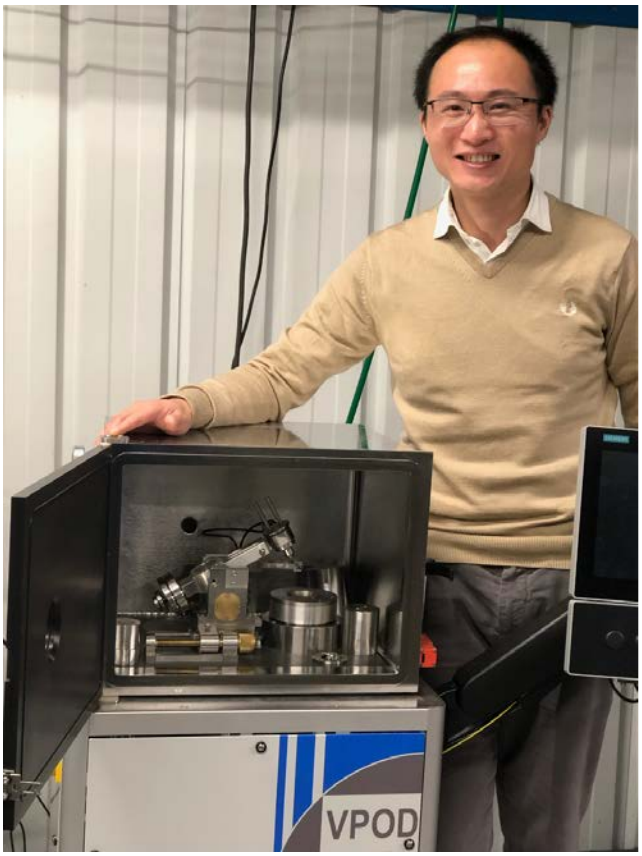
The Bragg Centre's XCT facility is managed by Dr Alice Macente. A geologist by background, Alice has over eight years' experience working at the interface between geoscience, material science and civil engineering. Her expertise is focused on understanding fluid-solid interactions in porous media, their effects on microscale dynamics over changing conditions and their link to macroscale behaviours. To date, Alice and the XCT facility have examined the microstructural behaviour of low carbon cements; effects of corrosion and carbonation on rock properties during carbon sequestration; strain localisation and mineral phases distribution in rocks; and the microscale behaviour of bones for biomechanical engineering. The Bragg Centre has further bolstered its range of X-ray characterisation techniques through the addition of an X-ray computed tomography (XCT) facility to its portfolio.



Tribology in Extreme Environments

The Bragg Centre is excited to announce the development of a bespoke tribological platform designed to simulate extreme environments.

The new equipment, which is hosted by the School of Mechanical Engineering and was made possible by an investment of **£90K** from the **Henry Royce Institute**, offers unique mechanical testing equipment for the evaluation of friction, wear, and lubrication properties of materials and coatings under extreme conditions.

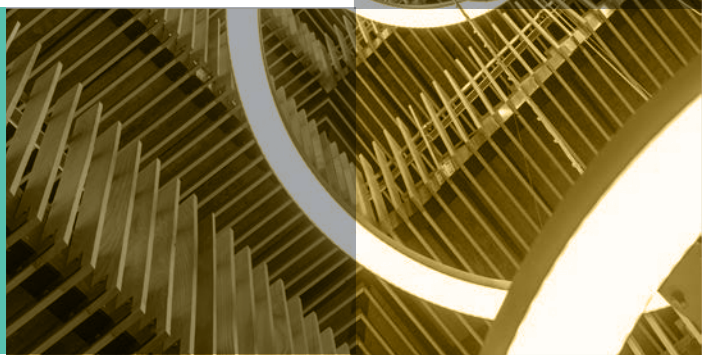


The bespoke system can handle samples with a maximum diameter of 50mm and can operate in three different modes including a hydrogen or nitrogen gaseous environment; an ambient environment with liquid or grease lubricant and controlled humidity; and in a medium to high vacuum environment. Alongside this, the material behaviour can be further assessed across a wide range of temperatures, including rapid temperature changes, whilst within any of these environmental regimes.

This platform opens up new research and innovation opportunities to design and evaluate surface coatings in extreme and demanding environments, complimenting the Bragg Centre's existing Physical Vapour Deposition & Plasma Enhanced Chemical Vapour Deposition (PVD/PECVD) coating system. It is expected that current research into coating materials for space and hydrogen environments will be particularly enriched, with discussions already underway with industrial collaborators in the Yorkshire region and more widely across the UK.

The Bragg Centre has been key to promoting Leeds' tribological expertise and capability, as well as driving the development of new collaborations. Referencing the Centre's support, the lead investigator for the tribological platform Dr Liuquan Yang said:

This new equipment is a perfect example of exciting capability that was promoted by the Centre and was pitched to a wider audience at the Royce National Conference in September 2023.



Materials 4.0

Dr Nick Warren
Associate Professor
School of Chemical & Process Engineering

Our current lifestyle relies on a broad range of complex products whose performance is governed by the implementation of polymers or nanoparticles. There is an increasing need to enhance the performance and the sustainability of these coatings, adhesives and dispersants to meet both societal and environmental demands. However, the current pipeline for development of these materials relies on dated laboratory and process research techniques, which are often slow, risky and expensive. This can mean that a 20-year development cycle is not uncommon for safety-critical applications.

The **Henry Royce Institute's** Materials 4.0 vision aims to address this with a digital materials revolution which will accelerate the discovery, innovation, and validation of new materials. It will provide capability and know-how to enable the UK to respond quickly in the cross-sector adoption of a materials informatics framework, combining capabilities from risk management, materials modelling, AI/machine learning, manufacturing informatics, and life-cycle simulation.

Work at Leeds led by Dr Nick Warren fits right at the heart of this Materials 4.0 vision, working to design new self-optimising reactor technologies capable of identifying and creating new materials for the modern era. This work cuts across the interface between the Bragg Centre and the **Institute of Process Research and Development (IPRD)**; transcending chemistry, materials characterisation, chemical engineering, and automation. Here, Nick is connecting IPRD's latest advances in chemical reactor platforms equipped with advanced online monitoring instrumentation and computationally intelligent control interfaces, to the post-synthesis electron microscopy and X-ray scattering characterisation capabilities of the Bragg Centre.

Nick currently leads several projects in this area, including an EPSRC Precision Manufacturing project in collaboration with Prof. Richard Bourne and Prof. Thomas Chamberlain from the School of Chemistry, and partners at the Universities of Sheffield and York, to implement machine learning to optimise the production of nanoparticles. It is anticipated these reactor platforms will become part of both academic and industrial laboratories around the world, and thus accellerate research on polymer and nanomaterials science in the years to come.

Through his forward-thinking work, Nick is training a new generation of scientists uniquely equiped to address the Materials 4.0 vision with a range of skills across chemistry, chemical engineering and computer science. In recognition of this contribution, Nick was recently appointed to the steering committee of the **Royce Chemical Materials Design theme**, and presented his teams latest work at the **Royce** annual conference in September 2023.

When reflecting on how the Bragg Centre has supported his work, Nick commented:

> ***[the Bragg Centre] provides opportunities for advanced characterisation of nanomaterials which would not be feasible individually without securing large grants, or travelling to remote facilities. The Bragg Centre also provides a route to integrating with the wider Henry Royce Institute which provides further access to world class facilities.***

Nick also highlighted the power of the Bragg Centre's community:

> ***Joining the Bragg Centre has facilitated interaction with a highly varied community of researchers across several departments. As a result, it provides an accessible forum for starting new collaboration and seeking alternative viewpoints for your research.***

Investigating the Micro-Mechanics of Ligament Replacements

Dr Anthony Herbert
Lecturer
School of Mechanical Engineering

Anterior cruciate ligament (ACL) rupture accounts for 40% of knee injuries, requiring 400,000 reconstructions annually worldwide. The growing rate of ACL injuries, particularly in those involved in sports, has recently gained significant attention in the national press due to the 2023 FIFA Women's World Cup.

Current surgical solutions for ACL rupture use grafts from the patient themselves (autograft) or from a deceased donor (allograft) as a replacement material for the damaged structure. In both graft types, cell death occurs soon after implantation, leading to inflammation and a compromised rate of healing.

To combat this, the University of Leeds has patented a process to decellularise animal or human tendon and ligament tissues. This has the benefit of reducing the risk of rejection or disease transmission to the patient whilst promoting constructive tissue remodelling and quicker integration to the host. In this process the extracellular matrix (ECM) remains to provide mechanical strength and functionality, whilst providing a close to native scaffold structure for the patient's cells to populate.

Recent work by Dr Herbert has successfully developed a decellularised porcine tendon graft, which has shown promising regenerative capacity in an ovine model of ACL replacement. However, a reduction in the static and dynamic mechanical properties of this graft have been identified as an area for further study.

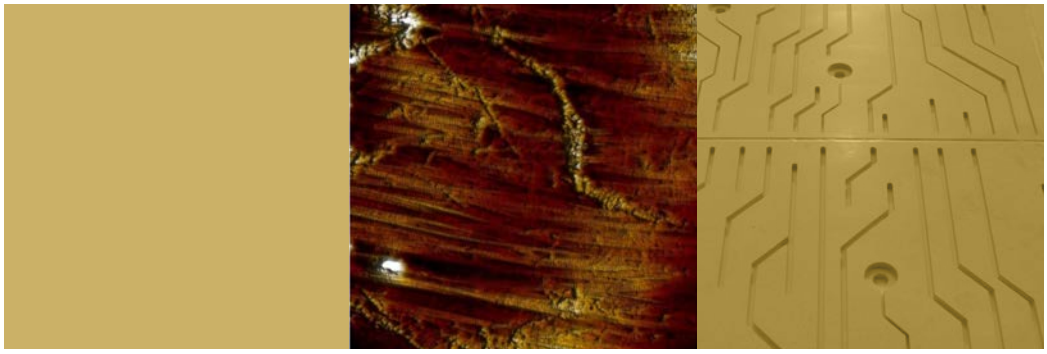
To gain a deeper understanding of this structure-function relationship, Tony's team have made use of the Bragg Centre's Atomic Force Microscopy (AFM) capabilities to investigate if the decellularisation process changes the tendon ultra-structure. A comparison of the 3D topography of native and decellularised tendon clearly revealed the constituent longitudinally aligned collagen fibrils, with no significant differences found in the collagen fibril D-spacing, diameter and directionality between native and decellularised groups. However, it was evident from the AFM of the decellularised specimens that the fibrillar structures were more prominent, which was found to be due to the absence of the enveloping interfascicular matrix which is rich in elastin and glycoproteins.

This work has significantly advanced the understanding of how decellularisation can affect the ECM of tendon, with the loss of elastin and glycoproteins likely to have consequences for cell-matrix interaction and scaffold micro-mechanics. These preliminary insights, formed the basis of a successful application for a Bragg PhD studentship which started in October 2023 as part of the Centre's 4th cohort.

This project highlights the crucial enabling role of the Bragg Centre, providing access to equipment, studentship opportunities and the forging of collaborations across the Schools of Mechanical Engineering, (Dr Herbert and Prof. Claire Brockett), Biomedical Sciences (Dr Jen Edwards and Dr Hazel Fermor) and Physics & Astronomy (Dr Simon Connell and Dr Lekshmi Kailas). When commenting on the role of the Bragg Centre, Dr Herbert said:

> ***The Bragg Centre offers the perfect opportunity to find like-minded academics interested in similar areas of research, but who possess different skill sets to fill vital knowledge gaps when addressing ambitious research questions. The Bragg community and PhD scheme, together with the availability of world class technical resources, is the ideal means of building these links.***

Tony has always been inspired by the structure-function relationships of the materials around him, in particular biological materials. This led him to begin his career with a BEng, MSc and PhD in Biomedical engineering, after which he joined Leeds as a postdoctoral fellow characterising decellularised musculoskeletal biological scaffolds. During this time, Tony won a prestigious EPSRC E-TERM (Engineering in Tissue Engineering and Regenerative Medicine) landscape fellowship, the 2018 British Orthopaedic Research Society International Travel fellowship and the 2018 UK Society for Biomaterials Young Investigator award, which propelled him onwards to gain an academic post.

