NPL

Department for Science, Innovation, & Technology

University of Strathclyde

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PGI PostGraduate Institute for measurement science

A Year in the PGI

2023 Edition

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A Year in the PGI

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A few words on the PGI

Richard Burguete
PGI Director

This past year has been marked by a welcome return to in-person engagement and seeing the Postgraduate Institute for Measurement Science (PGI) community grow because of the influx of new students and the high levels of participation in cohort events. These have been held at different locations across the United Kingdom (UK) where there are clusters of PGI researchers, and it is always exciting to see the quality of research that delivers critical measurement solutions to a diverse set of global challenges.

In this publication, we have selected a few highlights that showcase the breadth of activities across the PGI which have been carried out in collaboration with industry and academia. We would like to extend our thanks to all the people that support our work, and especially our strategic partners, the University of Strathclyde, and the University of Surrey.

- Transitioning talent
- Engineering the future
- Pioneering through quantum computing
- Advancing measurement science
- Contributing to innovation in healthcare and well-being
- Creative development of new materials
- Responding to global challenges
- Responding to industry need

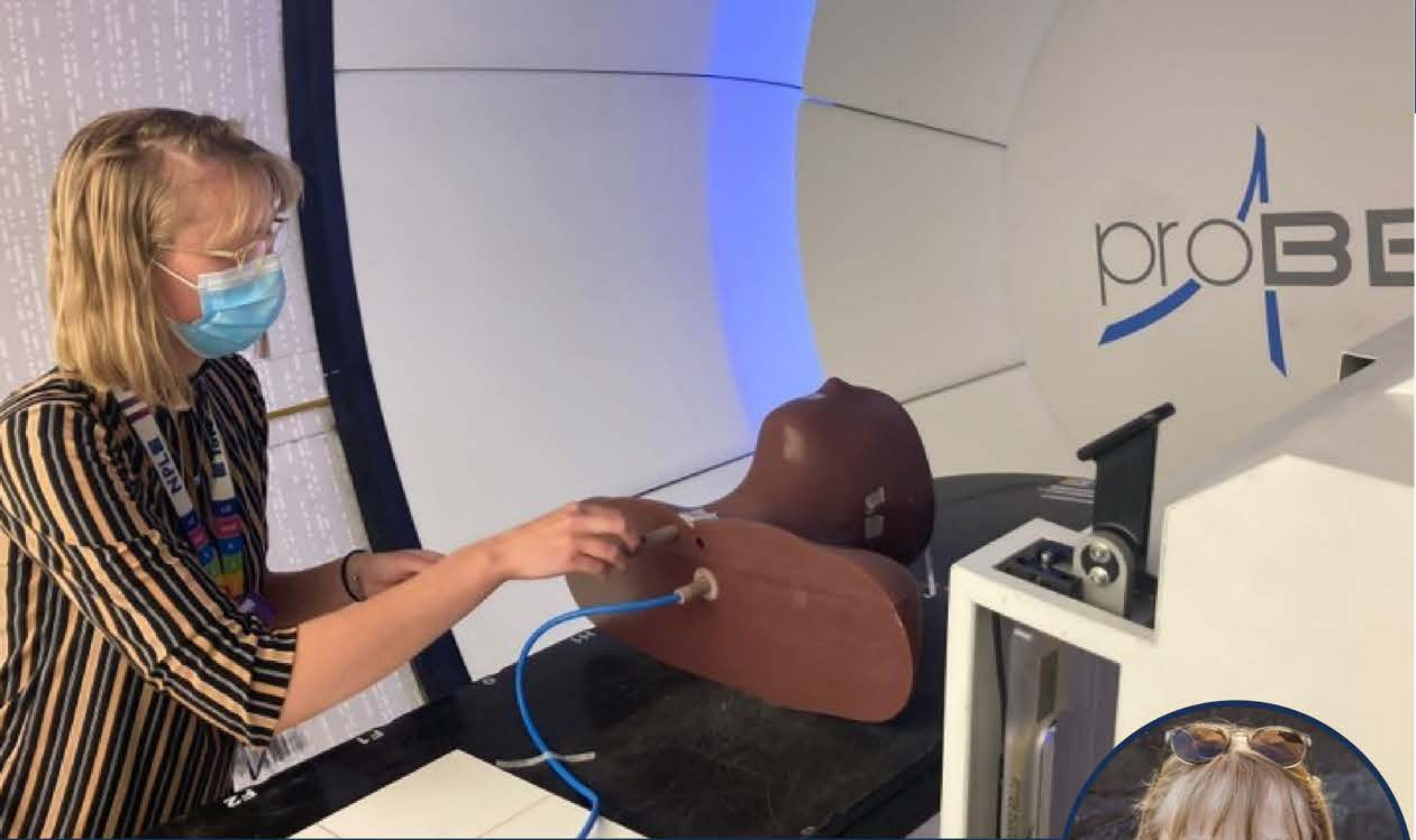


Image: Hannah Cook

Transitioning talent

Shaping the research and development landscape

The PGI alumni community is growing and making a significant impact across many sectors. The destinations of these students are not only noteworthy but are also diverse, ranging from postdoctoral research positions to patent attorneys and one CEO at a Quantum Technology start-up. Over 45% of our graduates now work in industry and hold a variety of different types of roles, with many having achieved significant promotions in their company. A considerable number of students have been successful in securing roles at NPL after completing their PhD, where they continue to be great advocates for the PGI. 9% of students are applying their skills to other sectors including scientific charities and government departments.

Hannah Cook - PGI Alumna and Higher Scientist at the National Physical Laboratory (NPL)

Background

I began my career in the field of Medical Physics in 2017 when I undertook a masters (MRes) at University College London. Since then, I have completed a PhD and begun work as a Higher Scientist within the Medical Radiation Physics group at NPL.

