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ISSUE 31

DEPARTMENT OF ENGINEERING

NEWS

UNIVERSITY OF CAMBRIDGE

In this issue

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Cover image: Alumna Dr Giorgia Longobardi, founder and CEO of Cambridge GaN Devices (CGD) – a spin-out from the Department of Engineering. Credit: StillVision.

Note from the editors

Thank you to all those alumni who completed our newsletter survey in the last edition. Your feedback is important to us, and we really appreciate the time you have taken to participate. Your contribution will help us to identify how we can improve.

Of those who responded, 43% would like to continue to receive a printed version of the newsletter and 56% wish to receive an electronic version.

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Once again, many thanks for sharing your thoughts, views and opinions with us.

Charlotte Hester and Jacqueline Saggers

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Head's welcome

You may notice the new face – on February 28 this year, Professor Richard Prager stepped down to take up a new role as Chief Scientific Adviser to the Government at the Department for Levelling Up, Housing and Communities. On March 1, I stepped into the role of interim Head of Department, having previously served as Deputy Head (Teaching) for three years.

The Department of Engineering continues to grow in new directions, with a number of appointments in recent months in the areas of Scale-up, Industrial Sustainability, Water Engineering, Fluid-Structure interactions, Quantum Engineering, Applied Mechanics and Innovative Computational Methods. We now have more than 140 faculty members working in a wide range of traditional and emerging areas of engineering.

You may look at this and wonder what it is that links these seemingly disparate areas, and if indeed there is a link at all. In essence, they are all areas of importance to modern society, and they are interesting problems that need to be solved. This is what makes engineering such an exciting and rewarding field to work in, as we spend our days working on problems that matter.

Looking through this edition of the newsletter, you will notice some major initiatives that have taken off recently, including the Centre for Human-Inspired Artificial Intelligence (CHIA), which is a multi-department activity looking at how to ensure that society benefits from advances in AI. This will be enabled by considering the entire system, from research all the way through to commercialisation and policymaking. The CHIA is being co-directed by Professor Per Ola Kristensson, and you can find the story on **page 4**.

Next you will see the story on **page 5** on 3D printing of soft matter, led by Professor Shery Huang, who is based at The Nanoscience Centre, which is an interdisciplinary centre and part of the Electrical Engineering division of the Department. This technology has diverse applications across many sectors from tissue engineering to food.

On **page 8** you will see the inspiring story of a start-up founded by an alumna, Dr Giorgia Longobardi, who has been working on GaN-based electronics for more energy-efficient power electronics.

It was also a real pleasure to see a former Head of Department, Professor Jacques Heyman, being presented with the Sir Frank Whittle Medal in recognition of his lifelong work in structural design.

There are a number of articles in this edition about some of the amazing things our alumni have been getting up to, beyond what I have mentioned above, which I hope you find interesting.

Closer to home again, we are undergoing a complete redevelopment of the EIETL (Electrical and Information Engineering Teaching Laboratory) this summer, which will see the old wooden benches replaced with more modern pods, where groups of students can work on labs and projects.

As part of this, we are working together with a major developer of electronic test and measurement equipment to kit the lab out. A number of other capital projects are underway or about to start, which we will report on in later editions.

To loop back around to the earlier point about the breadth of the Department and the work we carry out, you will see that, as ever, what brings engineers together is a curiosity about the world around us; a burning interest in solving problems; and the desire to make the world a better place. We will continue to do this as a Department and to train the engineers of the future to tackle the pressing problems that we face, in the unique way that only Cambridge engineers can.

Professor Colm Durkan FIET, FInstP

Cambridge research centre puts people at the heart of AI

Credit: Trahko – stock.adobe.com

The University of Cambridge has launched a new research centre dedicated to exploring the possibilities of a world shared by both humans and machines with artificial intelligence (AI).

The Centre for Human-Inspired Artificial Intelligence (CHIA) brings together researchers from engineering and mathematics, philosophy and social sciences; a broad range of disciplines to investigate how human and machine intelligence can be combined in technologies that best contribute to social and global progress.

Anna Korhonen, Director of CHIA and Professor of Natural Language Processing, said: "We know from history that new technologies can drive changes with both positive and negative consequences, and this will likely be the case for AI. The goal of our new Centre is to put humans at the centre of every stage of AI development – basic research, application, commercialisation and policymaking – to help ensure AI benefits everyone."