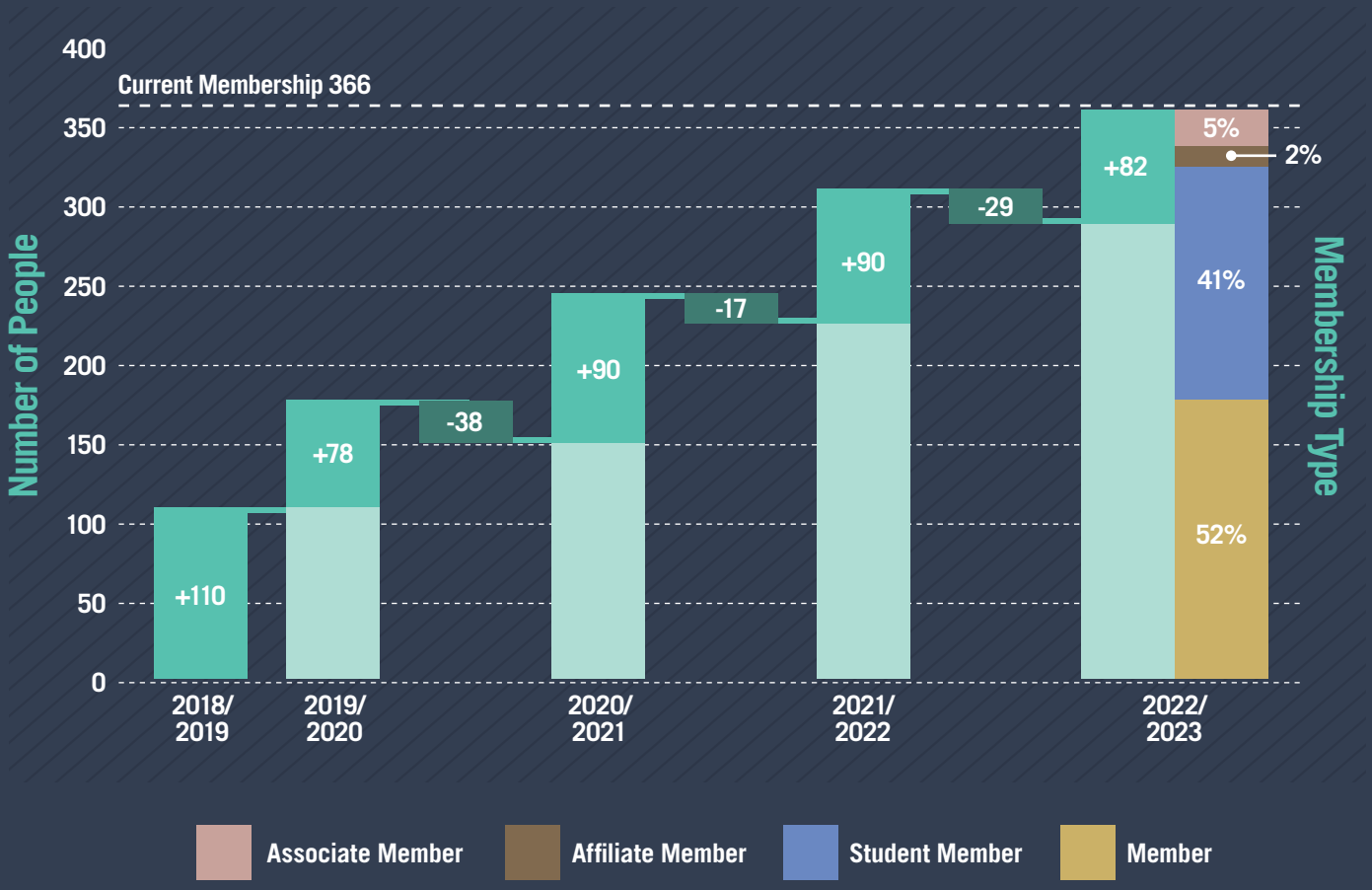


Collaborate

Membership

The Bragg Centre's community has enjoyed steady growth throughout the reporting period, **increasing by 17%** to reach a **total of 366 members**. Despite a small turnover in memberships, this increase was primarily driven by another year of sustained growth in the student community, **increasing by 24%** to reach **150 student members**.

Membership Growth



Priming Novel Collaborations

The Bragg centre's vision is to enable the greatest materials research beyond disciplinary boundaries. To that end, the Centre continues to prime collaborations between schools and faculties through schemes such as its PhD studentships and Undergraduate internships.

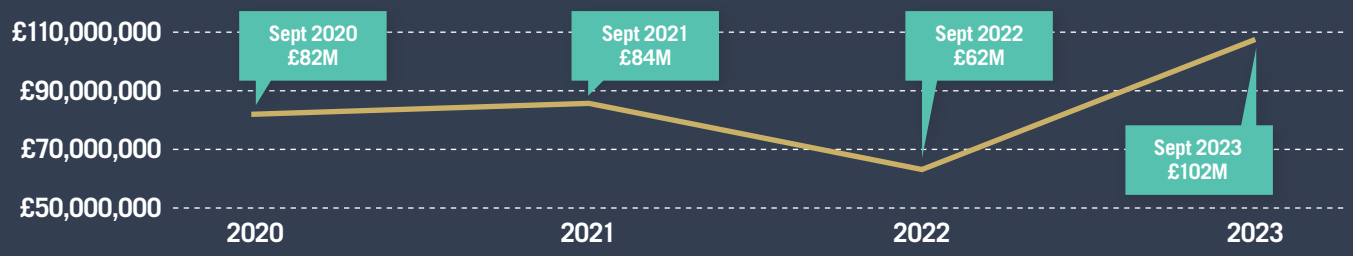
Over the last five years, the PhD studentship scheme alone has **enabled 197 novel collaborations to be explored**, developed, and ignited. These connections are highlighted in the heatmap below. Alongside significantly strengthening cross-school activity within the Faculty of Engineering and Physical Sciences (FEPS), the Centre has enabled significant growth between FEPS and the faculties of Biological Sciences (FBS), Medicine and Health (FMH), Environment (FENV), and Arts, Humanities and Culture (FAHC). Most notably the Centre has enabled new connections to develop between FEPS and the school of Design (FAHC) centred around nanocomposites. In addition to this, the Centre has supported the strengthening of connections between FBS and FMH directly without a FEPS link.

FACULTY	SCHOOL	Design	Business	Biology	Biomedical Sciences	Molecular & Cellular Biology	Earth & Environment	Food Science & Nutrition	Chemical & Process Engineering	Chemistry	Civil Engineering	Computing	Electronic & Electrical Engineering	Mathematics	Mechanical Engineering	Physics & Astronomy	Dentistry	Institute of Cardiovascular & Metabolic Medicine	Institute of Rheumatic & Musculoskeletal Medicine	Medicine
FAHC	Design							1	2		1				3					
FB	Business								1										1	
FBS	Biology							2						1	4	1	1		1	1
	Biomedical Sciences									3			1		2	7				
	Molecular & Cellular Biology								1	3										1
FENV	Earth & Environment														1					
	Food Science & Nutrition								4	4		1	1		4	11	4			3
FEPS	Chemical & Process Engineering									15	2	5	3	1	9	19	1			3
	Chemistry										2		4	1	1	8				2
	Civil Engineering											1			4					
	Computing																			
	Electronic & Electrical Engineering														3	13				4
	Mathematics															3			1	
	Mechanical Engineering															4	3		3	1
	Physics & Astronomy																1	1		7
FMH	Dentistry																		1	
	Institute of Cardiovascular & Metabolic Medicine																			
	Institute of Rheumatic & Musculoskeletal Medicine																			
	Medicine																			

Grant Portfolio & Highlights

The Centre has seen a rebound in its grant portfolio throughout the reporting period Sept 2022 - Sept 2023, boasting 175 active grants with a resulting total open portfolio of £102M across the breadth of the Bragg Centre's remit.

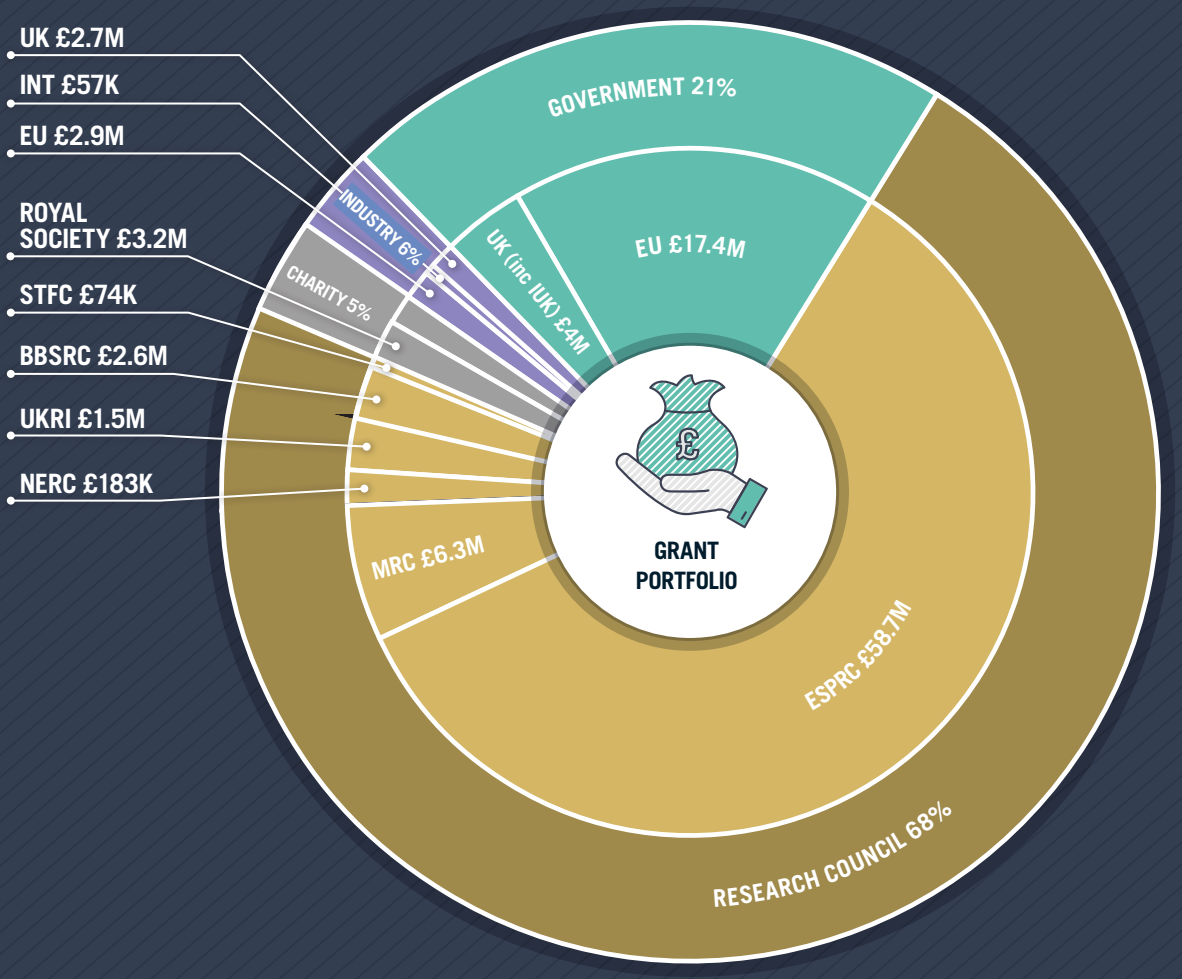
Change in Total Grant Portfolio



This strong trajectory is set to continue with **new awards totalling £29.8M secured** throughout the reporting period and due to come online in the next year.