Over the past 5 years, I have been working in proton therapy dosimetry and end-to-end audit development. Proton therapy is an innovative method of radiotherapy delivery which has been recently adopted in the U.K. My work has focussed on the development of novel materials and devices, known as end-to-end audit phantoms, which can be used to perform quality assurance (QA) measurements within the clinical radiotherapy environment. QA measures are essential within radiotherapy to ensure safe and accurate delivery of the novel and complex radiotherapy treatments. Recently, my work at NPL has looked to transition my academic research into an end-to-end audit measurement service. This audit service will provide independent testing of the patient treatment pathway without the need for real cancer patients. The audit service could potentially identify issues which may cause patient harm, and so ensures safe implementation of radiotherapy techniques and the best practice for clinical trials within the field of proton therapy.

In the news

NPL scientists set out to transform cancer treatment with more accurate radiotherapy - More info.

Publications

Cook H, et.al. Development of optimised tissue-equivalent materials for proton therapy. Phys Med Biol. 2023 Mar 23;68(7). doi: 10.1088/1361-6560/acb637. PMID: 36696694.

Cook H, et. al. Development of a heterogeneous phantom to measure range in clinical proton therapy beams. Phys Med. 2022 Jan;93:59-68. doi: 10.1016/j.ejmp.2021.11.006. Epub 2021 Dec 28. PMID: 34968893.

"Proton therapy dosimetry and audit development is very interesting and rewarding research. The aim of our work is to provide confidence to clinical centres offering proton therapy treatment within the UK and worldwide, with the hope to further improve cancer patient outcome."

Hannah Cook on the importance of her field.

Improved metallurgical manufacture via multi-axial testing

John Catterson – University of Strathclyde and NPL

My project, a collaboration between the University of Strathclyde and NPL, is seeking to develop a methodology which would allow for the in-situ verification of materials. In practice, this would utilise a Scanning Electron Microscope (SEM) and a custom biaxial deformation rig which could deform material within the confines of the SEM. This would allow the use of real-time imaging and Differential Interference Contrast Microscopy (DICM) to understand how materials behave under complicated loading conditions, which are more indicative of the conditions seen in sheet-metal manufacture which is used thoroughly in the aerospace and automotive industries.

This is important as the closer our ability to characterise materials aligns with their actual performance, the better we can choose and utilise materials for their intended purpose; lesser material usage means lesser costs and emissions which are both important for removing wasted value from the production chain and preventing further pollution of our environment from materials-related industries.

Developing a novel means of characterising materials, and subsequently characterising previously unknown materials presents new opportunities for industry to better fit their requirements. Furthermore, more detailed characterisation of known materials may reveal new information which could change how they are currently used.

Engineering the future

Advanced manufacturing is transforming industry and productivity. Ensuring that material formulation and manufacturing technologies meet the standards and specifications that businesses demand and can be traced, is vital to control manufacturing processes and assure the quality of products. **Good measurements are critical to productivity, acceleration of product to market and innovation.**

Image: John Catterson

The graph (right) shows the results from a stress simulation which was performed on a cruciform sample of our own design. The design of the sample builds upon existing standards and is optimised for biaxial tensile testing. The aim is to have an area of uniform high stress in the centre of the cross where measurements will be made at a micron-scale.