AI is a rapidly developing technology predicted to transform much of our society. While AI has the potential to tackle some of the world's most pressing problems in healthcare, education, climate science and economic sustainability, it will need to embrace its human origins to become responsible, transparent and inclusive.

Per Ola Kristensson, Co-Director of CHIA and Professor of Interactive Systems Engineering, said: "For true progress and real-life impact, it's critical to nurture a close engagement with industry, policymakers, non-governmental organisations and civil society. Few universities in the world can rival the breadth and depth of Cambridge, making us ideally positioned to make these connections and engage with the communities who face the greatest impact from AI."

Designed to deliver both academic and real-world impact, CHIA seeks partners in academic, industrial, third sector and other organisations that share an interest in promoting human-inspired AI.

John Suckling, Co-Director of CHIA and Director of Research in Psychiatric Neuroimaging, said: "Our students will be educated in an interdisciplinary environment with access to experts in the technical, ethical, human and industrial aspects of AI. Early career researchers will be part of all our activities. We are committed to inclusivity and diversity as a way of delivering robust and practical outcomes."

CHIA will educate the next generation of AI creators and leaders, with dedicated graduate training in human-inspired AI.

Professor Mark Girolami, from the Department of Engineering, said: "As AI becomes increasingly pervasive, it's critical to align its development with societal interests. This new University-wide Centre will explore a human-centric approach to the development of AI to ensure beneficial outcomes for society. Cambridge's depth of expertise in AI and a focus on interdisciplinary collaboration make it an ideal home for CHIA."

Apart from research and education, CHIA will also host seminars, public events and international conferences to raise awareness of human-inspired AI. Forums will be convened around topics of ethical or societal concern, with representation from all stakeholders.

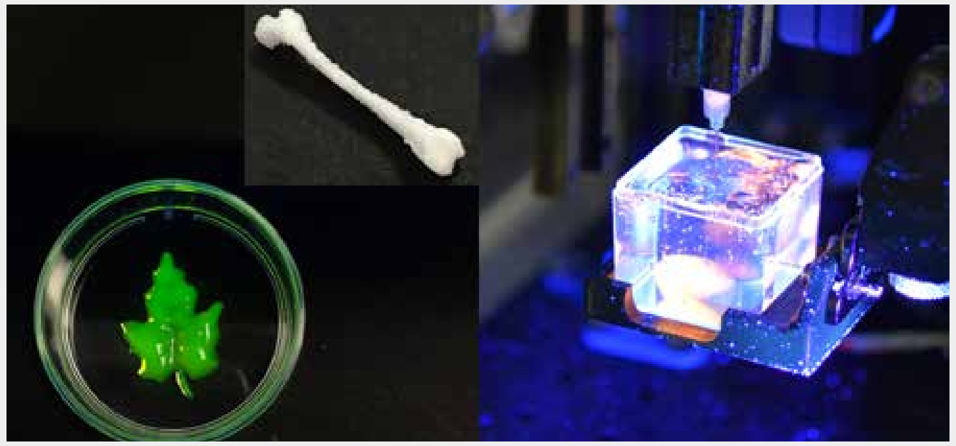
Professor Anne Ferguson-Smith, Pro-Vice-Chancellor for Research, said: "If we're to ensure that AI works for everyone and does not widen inequalities, then we need to place people at its heart and consider the societal and ethical implications alongside its development. Cambridge, with its ability to draw on researchers across multiple disciplines, is uniquely positioned to be able to lead in this area."

Neil Lawrence, DeepMind Professor of Machine Learning, added: "AI is provoking new questions in our societies. It's vital that we deliver the answers in a people-centric manner. CHIA will provide a new interdisciplinary hub that delivers the solutions for these challenges."

Written by Craig Brierley

www.chia.cam.ac.uk
Watch the video:
youtu.be/jsESFNuYuJM

→ Complex designs made possible using 'Printer.HM'. From left, a leaf-shaped scaffold with cellulose-based hydrogels; a femur model printed with bioceramic hydrogel; embedded printing in a support bath



Introducing 'Printer.HM' – the future of 3D printing for soft materials

Researchers have developed a hackable and multi-functional 3D printer for soft materials that is affordable and open design. The technology has the potential to unlock further innovation in diverse fields, such as tissue engineering, soft robotics, food, and eco-friendly material processing – aiding the creation of unprecedented designs.