The Centre's current portfolio boasts a doubling of direct industrial funding over the previous year, up to **£5.7M active in this reporting period**. This is drawn from a diverse range of partnerships, including Unilever, UCB Pharma Ltd, Synthomer Ltd, Sulzer Pumps (UK) Ltd, Sika Ltd, Glass Futures Ltd and Greenbone Ortho SPA.

Whilst the Centre has experienced an increase in funding from the **European Union to £17.4M**, the portfolio drawn from **charitable organisations has held steady at £5M** across the last year.



Facility Usage

Over the course of the year, the Centre has expanded its portfolio of experimental capabilities with the installation of new world-leading imaging and characterisation equipment (see pages: 16 - 19), alongside the final integration of the Royce deposition System in new dedicated space within the Sir William Henry Bragg Building (see page 14).

Alongside these key milestones, the Centre has ramped up its engagement with international, industrial, and non-academic stakeholders, increasing the spotlight on the capability and expertise of our facilities and research technical professionals. In addition to dedicated stakeholder tours, the Centre opened its doors to staff and students from across the University for the inaugural Bragg Centre Facilities Open House (see page 26 for further details). This has led to a strong and sustained demand for the Bragg Centre's research facilities throughout the year.

Alongside this, the **Henry Royce Institute** has continued to provide a national platform for our state-of-the-art capabilities, underpinning **more than £108K of access** across our facilities in this reporting period. This represents a **year-on-year increase of 36% of external access** provided through the **Royce Access Scheme**, with more than **17 different users** from **12 UK Universities and Research Technical Organisations** utilising the Centre's capability. This activity was split across fabrication services utilising the Physical Vapour Deposition facility, Nanotechnology Cleanroom and Royce deposition system; as well as characterisation with the Centre's Electron Microscopy and Near Ambient Pressure X-Ray Photoelectron Spectroscopy capabilities.

£108K
OF ACCESS

36%
YEAR-ON-YEAR INCREASE

x17
DIFFERENT USERS

x12
UK INSTITUTIONS

New Award Highlights

- Combining Advanced Materials for Interface Engineering (CAMIE), EPSRC, EP/X027074/1, Bryan Hickey, **£6,553,083**
- High Resolution Imaging Using Transient Binders, EPSRC, EP/W034735/1, George Heath, **£1,219,312**
- Label-free Chemical Imaging with High Temporal Resolution for Application in Advanced Materials, EPSRC, EP/Y01488X/1, Steve Evans, **£1,698,037**
- Amorphous Microstructure Imaging at Composite Interfaces in Metal–Organic Frameworks, EU, Sean Collins, **£2,408,573**
- Magnon dynamics in low-dimensional structures, Royal Society, URF\R\231026, Joseph Barker, **£733,703**
- Super selective cell targeting through multivalent lectin-glycan interactions, BBSRC, BB/X00158X/1, Ralf Richter, **£742,540**
- Terahertz-frequency sensors for atmospheric chemistry and space research, MRC, MR/Y011775/1, Alexander Valavanis, **£686,907**
- Analytical electron and ion beam microscopy to enable precision engineering of complex chemical products for high value technology sectors, EPSRC, EP/X040992/1, Rik Drummond-Brydson, **£1,584,600**

Bringing the Community Together

The Bragg Centre supports a comprehensive events programme, which provides something for every member of its broad materials research community. Throughout the year the Centre has delivered 26 events across its remit including six Lunch@Bragg seminars; a Collaborate industry pitch event in conjunction with Attenborough Dental; two cross institute workshops connecting the community to the Astbury Centre and to Data Science colleagues; and a PhD careers workshop.

Alongside the Centre's mainstay monthly **Lunch@Bragg** series, which connects the community to practical information that transcends disciplines, this year the Centre also introduced the **Facilities Open House** in July 2023. This year's **Lunch@Bragg** topics included interfacing with the international SoftComp Network, the political and scientific legacies of Sir William Henry Bragg and William Astbury at Leeds, and the opportunities presented by Innovate UK's Knowledge Transfer Partnership scheme.

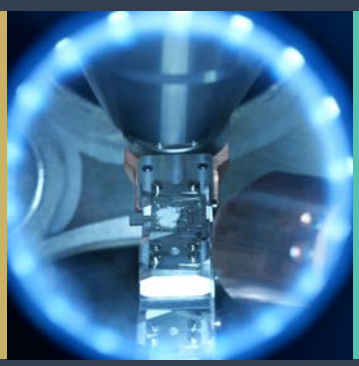
Whilst the Centre delivered its flagship annual events - the **Bragg Centre PhD Colloquium** in June and **the Bragg Exchange conference** in January - it also hosted a number of national network events on behalf of its community. These included the **Microbubble Symposium, the UK Molecular Beam Epitaxy (MBE) Meeting, the UK Surface Analysis Forum (UKSAF), the Bruker Atomic Force Microscopy Users Meeting, and the Royce Atoms to Devices PhD Summit**.

Facilities Open House

To further promote usage of the Centre's research facilities, this year the Centre introduced a new annual event which aims to *"unlock the capability"*. Launched in July 2023, the new Facilities Open House event invited all staff and postgraduate students from across the University to peak behind closed doors, see inside the experimental facilities and meet the experts who run them.

The **70 attendees** undertook a 90-minute self-guided tour in small groups around the Sir William Henry Bragg Building visiting the **Royce deposition System, Versatile X-Ray Photoelectron Spectroscopy Facility, Leeds Electron Microscopy & Spectroscopy Facility (LEMAS), Atomic Force Microscopy Facility, X-Ray Diffraction Facility, Leeds Nanotechnology Cleanroom**, and the **Physical Vapour Deposition Facility**.

At each stop, delegates were hosted by a **Research Technical Professional** to discuss the equipment's capability and the potential opportunities it might present for the delegate's research. Delegates are encouraged to come prepared with the problems they'd like to solve. The inaugural event was well received by both the facility staff and event attendees, with many interesting discussions undertaken and potential new users lined up.



The Bragg Exchange 2023

The Bragg Centre's annual conference draws together outstanding expertise from the Bragg community and external institutions to present the latest research alongside one another. With dedicated sessions for each of the Centre's thematic areas and a livestream to a public audience, the event is designed to be a platform for the exchange of ideas without boundaries.

This year the Exchange grew again with over **200 delegates** attending in person, including members of external institutions, and **600 people from around the world watching the public broadcast**. The conference featured **65 contributed posters** set alongside an exhibition of Bragg Centre facilities, as well as **12 invited talks** from internal and external speakers representing the latest advanced from across materials science and engineering.

Watch the event:
www.youtube.com/live/N5YcJKz2kaA?si=rbe7R2__hmxYsL8n

The UK Molecular Beam Epitaxy (MBE) Meeting

Since the 1980's, the UK MBE meeting has brought together the UK research and industrial communities working on Molecular Beam Epitaxy (MBE) to share their unique technical experience and recent results.

Driven by the Bragg Centre's strong track record in thin film deposition, the Centre hosted the annual meeting in April 2023 within the Sir William Henry Bragg Building. The one-day event was attended by **35 delegates** including academics, facility managers, postgraduate researchers, and **industrial exhibitors**.

x35
DELEGATES

The UK Surface Analysis Forum (UKSAF)

The UK Surface Analysis Forum (UKSAF) is a scientific society focussed on the techniques and applications of surface analysis.

The Bragg Centre hosted the 91st UKSAF meeting across two days from the 10 July – 11 July 2023 on the topic of *"Surface Analysis Beyond Model Systems"*. With **60 delegates** in attendance, representing **28 academic and industrial organisations**, the meeting was packed with dynamic discussions and debates on the current trends in the field.

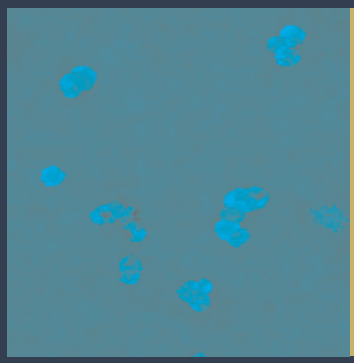
The Centre provided all the underpinning logistics to organise and deliver the event which included **13 talks, posters**, an **exhibition of 10 equipment manufacturers** and a conference dinner. The Centre further provided tours of its facilities for delegates.

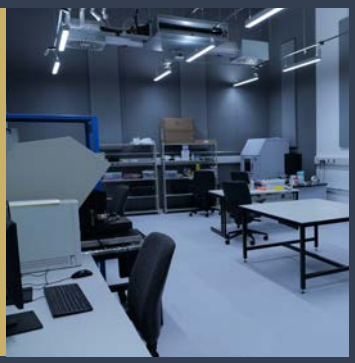
x60
DELEGATES

x28
ORGANISATIONS

x13
TALKS

x10
MANUFACTURERS





The Bruker UK Atomic Force Microscopy Users Meeting

In January 2023 the Bragg Centre played host to a gathering of the UK's Atomic Force Microscopy (AFM) community for a two-day workshop led by the multi-national equipment manufacturer Bruker.

This was the first AFM community meeting that had been convened in three years due to the COVID-19 pandemic, with users travelling from academic institutions across the UK to attend.

The workshop included a wide selection of academic talks set alongside practical demonstrations of the latest developments in AFM technology from Bruker.

By underpinning the event, the Bragg Centre **strengthened a key partnership with Bruker** and was able to showcase the cutting-edge microscopy capability housed within the world-class research environment at Bragg Centre, including the UK's first **NanoRacer high-speed AFM**.