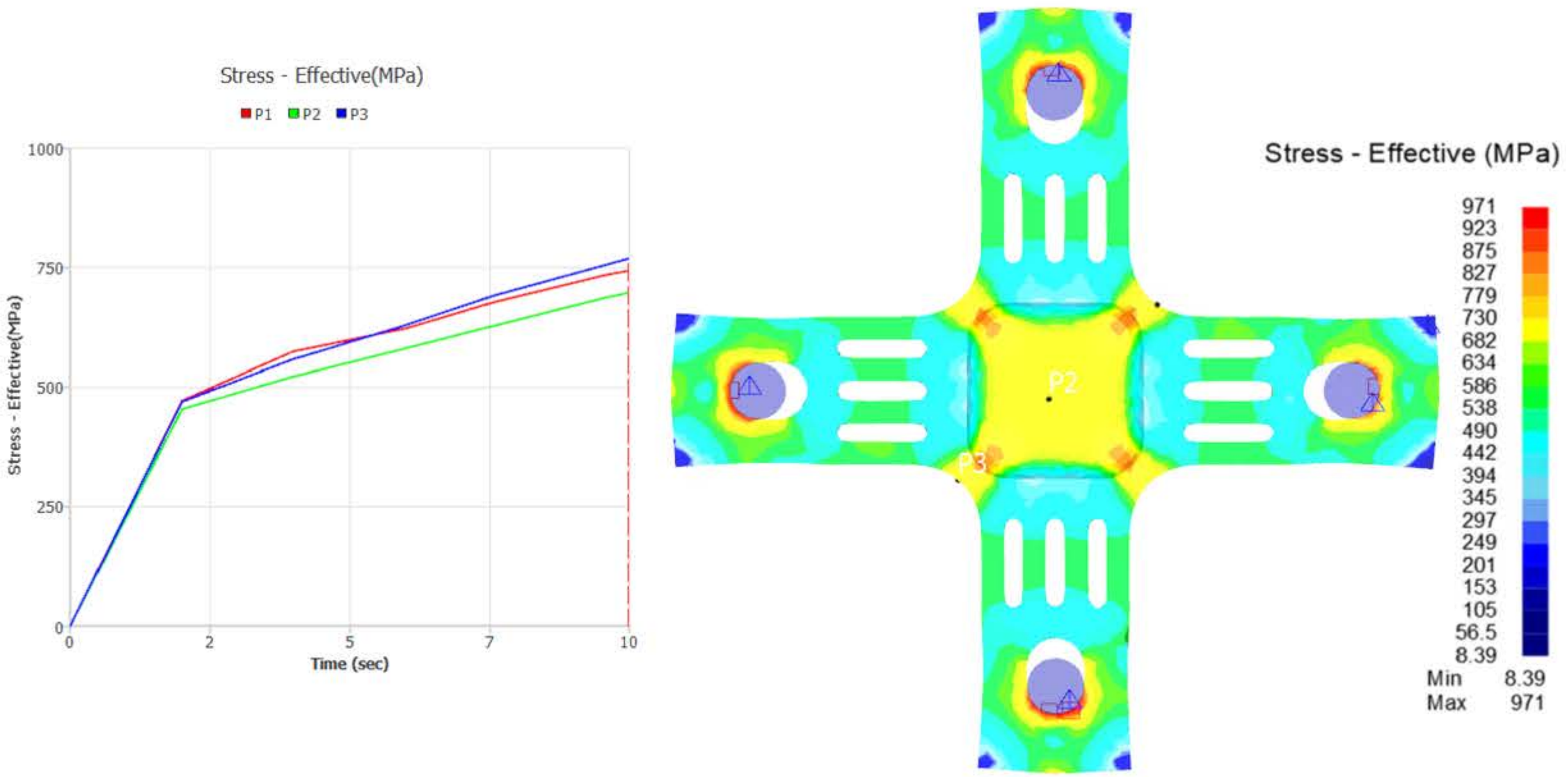
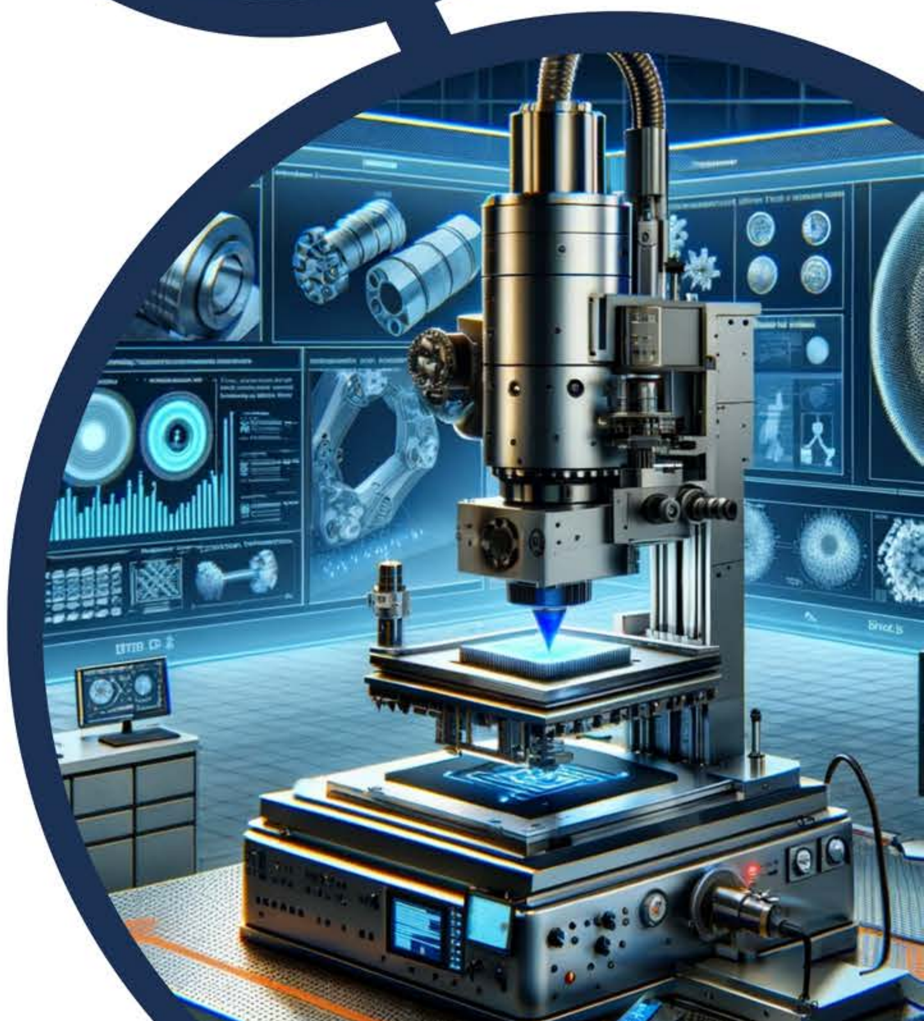


Image: John Catterson



Pioneering through quantum computing

A collaboration between the University of Manchester and NPL investigates two-dimensional (2D) materials. 2D materials have become a hot topic in recent years due to their promising physical, electrical, chemical, and optical properties, and they have useful applications, especially in computing. As processing chips become more powerful, they generate more excess heat, and we need new materials that can manage this.

Efficient semiconductor quantum light sources

Chris Hoole - University of Manchester

This PhD project, is researching the thermal properties of 2D materials. 2D materials are perfectly flat nanoscale crystals ranging from a few layers to one layer of atoms thick. Graphene, a hexagonal lattice of carbon atoms is a well-known example, but hundreds of other 2D materials exist as well. Studying these materials by using scanning probe microscopes and using a sample back-and-forth with a nanoscale needle-like probe is enabling an image of the sample surface to be produced.

2D materials can also improve existing semiconductor technology performance and add new capabilities. Their nanoscale dimensions, unique physical characteristics and easy integration with silicon technology makes 2D materials applicable to these challenges. Different imaging modes allow many different sample properties to be investigated, including thermal and thermoelectric properties.

The image (bottom), courtesy of Chris Hoole, shows a scanning thermal microscopy map of a 2µm-diameter 60nm-thick gold coil (left). DC currents of different amplitudes were passed through the coil during scans. The scans were taken with an SThM probe with a fixed probe voltage (0.8V) and frequency (2.536kHz). Height and SThM voltage profiles (right) taken across the dashed line.

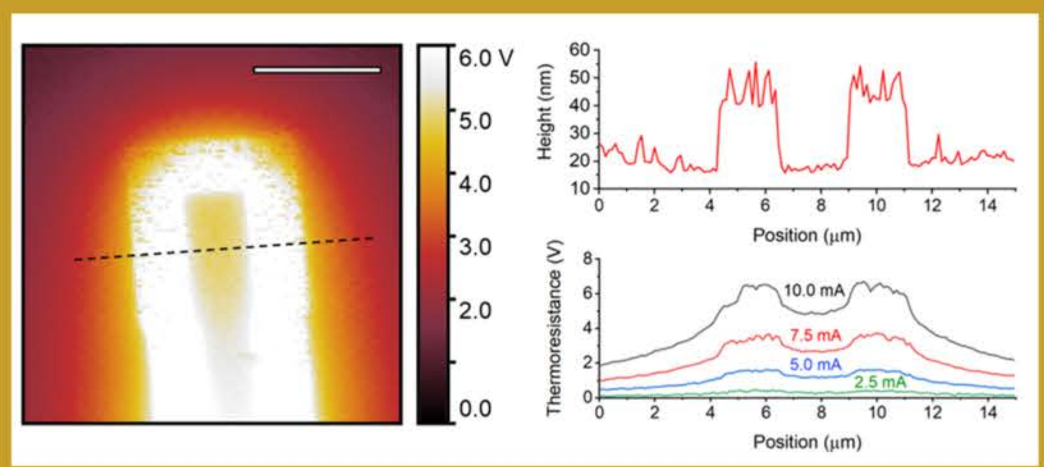


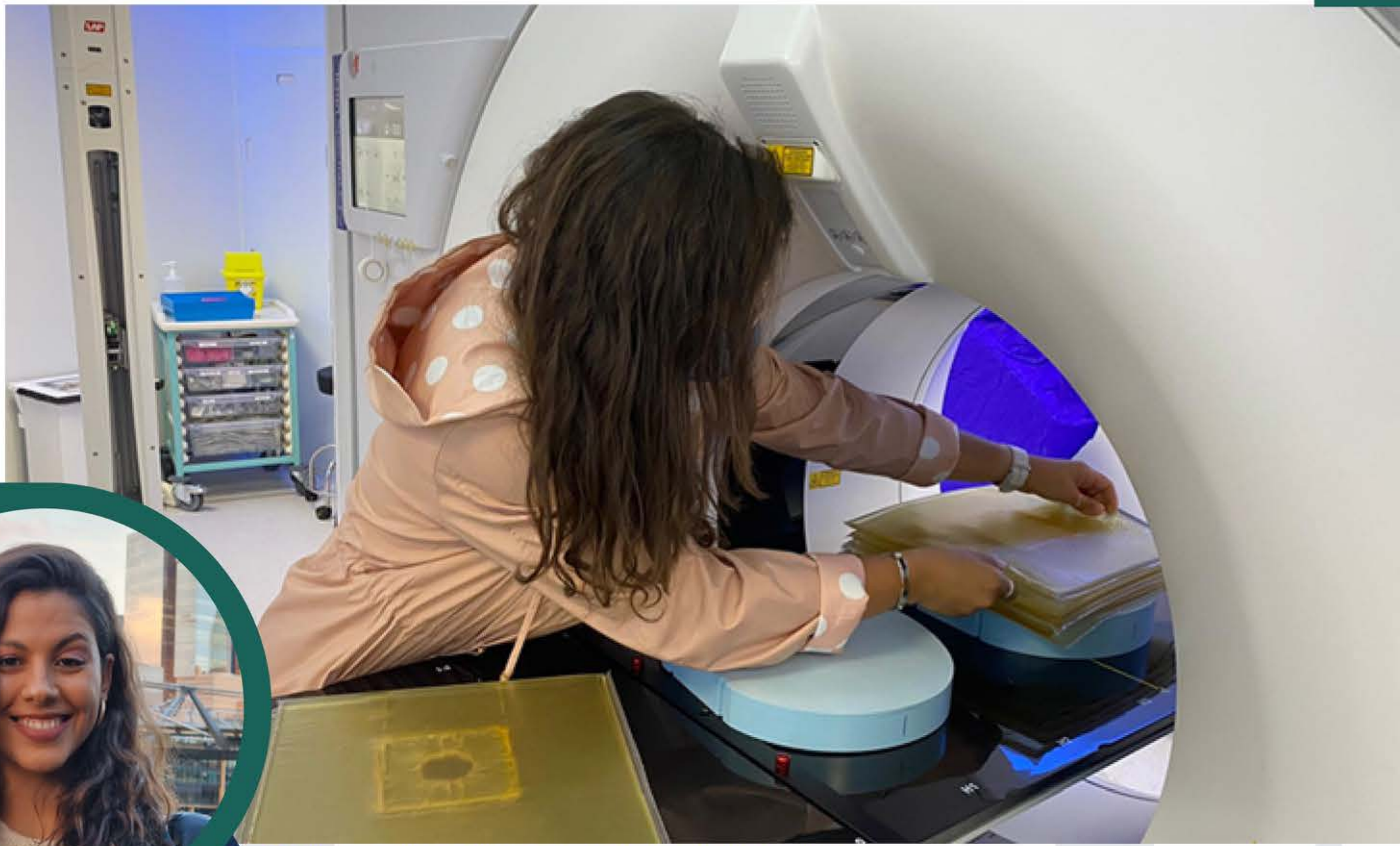
Image: Chris Hoole

"The impact generated from this research will increase our knowledge on the thermal and thermoelectric properties of 2D materials and how these properties can be measured using probe microscope technology."