The Royce Student Summit

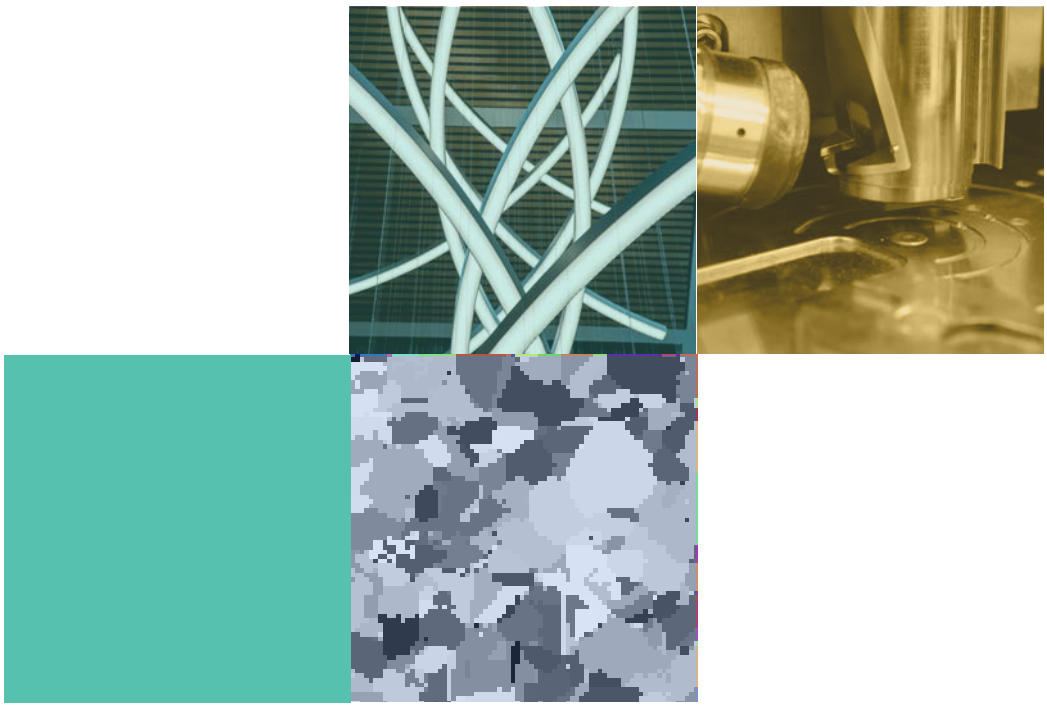
The Royce Student Summit on "Electronic and Photonic Materials" was held on the 26th July 2023 at the Bragg Centre. At the event, **21 students** from across the UK came together to discuss their research through **13 talks** and hear from key figures within the Royce Atoms to Devices theme.

x21
STUDENTS

x13
TALKS

These included insights from Prof. Edmund Linfield on "PhD Student to Research Area Lead" and Prof. Neil Alford on "Intellectual Property in Atoms to Devices". George Miller, Royce Student Engagement Manager, had this to say about the event:

> ***With Royce being a national partnership, it's great to be able to host events beyond Manchester and show-off some of the other facilities we have. The Bragg Centre was the ideal place for this A2D summit, with space for talks and networking and the assistance throughout the day from the Bragg team.***



Supporting the UK's £1Bn Semiconductor Strategy

In May 2023, the UK government launched its £1Bn semiconductor strategy, with a vision that:

> ***The UK will secure areas of world leading strength in the semiconductor technologies of the future by focusing on our strengths in research and development (R&D), design and IP, and compound semiconductors. This will facilitate technological innovation, boost growth and job creation, bolster our international position in order to improve supply chain resilience, and protect our security.***

Read the full strategy here:
www.gov.uk/government/publications/national-semiconductor-strategy/national-semiconductor-strategy

This national strategy aligns exceptionally well with the Bragg Centre's 'Electronic and Photonic Materials' theme, and as a result, the University of Leeds is playing an active role in supporting delivery of this vision.

Over the course of the year, the University has contributed to the technical and economic feasibility study as part of a consortium led by IFM Engage. Along with partners, Cambridge Econometrics, the Compound Semiconductor Applications (CSA) Catapult, Future Horizons, Imperial College London, the Photonics Leadership Group, Semiwise, Silicon Catalyst, and TechWorks; the study is assessing the UK's preparedness to support commercial R&D, grow the UK semiconductor sector and contribute to supply chain resilience.

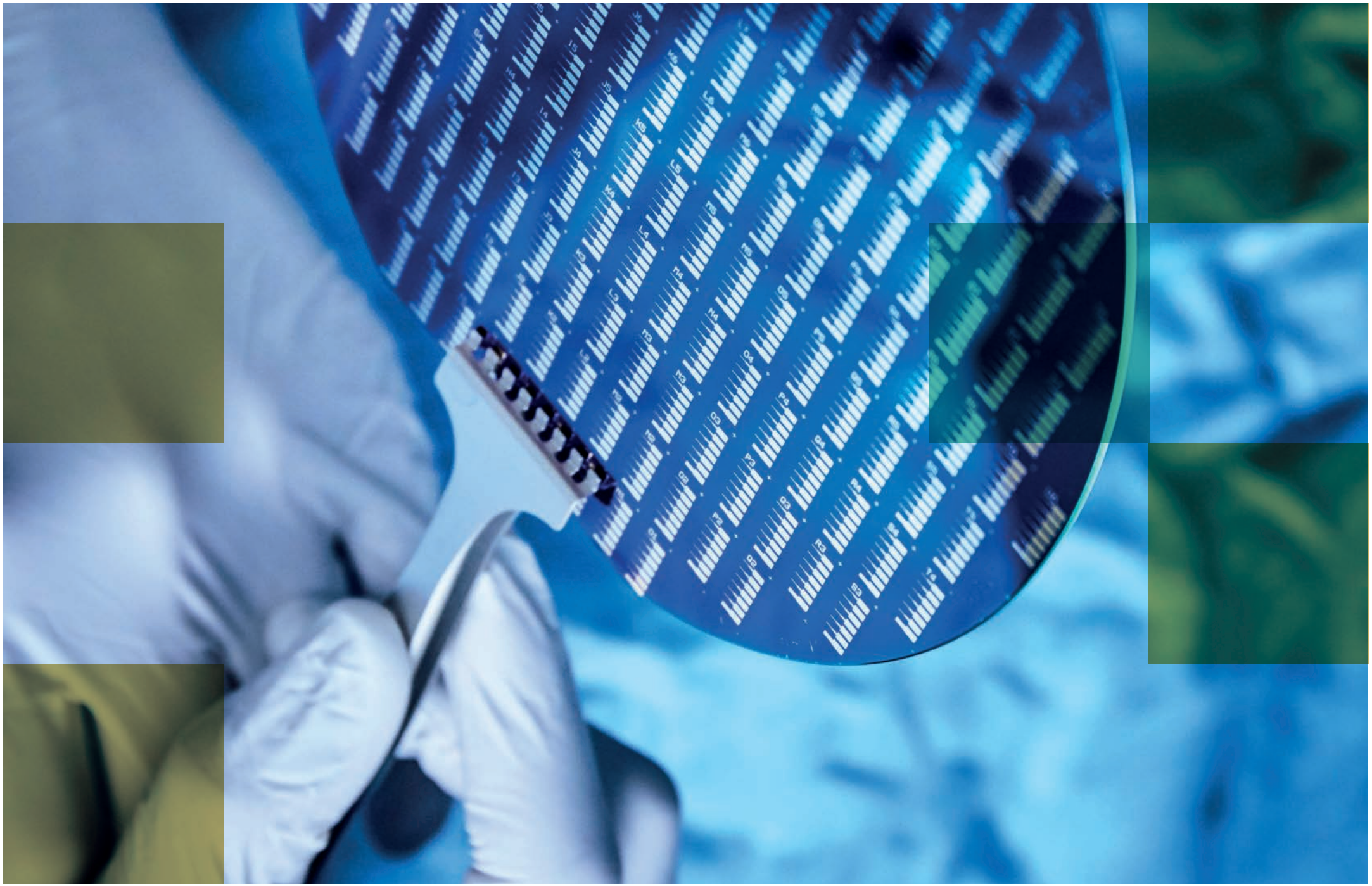
Find out more here:
https://engage.ifm.eng.cam.ac.uk/uk-semiconductor-infrastructure-initiative-2023/#:~:text=This%20will%20aim%20to%20reposition,Advanced%20packaging

In September 2023, the Centre was delighted to host a ministerial visit from the Department for Science, Innovation and Technology, to explore the contributions that the Bragg Centre is already making to the Semiconductor Strategy. During the visit, the delegation was shown how the Leeds Nanotechnology Cleanroom is being used regularly by companies to prototype their new devices, and how the Bragg Centre has developed a broad portfolio of R&D programmes based on compound semiconductors, with materials and devices also supplied to leading research laboratories internationally.

A specific focus for the national strategy is to address the development of advanced skill sets within the population to meet the needs of the UK semiconductor industry. The Bragg Centre is well placed to support this goal by leveraging the expertise of its Research Technical Professionals, in conjunction with its world-class infrastructure, to deliver training. In addition to establishing a new week-long Cleanroom training course (see page 40), the Centre has focused on outreach as part of a funded Innovate UK programme on 'Semiconductor industry skills and training' led by Swansea University with CS Connected Ltd, Immersify Ltd, and Warwick University.

More widely, a significant challenge that is faced by the semiconductor industry is the need to develop increasingly environmentally sustainable and circular technologies. To further this conversation, the Bragg Centre was delighted to co-host a *'Circular materials for sustainable functional devices workshop'* in conjunction with the UK Engineering and Physical Sciences Research Council's (EPSRC) Advanced Materials team. The one-day event, which cut across the EPSRC's Advanced materials, ICT and Circular Economy themes, was supported by the **Henry Royce Institute** and brought together academics, research technical organisations, policy makers and those working in industry for an active discussion about a materials focus for a sustainable digital future.

With a significant amount of activity already underway, there remains much to be done in 2024 to support the UK Government's Semiconductor Strategy, and the Bragg Centre looks forward to playing its part!



Establishing Strategic Partnerships

QinetiQ on campus

This year the Centre was delighted to welcome a member of QinetiQ staff – Dr Richard Moore – on campus at Leeds to join the materials research community.

To capitalise on the growth of the materials research community and world-leading research environment afforded by the move of the Centre's facilities into the Sir William Henry Bragg Building, the Centre has developed a vision to increase the breadth, depth and longevity of its research collaborations by embedding industry into its community as equal partners. Over the course of this year, the Centre has begun to realise this vision and has been delighted by QinetiQ's decision to place a member of staff permanently on campus as part of a long-term strategic partnership with the University.

The development of this partnership began in 2022 with a **Royce 'Atoms to Devices' theme** meeting at Leeds attended by QinetiQ, which provided the opportunity to showcase the University's facilities, and especially the new Royce deposition System.

In October 2022, QinetiQ awarded an iCASE studentship to Bragg Centre member and theme lead, Prof. Christopher Marrows (School of Physics & Astronomy) to work on magnetic materials using the Royce deposition System, and from this point the partnership has steadily grown. Over the course of the last year, QinetiQ has funded a number of Bragg Centre internship students, undertaken collaborative work in the Nanotechnology Cleanroom, and Dr Charles Footer - Head of Advanced Services and Products at QinetiQ – has joined the Bragg External Advisory Board.

There is significant mutual benefit from the partnership, whilst QinetiQ gain direct access to the Centre's skills and equipment, the Bragg Centre's community – from undergraduates and PhD researchers to senior academics – are benefitting from a deeper insight into industry's priorities and timescales. This close working relationship enables ideas and concepts to be rapidly explored and increases the effective transition of technology from the academic research laboratory to industrial demonstration.

Having Richard on site is fantastic for the Bragg Centre. QinetiQ have very broad ranging interests, and it is great to have the ability to meet over a coffee in the Bragg café, discuss a potential idea, and then find a way to take the project forward. This is precisely what we wanted the Bragg Centre to enable, and we hope the QinetiQ team on campus will grow in future years as more projects are co-developed with our researchers.'

Prof. Edmund Linfield, Bragg Centre Director

Working with the Bragg Centre at the University of Leeds has provided QinetiQ with access to a wealth of world-leading facilities, including an ever-growing list of unique and cutting-edge equipment enabling the rapid design and fabrication of novel materials. Of particular note are the facility operators whose unrivalled knowledge and understanding of the equipment has led to real breakthroughs and rapid advancements in novel material design.

Dr Richard Moore, Optical Scientist at QinetiQ

Augmenting Reality with Liquid Crystals

The market for augmented reality (AR) and virtual reality (VR) technologies is rapidly growing with the development of digital eyeglasses, switchable contact lenses, and headsets helping to revolutionise the education, health and business sectors.

To capitalise on this growing area, this year the University of Leeds signed a five-year research collaboration agreement with the leading science and technology company, Merck Electronics KGaA, to develop new AR and VR applications with liquid crystals.