Chris Hoole on the motivation for his research.

Advancing measurement science

Measurement solutions are critical to business and government, accelerating research and innovation, improving quality of life and enabling trade. Measurement science is always evolving and improving its methods. One of the next big steps forward is for superior digital measurement to become the norm in an effort to improve measurement accuracy and minimise human error.



This image, courtesy of Mariana Bento, shows a DmCRY structure.

Mariana Bento - University College London

Image: Mariana Bento

Radiotherapy is the most used form of cancer treatment. It uses ionising particles to target and kill cancer cells. The main goal in radiotherapy is to maximise the amount of radiation delivered to the tumour volume, while avoiding the irradiation of the surrounding healthy tissues and consequent radiation toxicity for the patients. Paediatric patients are more susceptible to radiation toxicity, as their cells and tissues are still growing, as such, accuracy in the treatment delivery for these patients is even more relevant.

Quality Assurance (QA) procedures have been proposed and developed in clinical centres to guarantee a safe and accurate delivery of treatments. Anthropomorphic phantoms, models that represent the anatomy and composition of the human body, are used for QA purposes in radiotherapy.

However, the commercially available anthropomorphic phantoms are very expensive and only a few are specific for children. This PhD project is exploring the potential of using additive manufacturing technology, or 3D-printing, for the development of paediatric anthropomorphic phantoms to be used in QA of radiotherapy treatments. 3D-printing allows for a higher model customisation, while not compromising in production time and cost.

Guaranteeing a successful radiation treatment delivery to paediatric patients has a major impact in the quality of life of these patients after treatment. Since children are more susceptible to suffering from radiation toxicity, they tend to develop worse late secondary effects, including impaired growth, cognitive deficits, and secondary cancer. Moreover, children are additionally expected to live longer after treatment, meaning they will live more years with a lower quality of life.

"Ensuring the uncertainties and errors associated with the treatment planning and delivery are kept to a minimum, will result in improved patient outcomes and a prospect of an enjoyable life for paediatric patients fighting cancer."

Mariana Bento discussing the impact of her research.

Contributing to innovation in healthcare and well-being

In the realm of healthcare innovation and well-being, the harnessing of routinely collected healthcare data opens new avenues for enhancing early cancer diagnosis. Focusing on pancreatic cancer, this approach leverages existing medical records to uncover vital indicators, paving the way for timely interventions and improved patient outcomes. This initiative approach a significant stride in the journey towards more personalized and effective healthcare solutions.a significant stride in the journey towards more personalised and effective healthcare solutions.

Image: Claire Price

Using routinely collected healthcare data to improve the early diagnosis of pancreatic cancer

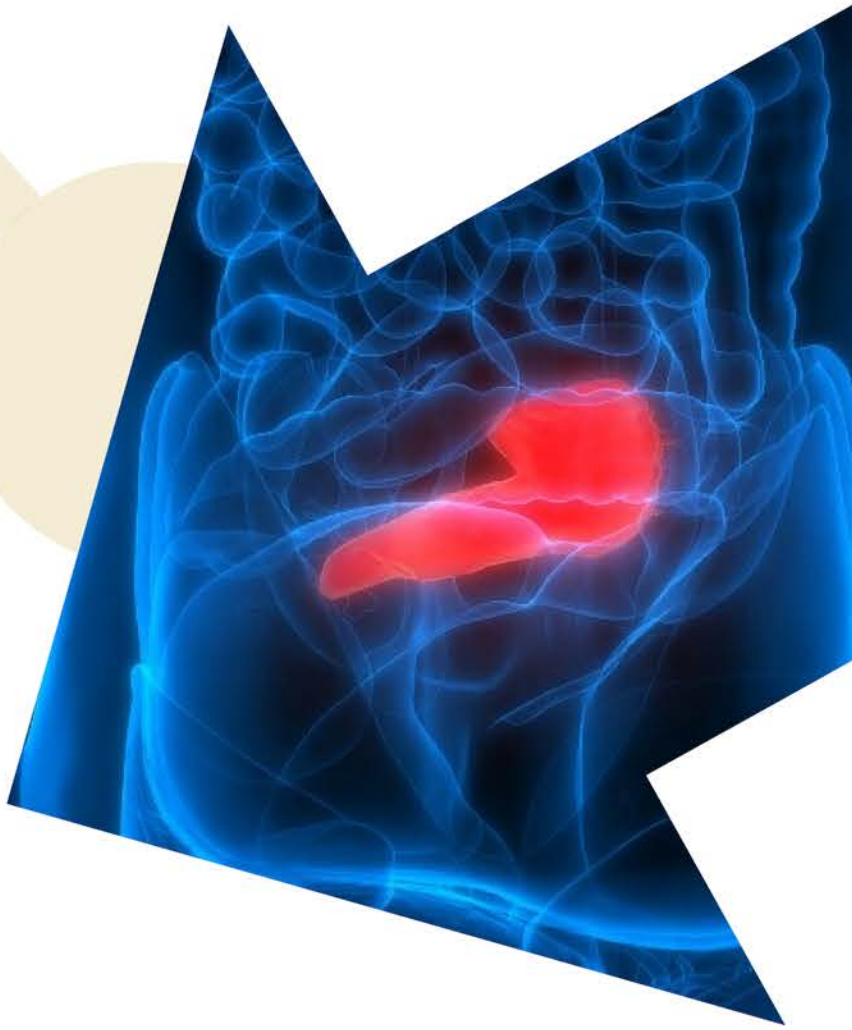
Claire Price - University of Surrey

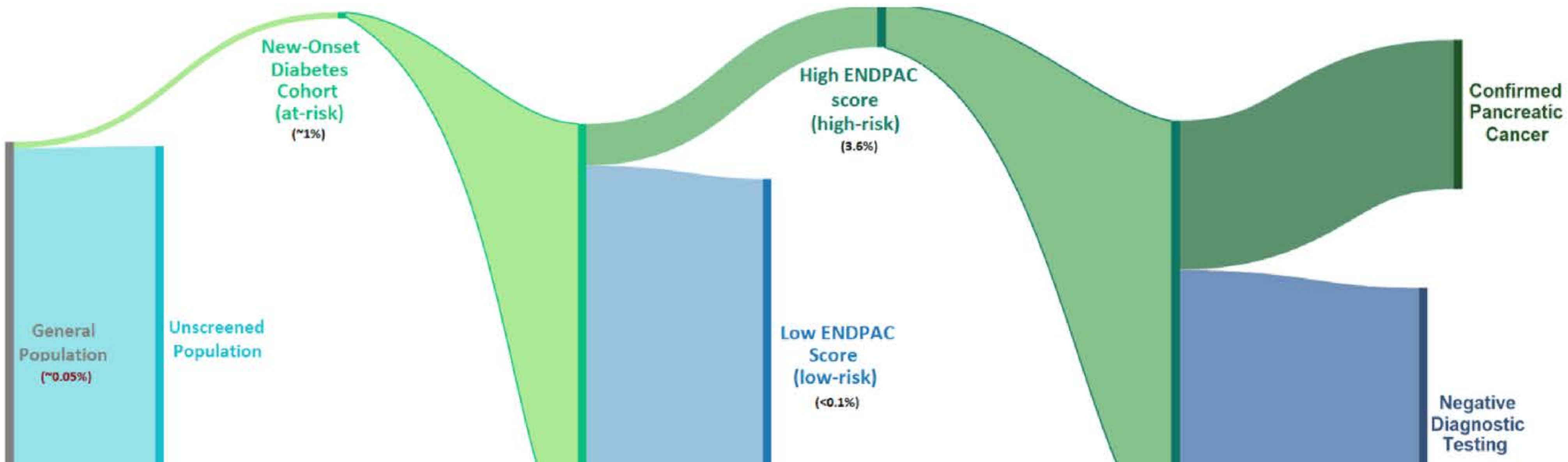
Pancreatic cancer is relatively rare, but because it is often diagnosed late, it has the worst survival rates among all the cancers in the UK. Early symptoms of pancreatic cancer such as indigestion, back pain, digestive issues, and the onset of diabetes are inherently non-specific. This lack of specificity presents a significant challenge in the timely detection of the disease.

Routinely collected primary healthcare data are a resource with great potential to help engineer healthcare tools of the future, for example for improving early diagnosis of many health conditions including pancreatic cancer. However, these data are currently underutilised due to restricted access as well as privacy and ethical implications.

A data-driven algorithm called Enriching New-Onset Diabetes for Pancreatic Cancer (ENDPAC), has been developed in the US which utilises healthcare data to predict pancreatic cancer. This project, a collaboration with the University of Surrey, is investigating the effectiveness of the ENDPAC algorithm for the UK setting by using a retrospective case-control study using the nationally representative Oxford-Royal College of General Practitioners Clinical Informatics Digital Hub (ORCHID) database.

ORCHID holds more than 10 million primary care electronic healthcare records including those of nearly 14,000 people diagnosed with pancreatic cancer. The predictive power of ENDPAC for the detection of pancreatic cancer will be evaluated to enable a new approach to analysis, including the development of trusted research environments code that can be open source whilst patient privacy is ensured.