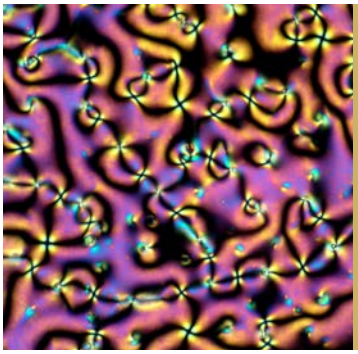
As a global market leader in liquid crystals technologies and applications, Merck have expressed interest in the great potential for liquid crystals to break into the AR & VR market. To address this, Merck are investing **£2.8M** in a collaboration with Leeds' scientists to focus on the deployment of liquid crystals, commonly used in smartphones and TV screens, into devices suitable for augmented reality and virtual reality applications. This partnership is being delivered by an interdisciplinary team of Bragg Centre members including Dr Richard Mandle (Schools of Physics & Astronomy and Chemistry), Prof Helen Gleeson (School of Physics & Astronomy), Prof Gordon Love (School of Computer Science), and is led by Dr Mamatha Nagaraj (School of Physics & Astronomy).

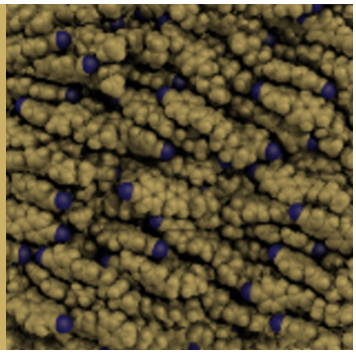
A liquid crystal is a thermodynamic stable phase that is characterised by the anisotropy of its properties without the existence of a three-dimensional crystal lattice. In this state, the molecules have significant translational freedom, like a liquid, but have a tendency to point along a common axis providing long range order, similar to a solid.

The aim of the Leeds Merck partnership is to investigate novel liquid crystal chemistries across a range of projects from theoretical understanding, novel materials synthesis, and prototype device fabrication. The Leeds team has a sustained record of inventing applications for liquid crystals beyond the traditional market-ready technology of flat panel televisions and computer monitors, including the recent **£1M** project to develop digital liquid crystal-based optics devices with Merck.

When reflecting on this ongoing partnership with Merck, Dr Nagaraj said:

We are very excited about this partnership. Augmented reality, virtual reality and mixed reality technologies are transforming the way we see the world and perceive and process information. At Leeds, our ability to characterise and understand soft materials, chemically manipulate and use them in devices uniquely places us to deliver new science and applications. The expertise of Bragg's community and infrastructure offers an ideal environment to support these activities.





A Prosperous Partnership

Prof. Louise Jennings
Professor of Medical Engineering
School of Mechanical Engineering

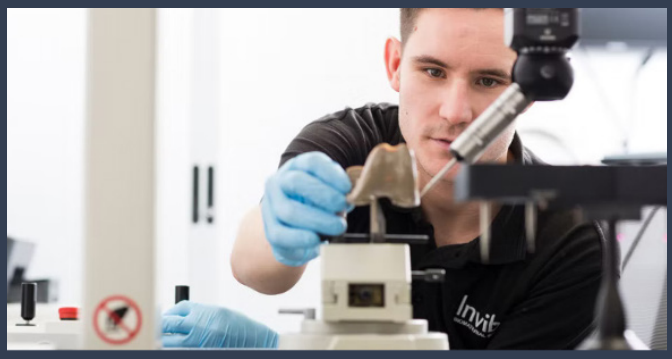
According to the National Joint Registry, Total Knee Replacement is generally a successful elective operation, with more than 100,000 procedures performed every year in England and Wales alone. However, currently nearly 30% of recipients report little or no symptom improvement, and up to 10% require reoperation and replacement within 10 years of initial surgery.

Conventional knee replacement joints are composed of metal femoral and tibial components, which are typically made of a cobalt chrome (CoCr) alloy due to its high strength and resistance to corrosion; whilst a plastic tibial insert and patella are formed from polyethylene capable of withstanding high wear. Although they have been in use for years, these conventional joints can present major complications for up to 15% of the population that display sensitivity to the constitute metals.

Work by Prof. Louise Jennings and Invibio Biomaterials aims to disrupt this conventional approach with a new knee replacement joint manufactured by Invibio entirely from a biologically compatible PEEK polymer, namely Invibio's trusted material, PEEK-OPTIMA™.

Through their partnership, Invibio have already produced a PEEK-OPTIMA™ knee product which removes the use of heavy and stiff metallic materials from the joint replacement operation, thereby reducing the potential for harmful reactions seen in some sensitive patients. This first iteration of a PEEK-OPTIMA™ femoral knee joint, which comprises a cemented femoral component used in conjunction with an all polyethylene tibia and patellar replacement component, has already been implanted into a small number of patients in a pre-market, global feasibility study designed to assess safety and efficacy.

This year, Louise further strengthened this partnership with the receipt of a **£1.7M** EPSRC Prosperity partnership, one of only 19 awarded. Prosperity partnerships are designed to support co-creation between businesses and academia, responding directly to an industrial need. This grant will fund the investigation of alternative ways to fix the knee replacement into bone and explore how the natural tissue of the kneecap interacts with the polymer. Through this project the partnership hopes to improve clinical outcomes and the quality of life for patients with osteoarthritis.



The research programme will make use of the tribology and microscopy capabilities of the Bragg Centre, in particular the expertise within the Leeds Electron Microscopy and Spectroscopy (LEMAS) facility. As well as building on her established collaboration with Invibio, this project will support Prof. Jennings to establish new collaborations with Geistlich Pharma, as well as academics at the Centre for Medical Materials, part of University of Cambridge.

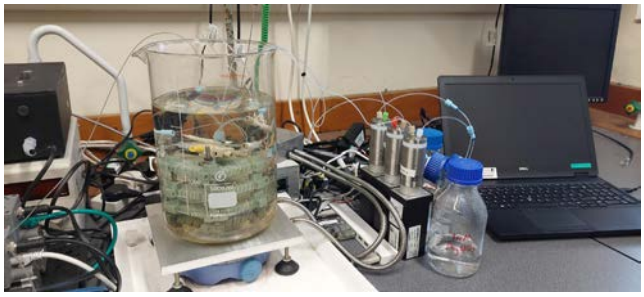
Professor Jennings' interests are predominantly experimental in nature, developing functional pre-clinical simulation and research methods that can then be applied to medical devices and interventions. With a background which spans industry and academia, Louise is ideally placed to support innovation across this boundary. As a Chartered Mechanical Engineer with the Institution of Mechanical Engineers, she continues to work closely with industry, applying pre-clinical research methodologies to medical devices in commercial development in order to enhance their safety and reliability.

Safety by Design

Prof. Andrew Nelson
Professor of Nanotoxicology
School of Chemistry

Nanomaterials have the potential to be harmful to humans and other forms of life in ways that have not been fully understood yet. In response to this a team of 18 international organisations led by Prof. Andrew Nelson at Leeds has come together with the aim of applying the "Safety by design" concept to minimising these risks.

The SAfety BY Design Of nanoMAterials (SABYDOMA) project is funded through the EU Horizon 2020 programme and aims to create a high-throughput flow through platform for nanotoxicological screening of nanomaterials, providing a direct feedback loop at the point of manufacture and thus avoiding the release of unsafe materials into the environment.



The idea for the SABYDOMA project was first conceived over forty years ago in the context of water quality regulations. At the time there were intense discussions over whether, in the process of cleaning up rivers, discharges of noxious materials should be banned completely or whether the rivers should be continually monitored for these compounds. In the latter case if the levels exceeded a "safe" concentration, a negative feedback response should be fed back to the discharge source to decrease the output of these materials. This policy in environmental management was termed "Environmental Quality Objectives (EQO)". In the Environmental Health context, this policy of "feedback loop control" has a very general application and Andrew's team therefore tailored the SABYDOMA project around this idea and applied it directly at the point of manufacture instead.

The essence of SABYDOMA was to directly couple the online screening of a nanomaterial with its online production procedure. If the nanomaterial's toxicity goes above a recommended "safe" level, then the screen signal "tells" the nano production line to moderate the nanomaterial characteristics, such as particle size or surface coating, which render it less biologically-active.

A direct coupling of the screening to the production line removes the time interval between production and testing which can lead to deterioration in the nanomaterial in the environment and thus provide unrepresentative results of its impacts. The SABYDOMA platform is itself rapid and ensures a continuous supply of high-quality screened nanomaterial. A further significant advantage of this technology is that manual handling is taken to a minimum which decreases input error and lessens the hazard to workers.

Highlighting the unique approach of SABYDOMA, Prof. Nelson pointed to the industrial validation of the SABYDOMA platform which was completed across four independent companies located in four separate countries. Now in its fourth year, SABYDOMA is successfully achieving all of its objectives, with the the "Biomembrane screen" having been validated by APPNPS in Barcelona, the "Mini-Release Accelerator" having been transferred to Cnano in Athens and RESCOLL in Bordeaux, and the "cell-based screener" has been coupled to the nano-production line onsite at Fraunhofer.

In the final three months of the project, the respective technologies will be refined and demonstrated on their industrial sites to enable them to be used for the ultimate benefit of the community. The SABYDOMA technology will provide immediate benefit to nanomaterial manufacturers who wish to produce safe nanomaterials with minimum negative impact and maximum function. Apart from the transfer of the technology to four respective companies who will use it to maximise their output, the released flow cell coupled to the Biomembrane sensor has now been commissioned as a key platform for preliminary screening of advanced coatings in the Horizon Europe project Bio-SUSHY which Andrew and Prof. Nik Kapur (School of Mechanical Engineering) will contribute to from Leeds over the next three years.

This project is an outstanding example of interdisciplinary collaboration in safe design of materials, something which the Bragg Centre is keen to continue to champion. The centre provides many facilities which can be used for the development of platforms such as SABYDOMA, including advanced nanomaterial characterisation. In reference to this, Andrew said:

The fact that these facilities are all located in one 'shop' is tremendously advantageous to us.

Educate

The Bragg Centre continues its commitment to develop a skills pipeline in materials research and engineering. This year, the Centre has expanded its internship programme and welcomed a further cohort into its PhD Studentship programme.

Undergraduate Summer Internship Scheme

Throughout the summer of 2023, the Bragg Centre enabled a further eight undergraduate students to undertake research internships supported through a combination of Bragg Centre, **Royce** and Industrial funding. The scheme offers final year undergraduates 8-week funded research placements which tackle cross-cutting interdisciplinary activity in a materials area. Alongside their research, the students joined other interns from across the faculty to engage in a series of employability skills workshops, including a tour of the Bragg Centre facilities, to provide insights into a career in research. The scheme culminated in a poster showcase hosted in the Bragg Centre and with poster prizes sponsored by the **Henry Royce Institute**.

When commenting on the support that the Bragg Centre provides to Undergraduate interns across the wider faculty, Poppy Beacock, faculty employability and placements officer said:

> ***the Bragg Centre also provides a wide range of additional support which enhances the scheme. In our feedback from the scheme, 71% of interns selected the [Bragg Centre] tour as the additional activity they enjoyed the most…***

The Bragg Centre is proud to continue to support widening participation in research through the provision of events, training opportunities and funding. These internships are a brilliant way for students to support themselves throughout the summer and provide many with their first experience of real research within a world class environment. Not only do these internships support the talent pipeline, but they provide a test-bed for new ideas and collaborations across the Bragg Centre's remit.