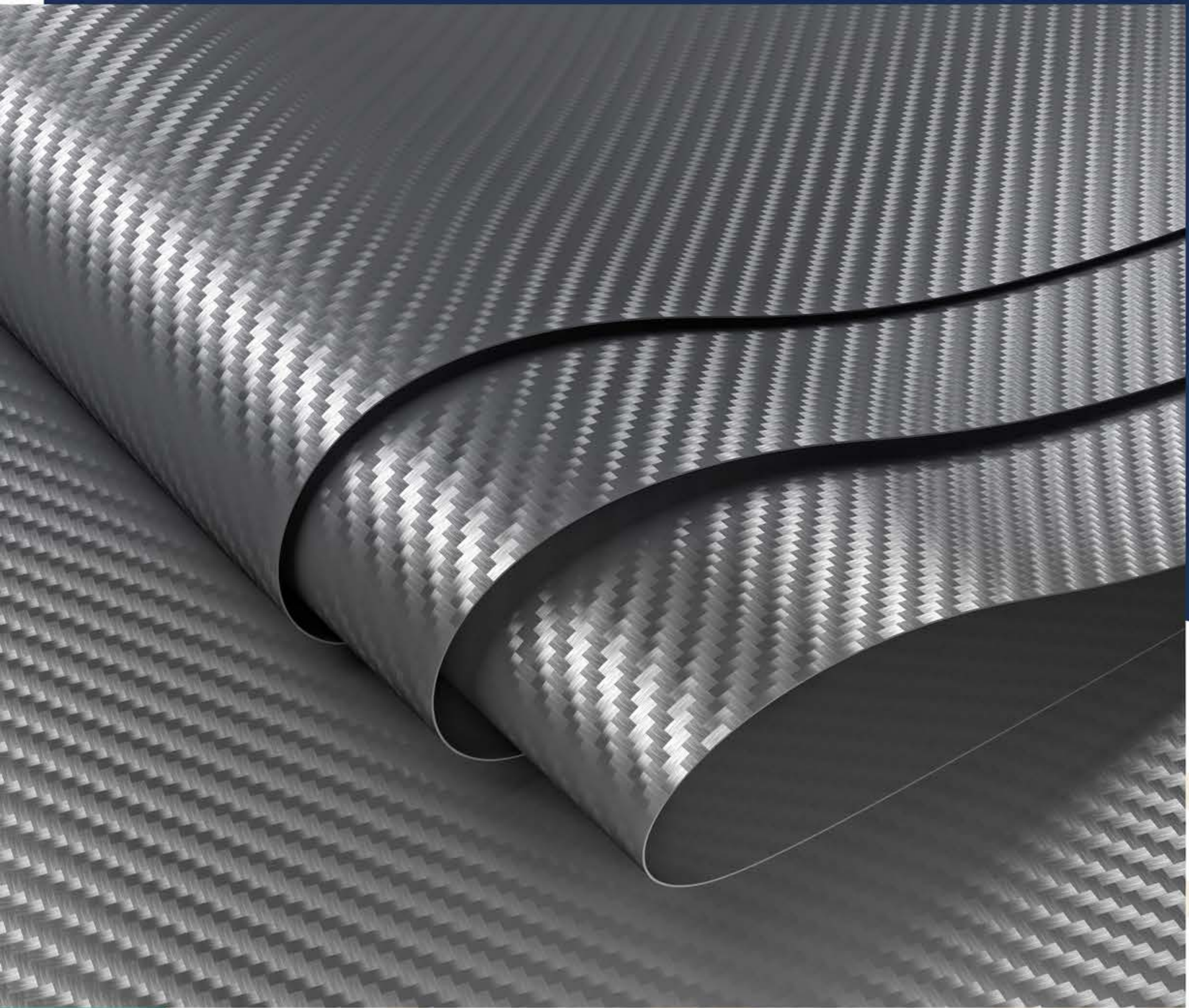




A Sankey diagram (left) depicting the flow of the general population through the ENDPAC algorithm for the detection of pancreatic cancer

Creative development of new materials

Materials that can endure the harshest conditions are needed to allow us to dig at the bottom of the ocean and to transport the fuels of tomorrow. Learning to manufacture these materials at scale and incorporating safety and sustainability into their design and innovation is as important as their discovery and development. This effort is essential to unlocking innovation across all major industrial sectors and could not be achieved without measurement science.



Muhammad Osama - University of Strathclyde

This project, a collaboration between NPL and the University of Strathclyde investigates the factors which incur damage and degradation to carbon fibre reinforced polymer (CFRP) aerostructures using a taxonomy which collates causes of failure and resulting degradation to CFRP is produced. In this taxonomy, failure mechanisms are categorised by thermal, chemical, mechanical (stress, strain, impact) and electrical modes.

CFRP is widely used for aircraft structures, owing to its lower density and superior mechanical properties compared to aluminium. More than 50% of structures on state-of-the-art aircraft are made from CFRP. Aircraft operation is safety critical since it operates in a hazardous environment, such as extreme temperature, low air pressure, vibration and high risk of lightning strike. As such, aircraft structures and systems are highly prone to a variety of failure modes.

Characterisation of damage caused to CFRP is more difficult to articulate due to the inhomogeneity and non-linearity associated with CFRP properties compared to aluminium. If failure modes are not well understood, then systems with CFRP aerostructures require significant over-engineering to ensure that catastrophic failure cannot occur.

Such over-engineering brings weight and volume penalties and prevents optimised systems design. For example, in state-of-the-art aircraft electrical cables must be kept physically separate and distanced from CFRP structures.

The outcome of this project is a safer and more reliable aerospace electrical systems, a reduction in maintenance costs through data-driven prognostics and an accelerated adoption of advanced composites in aviation.

"My project is using measurement science to support the development of aviation light weighting goals by managing risks with advanced composites, and improving safter through predictive maintenance"

Muhammad Osama
reflecting on his research.

Image: Muhammad Osama

Discovery of dementia biomarkers within the retina

Cayla Harris – University of Surrey

While the central nervous system is fundamental to the complicated mechanics of biological systems, exploring its intricate workings poses a significant challenge due to the limited means for direct observation. Yet, within this intricate network, the neurons residing in the retina offer a unique non-invasive window, providing an avenue of research with great potential for advancing our understanding of neurological conditions.

The importance of this work, a collaboration between NPL and the University of Surrey, is becoming increasingly apparent, given the discovery of dementia-related biomarkers present and observable within the retina up to decades before cognitive decline, especially in light of the demographic shift towards an aging population.

Relevant link: https://www.biodynamo.org/home-page

The strategy involves the use of agent-based modelling (ABM), a powerful tool for deciphering biological patterns in biomedical research. Using one of the leading ABM platforms, BioDynaMo, aiming to construct a detailed model of the functional retina. This approach will allow the observation of the retina under definable conditions and constraints that would not be possible in vivo, ultimately aiding the understanding of these neurodegenerative biomarkers, which may allow us to take action earlier than the techniques we currently have.

"In essence, this research has the potential to impact the early detection and management of neurological conditions."