This year's projects included:

QinetiQ Funed:

- Developing methods for high-speed video analysis - **School of Physics & Astronomy**
- Simulation of tensile behaviour of cold-formed steel plates using Ansys and Abaqus software programs - **School of Civil Engineering**
- 2D nano-materials produced from waste for strengthening cement or other binders for concrete - **School of Civil Engineering**

Royce Funded:

- Building functional biomaterials using proteins as Lego building blocks - **School of Physics & Astronomy**
- Fabricating and imaging an organic molecular film - **School of Physics & Astronomy**
- Topological insulator optoelectronics – **School of Electronic & Electrical Engineering**
- Elucidating the CO2-Cement interaction via scanning electron microscopy and Raman imaging mapping - **School of Civil Engineering**

Bragg Funded:

- Tribology as a design tool to tailor soft food materials for healthy ageing - **School of Food Science & Nutrition**

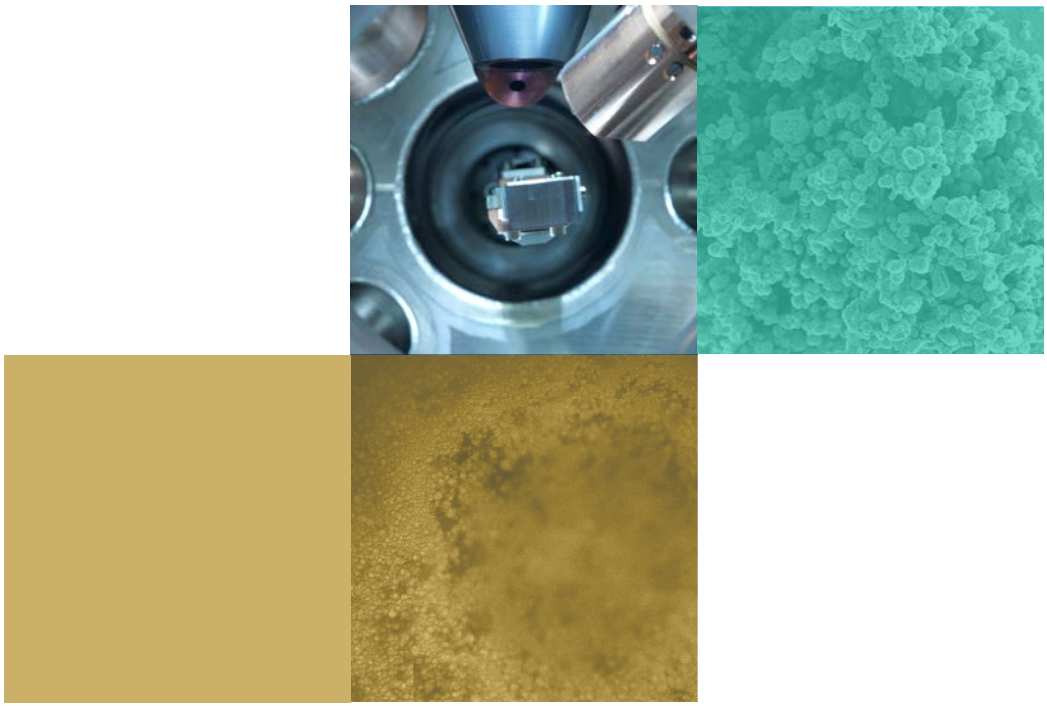
The Bragg Centre PhD Colloquium 2023

The Bragg Centre is committed to supporting the career and personal development of the wider student community in materials research. As part of that mission, the Centre's PhD Colloquium provides a platform to develop confidence, communication skills, and an awareness of career opportunities.

The PhD Colloquium returned in June 2023 with a stronger focus on developing presentation skills. To support this, each speaker was provided with slide templates, detailed coaching, and strictly monitored timekeeping.

Learning how to communicate with other scientists and engineers across disciplinary boundaries is a critical skill to enable future collaborations and innovations. The PhD Colloquium enables students to develop these skills across the wide breadth of the Centre's constituent disciplines. This year's event saw **67 Postgraduate researchers** from 11 schools and 4 faculties deliver **12 talks**, **34 posters** and engage in cross-disciplinary networking.

In addition, the students joined a lively debate with industry experts during a panel discussion on *"Materials for a sustainable future and circular economy"*. This year's panellist included Dr Sheetal Handa, Materials Science Advisor, BP; Dr Linda Pravinata, Lead Innovation Scientist, Marlow Ingredients; Scott Butler, Executive Director, Materials Focus; and Athina Papakosta, Sustainability and Carbon Lead, SCS Railways. The hour-long session was packed with wide ranging themes, from how to increase the sustainability of current research activities through to exploring the potential skillsets that future innovators will need to create the next generation of sustainable materials.



Bragg PhD Studentship Programme

Each year, the Bragg Centre offers several EPSRC funded PhD positions as part of its Studentship Programme. All projects supported by this highly competitive scheme are designed to establish novel connections between disparate research areas under the Bragg Centres' remit, putting our students at the bleeding-edge of materials research and engineering.

The programme encourages peer-support and cross-cohort activities, whilst the students benefit from being embedded within a vibrant interdisciplinary community which provides exposure to a much broader range of expertise and capability than a traditional PhD.

This year, the students have continued to excel right across the cohorts, with a strong active presence at the heart of the Bragg Centre community. Whilst the 1st cohort are now approaching their write up phase and looking to their next steps, the Centre is pleased to welcome its 4th and largest cohort to date, with six new students across a broad range of exciting projects.

Introducing the 2023 Cohort

Amy Truesdale

I gained an honours degree in Biomedical Science at the University of Strathclyde, and a master's in Industrial Biotechnology at the University of Aberdeen. Afterwards I worked on a Knowledge Transfer Partnership between the University of Aberdeen and a biologics company, in which I aimed to develop an antibody for use as a flow cytometry reagent and developed my interest in cell analysis techniques. Then during the pandemic, I joined the University of Edinburgh's COVID-19 TestEd project, which provided asymptomatic saliva-based PCR testing for their staff and students.

When looking for a PhD, I was hoping for something that would incorporate both innovation and collaboration, so the Bragg Centre was a perfect fit. I'm grateful for the opportunity to work across disciplines, apply my knowledge in a new context, and use exciting new equipment. My project aims to combine high-speed fluorescence microscopy with deformation cytometry to investigate a mechanosensitive ion channel in blood cells.

Sameena Kanakkayil

I attained my Bachelor's and Master's degrees at National Institute of Technology-Calicut, India, supported by the prestigious INSPIRE (Innovation in Science Pursuit for Inspired Research) fellowship. I chose the subject of material chemistry for both degrees, as I was fascinated by it. During those times, I learned a lot about the relationships between material synthesis, structure, and properties. After deciding to pursue a PhD in this field, I discovered the Bragg Centre and its multidisciplinary nature. I was attracted by the opportunity to interact openly with students and faculty from other departments, as well as the advanced facilities accessible, and being a member of an active research group.

My PhD project is to explore the concept of using water as a functional surface for material synthesis. It is fascinating since it is surfactant-free and flexible, and the material formed is easily transferred to any chosen substrate. Thus, my PhD project will establish a novel, sustainable approach for synthesising large inorganic thin films.

Victoria Haines-Woolley

After studying a Masters in Medical Engineering here at Leeds, I was keen to develop a deeper knowledge in tissue engineering. With a background in structural engineering I was hoping to apply my multi-disciplinary knowledge to new research.

I feel very privileged to have received a Bragg Studentship which is allowing me to undertake collaborative research between the Institute of Medical and Biological Engineering and the Faculty of Biological Sciences. The project will explore using animal tendon tissue as a graft material in the knee of the human body. The process of removing the animals cells to improve acceptance of the material will be explored, and how this changes the mechanical properties. The project will also study the cell matrix interactions by creating a dynamic mechanical environment in the laboratory that simulates physiological loading.

I look forward to being part of the Bragg Centre as it feels like a collaborative hub bringing the wider materials research community together. The wealth of expertise and state of the art facilities available will be invaluable to achieving high quality materials research.

Abigail Breeden

Having spent the last four years at Manchester Metropolitan University studying Pharmaceutical Chemistry I graduated with a first class MChem degree and as recipient of the RSC John Leach Memorial Award. Throughout my university years I discovered a passion for laboratory work and a deep-routed academic interest for applying chemical knowledge to biological systems. I was therefore very enthusiastic to continue studying, developing my skills and researching a topic that is so fascinating to me.

My PhD will look to address the issue of bacterial antibiotic resistance by developing atomically precise, multi-ligated metal nanoclusters as effective, new nano-antibiotics. The Bragg Centre with its multidisciplinary nature and huge range of technical and academic expertise works at the forefront of cutting-edge research, providing state of the art facilities and the opportunity to work collaboratively with different schools across the University of Leeds, and beyond, to develop my PhD topic as well as my own knowledge and skills.

Dylan Charnock

I recently completed my degree in Electronics and Computer Engineering here at the University of Leeds. Previously, my time was focused on video game modding, server distribution, competitive sports and music production which laid the foundation for my academic interests.

My final year undergraduate project was on nanopore signal processing. In essence, denoising, anomaly recognition, feature extraction and identification of 1D ionic current traces obtained from the translocation of nanoscale analytes electrophoretically through a nanoscale pore.

My PhD project carries on from this, utilising supervised machine learning methods for nanopore signals and other single-entity electrochemistry techniques. Another aim for the project is to integrate nanopore sensing and nano-impact electrochemistry, a technique used to analyse the charge transfer of an electrochemically active analyte upon impact with an ultra-micro electrode. The big picture is pertinent to low-cost, real-time, single-molecule resolution biosensors for disease detection, environmental monitoring and diagnostics.

The Bragg Centre garnered my interest due to the inter-disciplinary nature, state-of-the-art equipment and support network which enables the academic and professional development relevant to my interests.

Armin Gholizadeh

Industrial collaborators have developed and scaled up a novel process using batch flash pyrolysis for the economic bottom-up synthesis of turbostratic graphene at large scale. Armin's project will focus on the optimised processing and use of this material as a reinforcement material in sustainable composites.

Meeting the Skills Demand of the UK's Semiconductor Sector

In May 2023 the UK government published its national semiconductor strategy, detailing its plans to grow the UKs semiconductor sector, increase its resilience, and protect its security (see page 28). The strategy identifies the need to address gaps in the pipeline of advanced skills and train a workforce ready to meet the next generation of semiconductor development.

Already prepared to support this national strategy, this year the Bragg Centre leveraged the infrastructure and expertise of its nanotechnology cleanroom to establish a practical training course in cleanroom skills. Delivered in conjunction with partners at the **Universities of Cambridge and Swansea**, and supported by the **Henry Royce Institute**, the Centre hosted **20 attendees** for a **week-long training course** in January 2023.

The course focussed on the production of a field-effect transistor, with attendees learning sample handling, lithography, etching, deposition, and packaging through a combination of taught seminars and practical hands-on sessions in the cleanroom.

With a small diverse cohort that comprised **18 attendees** from **six UK Universities** and **two from multi-national industries**, each attendee benefited from substantial one-to-one support. When reflecting on their experience, one attendee remarked:

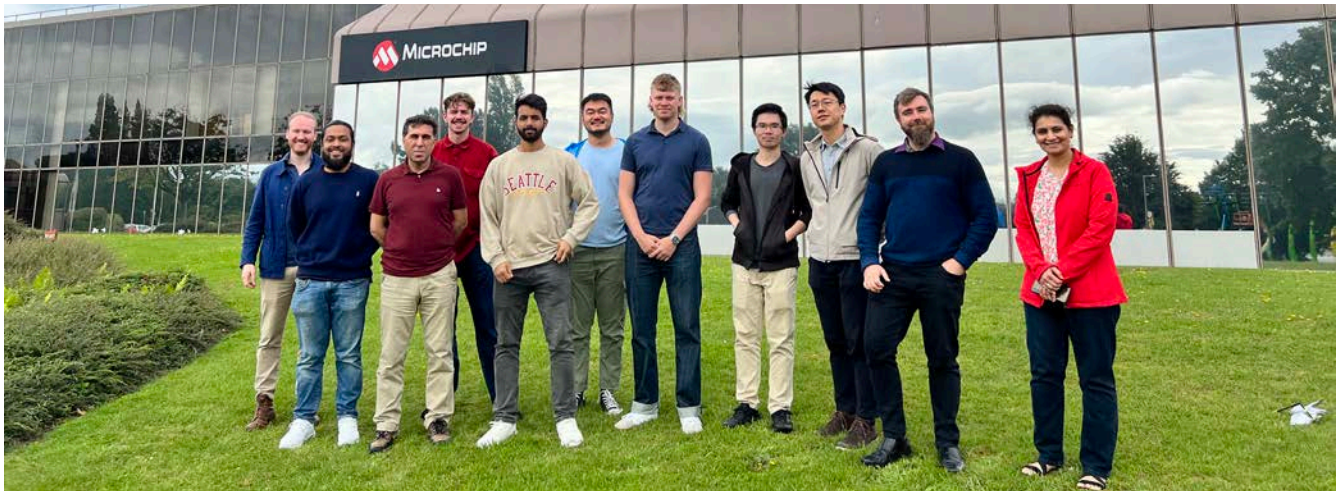
> ***There was a lot of practical work in the cleanroom, supervised by experts who were great at answering my questions. Also, the small group numbers meant that it was engaging and we received close supervision.***

Whilst the hands-on technical training was delivered by **expert experimental staff**, the theoretical underpinnings were provided by world-leading academics and the course was **designed with an industrially relevant focus** to prime the workforce of the future. With attendees from masters level through to post-doctoral staff, the wide relevance of the course was highlighted:

> ***I really enjoyed the course and I think it provides a thorough overview of cleanroom processes, the supporting theory, and how it all links to industry. I'd highly recommend it to any master's student, PhD student, or post-doc with an interest in building up cleanroom skills. Thank you for making it such an enjoyable experience!***

Following the success of this first course, the consortium which includes the Bragg Centre and **Royce Institute**, have committed to delivering the course on an annual basis with the aim of increasing uptake from industrial staff. In addition, the Bragg Centre and Royce will launch a new training course on Thin-Film Deposition in March 2024 leaning heavily on the capability of the Royce deposition system. This course will introduce thin-film deposition and analytical techniques for characterising their structure and electrical behaviours.

Touring Potential Career Paths



The Bragg Centre is proud to connect its staff and students to opportunities for training and career development. In August 2023 the Bragg Centre took nine PhD students and Postdoctoral staff on an excursion to the South Wales Semiconductor Cluster to explore potential career opportunities.

The two-day visit began with a tour of the University of Swansea's new Centre for integrative semiconductor materials (CISM) led by Prof. Paul Meredith. This state-of-the-art cleanroom facility is arranged in a ballroom configuration offering a manufacturing grade environment to enable the translation of semiconductor technologies from academia to industry. This capability compliments the activity of the Bragg Centre's cleanroom which focusses on earlier stage technology readiness level (TRL) research. During the visit, the attendees networked with colleagues at Swansea through a training and skills focussed workshop followed by an evening meal.

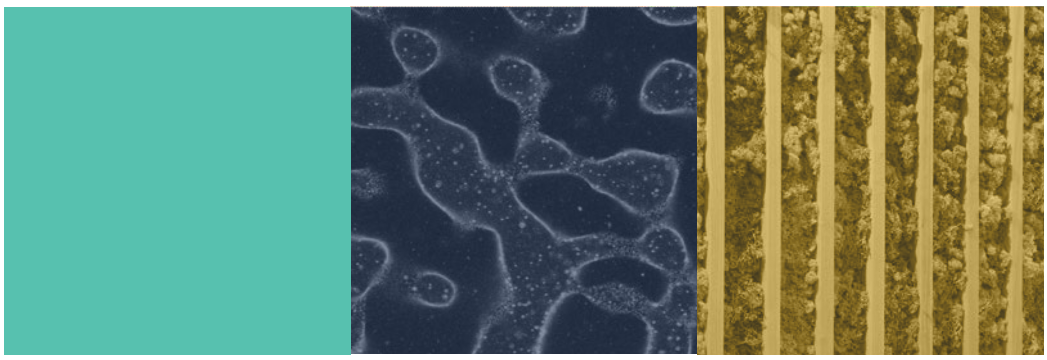
During the second day, attendees undertook a tour of industries situated along the M4 corridor which span the full semiconductor supply chain. Beginning with a visit to SPTS Technologies, a KLA company, which provides advanced wafer processing equipment including physical, chemical and molecular vapour deposition (PVD, CVD, MVD) systems to the semiconductor and microelectronics industries. The attendees were toured around the facility by SPTS's Senior Director of Compliance and Commercial.

This was followed by a visit to IQE Europe Ltd led by the Group Technology Director. IQE specialises in producing doped semiconductor wafers as underlying substrates at the start of the supply chain.

Next, the group explored the compound semiconductor applications (CSA) catapult innovation centre. CSA provides a platform to bring academia and industry together to commercialise the next generation of compound semiconductor products and technologies. Following an introduction from the CEO, the attendees toured the power electronics and packaging process facilities, discussing current projects with the research staff.

The visit concluded with a tour of Microchip, led by a Technical Staff Engineer and the Principal Design Engineer. Microchip develops advanced packaging processes and systems for environmental encapsulation of semiconductor and microelectronics devices.

Despite a long journey, the visit was well received by all attendees who noted the beneficial exposure to industry and insights the trip provided to them. Alongside this, the Bragg Centre strengthened key industrial links with the companies visited, with further engagements planned both in Leeds and in South Wales. The Bragg Centre is committed to enabling similar visits to industrial partners and national facilities in the future.



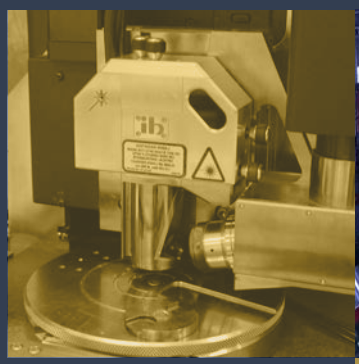
Inspire

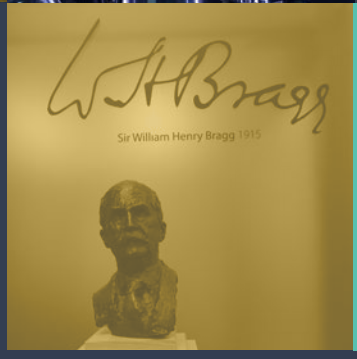
The Bragg Centre continues to reach a broad audience through its academic outputs, social media channels and public engagements, with the goal to widen participation in material science.

With the Centre's reputation growing rapidly, our community continues to contribute to the academic conversation publishing **302 journal articles** in the last year.

Throughout the same period, the Centre increased its audience across its social media platforms, where the Centre's Twitter audience has **grew by 16%** to **959 followers**.

Whilst, the Centre's audience on Linkedin has **increased by 37%** **to 578 followers** primarily from the local West Yorkshire region, but with its national following growing steadily; its video content was viewed **1,190 times** on its Youtube channel, reaching people from around the world including the UK, USA, Philippines and Germany.

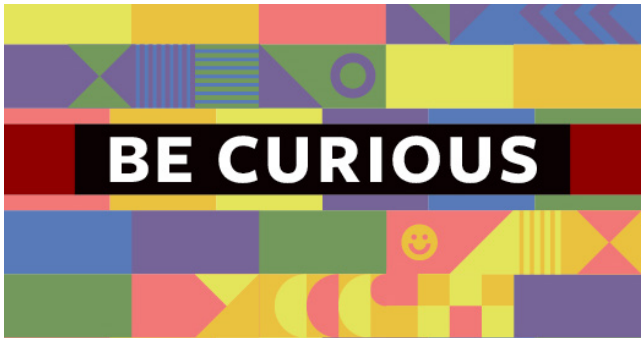




Inspiring the Next Generation of Materials Scientists

A core mission of the Bragg Centre is to widen participation in materials science by connecting the general public and school students to cutting edge research and innovation.

Be Curious Live



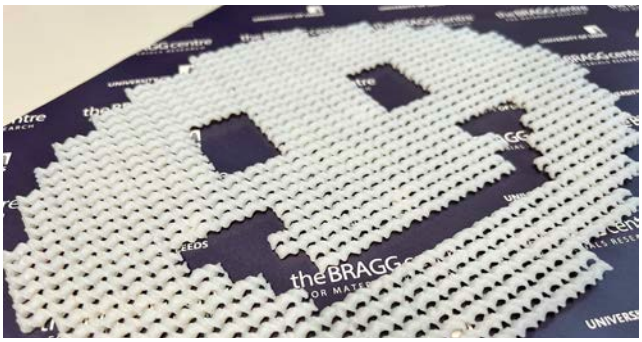
This year Bragg Centre members joined colleagues from across the University to welcome over **1600 people** to Leeds' annual family open day, Be Curious Live. As part of the event a team led by Dr Philippa Shepley (School of Physics & Astronomy), demonstrated how X-rays and Bragg's law can be used to look inside materials and understand how their atoms are arranged through the process of X-ray diffraction. The arrangements of atoms in regular repeating patterns, known as a crystal structure, defines the properties of the material, in some cases allowing it to conduct electricity or to be magnetic. By understanding the link between a materials crystal structure and its properties, the visitors were shown how scientists are able to tune the function of a material for a variety of applications. Families visiting Be Curious learned about the exciting legacy of Sir William Henry Bragg, X-ray diffraction and crystal structures at Leeds. Putting their newfound knowledge into practice, the visitors had a go at making their own crystal structures using the **Crystal creations maker kit**.

Crystal creations maker kit

Maker kits embrace creativity and creative thinking to allow young people and families to explore innovation in material design. The Crystal creations kit challenges the individual to create their own crystal structures using repeating patterns of coloured Pom Poms, where each Pom Pom colour represents a different type of atom. The Kit encourages people to consider what would happen to their pattern if the atoms were different sizes or if defects existed such as missing atoms. Crystal creations, is part of a wider collection of Maker kits which have been made possible by an EPSRC funded project led by Prof. Lorna Dougan (School of Physics & Astronomy).

Discover more MakerKits at:
www.creatematerialsinnovation.com/maker-kits

DNA Origami



This year the Bragg Centre's nationally acclaimed DNA Origami project completed its third round, reaching a further **117 students** from **12 schools** across the country with some surprising outputs.

The DNA origami project introduces students to materials research by taking something that they are familiar with, in this case DNA, and shows them how it can be repurposed for a different application. This approach is aimed at expanding the student's perspective beyond the discipline-specific and example-led learning of a school classroom, towards a creative and discovery-led way of thinking. Evaluation of the project has shown that, not only have the students benefited from developing key employability skills including creative problem solving, self-management and collaborative teamworking; but that the teachers involved have also been inspired and have begun integrating interdisciplinary approaches into their teaching.

This year, in addition to supplying practical kits, the Bragg Centre provided **£2K to support travel for 35 students from disadvantaged schools to visit the Centre** for its annual student workshop. During the event the students delivered presentations about their projects, undertook tours of the experimental facilities, and networked with PhD-level researchers about their post-graduate research in material science.