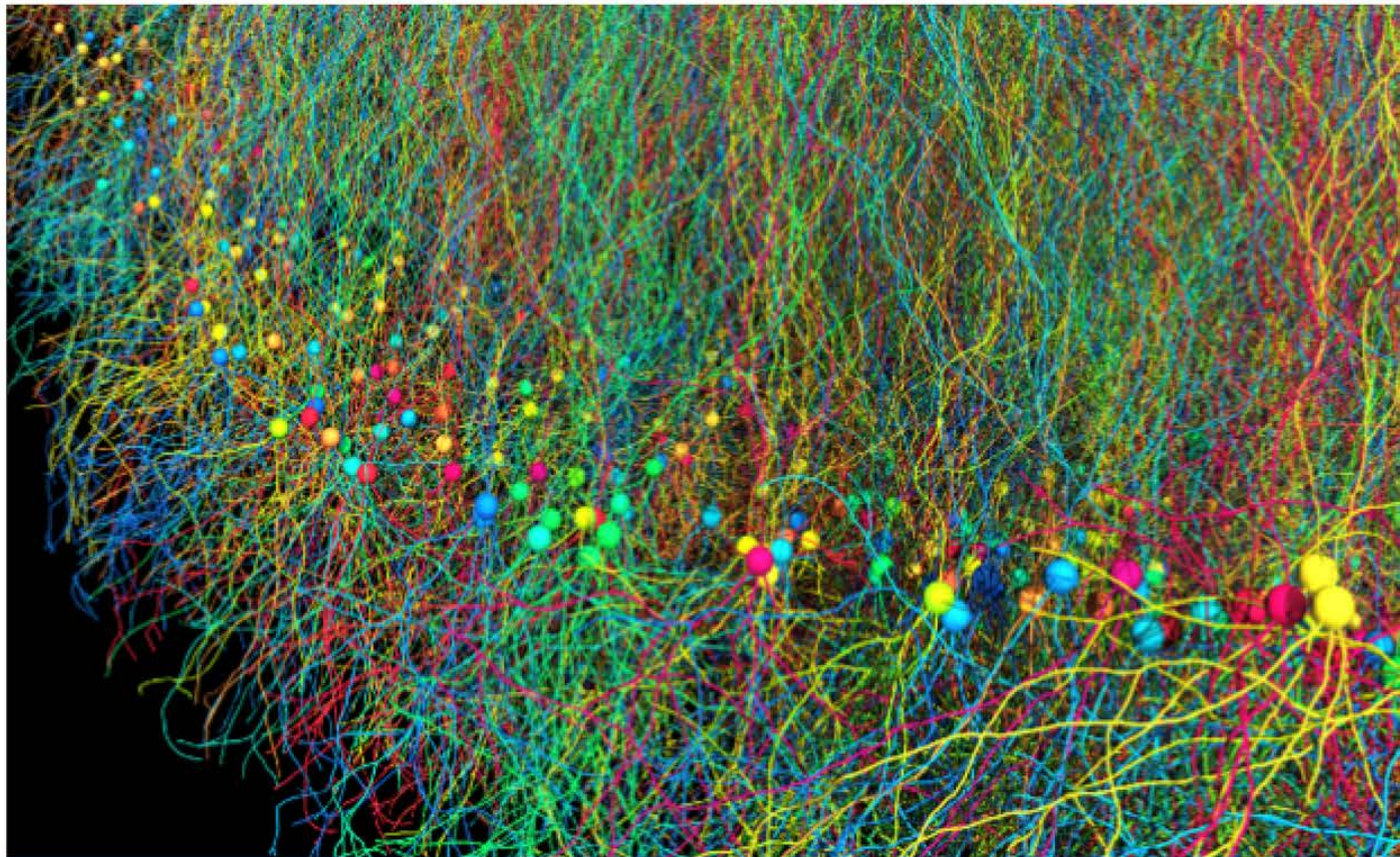


Image: Cayla Harris

Responding to global challenges

In the global pursuit to combat dementia, we turn our attention to the potential of retinal biomarkers. This endeavour requires a balanced approach, blending advanced medical research with patient-centric care. Our focus is on developing a unified, international strategy, anchored in reliable scientific data and cutting-edge imaging techniques. Measurement science plays a vital role in this context, offering precise identification and quantification of retinal biomarkers, which is essential for evolving more effective and personalised diagnostic approaches in dementia treatment.

"In essence, this research has the potential to impact the early detection and management of neurological conditions."

Cayla Harris on the potential of her research.

Responding to industry need

Universities and businesses across the world are making the most of the research and innovation opportunities by forming global partnerships and fostering relationships with other institutions. **The PGI is embedding measurement solutions in PhD projects for real world problems as well as creating global partnerships that focus on interdisciplinary research and development solutions.**

ChemBio correlative imaging expertise enables LightOx to characterise their novel probes

Camila Dondi - University College London and PhD at work.

Camila Dondi, a PhD at work student with University College London (UCL) was part of a group of Scientists from NPL's Biometrology and Surface Technology groups applying their expertise in raman and fluorescence microscopies to measure the properties of a class of light-activated compounds being developed for cancer therapies by LightOx. Some of those are commercially available through Merck.

LightOx is developing new light activated drug compounds, targeting a treatment for early stage and pre-cancerous lesions, as well as a family of novel compounds that are highly fluorescent, but also possess a strong Raman signal in the "cell-silent" region. LightOx's compounds can elicit the destruction of cells/tissues when activated by light, along with their therapeutic applications.

Image: Camela Dondi

This project's scope was to characterise the performance of the latest products, with Stimulated Raman scattering in combination with fluorescence since the fluorescence signal gives a readout of the local chemical environment whereas Stimulated Raman Scattering (SRS) can be used to quantify the local concentration. Camila's focus particularly on was the fluorescent imaging side of it, in specific cell preparation, dosing with compounds and imaging with confocal and super resolution microscopy.

This exciting project is part of The Innovate UK Analysis for Innovators programme led by Innovate UK in partnership with NPL was delivered in collaboration with the central laser facility at Science and Technology Facilities Council (STFC). Camila's role was in the fluorescent imaging side of it, in specific cell preparation, dosing with compounds and imaging with confocal and super resolution microscopy. The team had successfully developed new imaging protocols to analyse the subcellular localisation of the compounds, and their uptake into live cells as well as gaining a better understanding of the limitations of the measurements.

"It was great to be a part of a team supporting industry. The results and methods were incorporated in a marketing document and user guide, and a scientific publication is currently in preparation."

Camila Dondi reflecting on her research.