Beyond the successful completion of the project, the participating schools delivered a wide range of outputs and evolved the project into new areas beyond the Centre's expectations. Whilst students from Altrincham Grammar School for Boys, Manchester investigated a novel way to use DNA origami to fight organ rejection; a student from Liverpool Life Sciences UTC, Liverpool received the Business of Science Young Innovator of the year award for their design of a DNA nanorobot dentist. In addition, a brilliant year 8 student from Ralph Thorsby School, Leeds wrote his own piece of code to solve a compatibility issue between the opensource programs used to manipulate DNA designs. The academic developers at Massachusetts Institute of Technology were so impressed with his work that they have since incorporated his fix into their software benefitting the wider DNA nanotechnology field!

To capitalise on this enormous success, the project - which is generously supported with funding from the **Henry Royce Institute** - has been renewed for a fourth and final year. During this time the Bragg Centre will also look to develop a replacement project that builds upon the outstanding research conducted in its materials research community.

Legacy Materials

In September 2023, the Bragg Centre was delighted to host the University's annual Brotherton Circle event in the Sir William Henry Bragg Building.

The **Brotherton Circle** brings together over **300 alumni, supporters and friends** who have pledged a gift to the University in their Will. In reference to the impact that the Brotherton Circle has at the University, Sally Hind, Senior Development Officer, said:

> ***Gifts and legacies have played a crucial role in the development of the University since its foundation, and we are hugely grateful for the foresight of our supporters who have chosen to include the University in their Will. It was a pleasure to invite our supporters to explore behind the scenes for a truly insightful afternoon at the Bragg Centre for this year's event.***

During the event, guests heard a series of engaging talks from Prof. Edmund Linfield, Prof. Christoph Wälti and Dr Andrew Lee which showcased the Centre's active contributions in the areas of electronic materials, healthcare materials and the development of the UK's advanced skills pipeline.

Brotherton members were further introduced to the Centre's state-of-the-art capability with guided tours of the **Royce deposition system, Versatile X-ray Spectroscopy facility**, **Leeds nanotechnology cleanroom** and the **Wolfson high-speed imaging facility**. The visit was rounded off with afternoon tea and inspiring conversation accompanied by the Centre's academics and Research Technical Professionals.

When reflecting on their experience, one legacy donor commented:

> ***The afternoon was so stimulating. All the speakers and people showing us around the centre engaged my interest. I think they pitched it just right and the presentations were excellent. I made a note of some of the things that were mentioned or shown to us and have started exploring some of them online. I have already read the book written for primary children and will be sharing it with others including my great nephews and nieces. The conversation with some of the scientists over the excellent afternoon tea was also interesting.***

Whilst another legacy donor said:

> ***Immensely interesting and informative. Presenters and team so passionate about their work. I'm sure they will be inspiring a similar level of commitment to their students.***

Recognising Sustained Impact

Dr Zabeada Aslam
Research Officer: Electron Microscopy
School Chemical and Process Engineering

A formula one race car doesn't win the Grand Prix on its own, it takes the skilful handling of an expert racing driver to reach its full potential. This is also true of the cutting-edge experimental equipment on offer within the Bragg Centre's facilities, which is brought to life through the expertise of talented Research Technical Professionals (RTPs) such as Dr Zabeada Aslam.

Zabeada is a key RTP member of the **Leeds Electron Microscopy and Spectroscopy Centre (LEMAS)**, where she provides support to students, academics, and industrial customers; investigating the material structure and chemistry across a wide range of projects. LEMAS is one of the Bragg Centre's most heavily used facilities, providing approximately **3,500 hours** of work for **350 different users per year**.

Alongside her day-to-day activity, Zabeada also teaches at the annual Royal Microscopical Society Electron Microscopy School and in 2022, she played a key role in evaluating and procuring two unique electron microscopes representing a £4 million investment in to the Bragg Centre (see page 16).

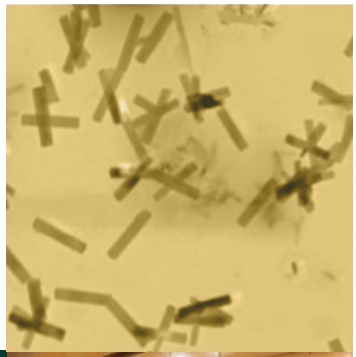
This year in recognition of this sustained impact, Dr Zabeada Aslam received the **Henry Royce Institute** Award for Outstanding Contribution by a Technical Professional from the Institute of Materials, Minerals, and Mining (IOM3).

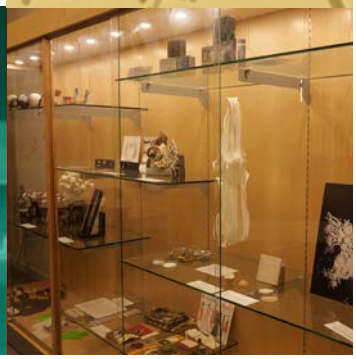
The honour, which debuted this year, recognises the work of one exceptional and established technical professional over a minimum period of ten years, across several projects or activities. Winners must go beyond the normal expectation of their role, sharing best practice and supporting the training and development of new staff.

Prof. Rik Drummond-Brydson and John Harrington, who nominated Dr Aslam for the award, praised Zabeada as:

> ***a very highly skilled, dependable, consistent, and expert individual…***
>
> ***…a model example of a modern RTP.***

Zabeada's journey began with an MPhys in Physics with Astrophysics at Leeds, where she developed an interest at the nanoscale. This led on to further studies in Nanoscale Science and Technology, concluding with a PhD investigating the growth of carbon nanotubes. Following this, Zabeada undertook a short stint at the University of Oxford as a Post-doctoral researcher specialising in *in-situ* electron microscopy where she studied the electrical properties of carbon nanotubes and graphene, before returning to Leeds to join LEMAS.





A Lifetime of Achievement

This year the Bragg Centre is proud to celebrate the outstanding achievements of Prof. Nora de Leeuw, who is the recipient of the 2023 Royal Society of Chemistry's (RSC) Interdisciplinary Prize in recognition of brilliance in research and innovation.

Professor de Leeuw is the Executive Dean of the Faculty of Engineering and Physical Sciences and her research focusses on creating computer models to simulate materials that are used in medical applications.

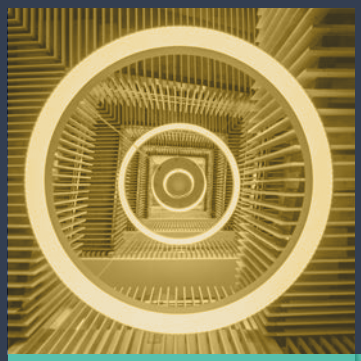
The human body is very complex, and it can be very difficult to investigate how the materials used in hip, knee and other bone implants, for example, interact with biological tissues. Nora's work provides a theoretical framework to understand these interactions, as well as exploring how hard and soft tissues age and repair themselves in relation to implanted devices.

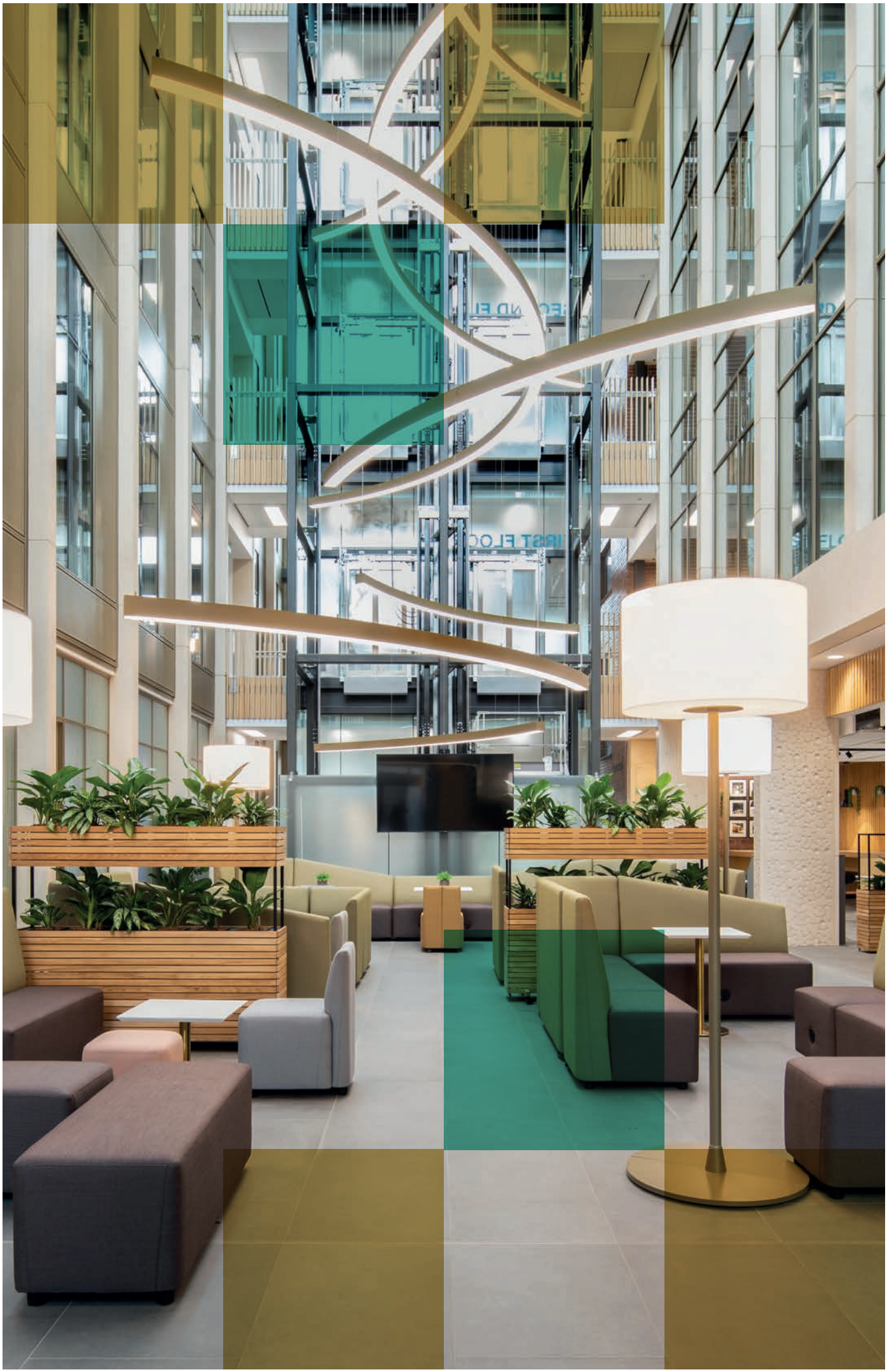
Prof. de Leeuw's prize recognises the huge impact of her computational chemistry approach, which provides atomic-level insights into biomedical materials for *in vivo* applications, as well as nature-inspired catalytic systems to produce non-fossil renewable fuels.

The RSC prizes have recognised excellence in the chemical sciences for more than 150 years. The Research and Innovation Prizes celebrate brilliant individuals across industry and academia, where Prof. de Leeuw now joins a prestigious list of past winners in the RSC's prize portfolio, 60 of whom have gone on to win Nobel Prizes for their work.

When reflecting on her award, Prof. de Leeuw said:

> ***It is a great honour, not just for me but also for all the colleagues, postdoctoral researchers and PhD students that I have had the pleasure of working with throughout my career. Science is a real team effort, and I very much feel that this prize is recognition of all the people I have worked with over the years.***





Get in touch

To find out more about the Bragg Centre for Materials Research, please contact us:

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