'Printer.HM', as it is known, is a highly customisable extrusion-based 3D printer to rival commercial 3D bioprinters. It is capable of accepting different geometry inputs – including computer-aided design (CAD) models, coordinates, equations, and pictures – to create prints of distinct characteristics.

The development of this multi-printhead system – built on a hackable robotic arm and offering multi-functionalities in one platform via heating and ultraviolet (UV) modules – is the brainchild of researchers from the Department of Engineering, University of Cambridge, and The Nanoscience Centre, University of Cambridge, in collaboration with the Universities of Macau and Oxford. Details of their affordable printing approach are reported in the journal *Scientific Reports*.

In addition to offering excellent print compatibility with a wide variety of liquidous and soft materials, a multitude of operations can be performed, including: liquid dispensing; multi-material printing; printing with variable speed; embedded printing (creating freeform and overhanging structures); non-planar printing; pick-and-place application.

With the optional heating and UV modules, the printability of thermal-responsive and photo-polymerisable hydrogels can be tuned, and these are of use in a wide range of biomedical applications including drug delivery, tissue engineering and wound healing.

Printer.HM offers its user the design freedom and ability to customise the print path to create prints of distinct characteristics. These are: simple patterns (coordinates); one stroke printing (equations); 3D designs (G-code); and customisable 2D motifs (pictures), the latter can easily convert hand-drawn sketches into prints without the need to create a CAD model.

Print path customisability is especially useful for soft robotics applications, as demonstrated by the researchers' creation of a soft morphing system made of a pH-responsive hydrogel. The researchers used Printer.HM to create a 2D sketch of a flower motif that then swelled and morphed into a 3D flower shape within four minutes. And this is just the beginning; because the control programme is entirely hackable, users can reconfigure the setup and expand its functionalities for 3D printed designs never achieved before. The researchers also demonstrated the potential of Printer.HM to generate sophisticated tissue anatomy, by successfully creating a model of the respiratory system with lungs and trachea, made of alginate inks, and printed inside a support bath.

Dr Iek Man Lei, first author and an Assistant Professor at the University of Macau, is a former PhD student from the Biointerface Research Group at Cambridge.

Dr Lei said: "The versatile functionalities of Printer.HM, together with its open design and affordability (a total cost of between £900 and £1,900), make it a credible option for the future of 3D printing innovation using soft, biological and sustainable material architectures. The modular design allows the research community to expand the functionalities of Printer.HM further, opening up the possibility of endless new designs. Other benefits include compatibility of the printhead with syringes of a smaller size that are desirable in small-scale biological applications, and ease-of-use for those without CAD experience to customise the print path using the picture geometry input – this is particularly beneficial for controlling the morphing behaviours of stimuli-responsive hydrogels."

She added: "Printer.HM has the potential to open the door to innovative 3D printing in diverse fields, such as tissue engineering, soft robotics, food, and eco-friendly material processing. Its open design, affordability, improved customisability and all-in-one functionalities will benefit the do-it-yourself research community, providing a viable alternative to existing commercial printers."

Watch Printer.HM in action:
youtu.be/VI0K63yUBVM
Open access paper:
www.eng.cam.ac.uk/printerhm
biointerface.eng.cam.ac.uk
www.nanoscience.cam.ac.uk

→ Maize seedling in a cultivated agricultural field with graphic concepts showing modern agricultural technology, digital farm and smart farming innovation.

lamyai – stock.adobe.com

Digital Twins in the agrifood sector: a force for a sustainable future

Combining Digital Twins with Artificial Intelligence (AI) decision-making technologies can transform agrifood production systems and supply chains – offering possible remedies to the problems of malnutrition, greenhouse gas (GHG) emissions, and food waste, say researchers.

A review of the potential benefits of using Digital Twins (virtual replicas) alongside AI, smart sensors and other embedded systems, has found techno-economic limitations as well as barriers to their deployment, which threaten the goal of building inclusive, productive, and sustainable agrifood systems. The findings are reported in the journal *npj Science of Food*.

Creating virtual representations of entire farming systems and combining them with advanced decision-making technologies can bring many benefits, say the researchers, at a time when agrifood production systems and supply chains are not currently on track to meet the Sustainable Development Goals.

Using reinforcement learning, Digital Twins can determine the best strategy when it comes to maximising crop yield, for example, in addition to offering predictions and 'what-if' simulations for testing and identifying pathways to improving agrifood sector sustainability.

The digitalisation of agricultural production shows promise for resource efficiency gains, like labour cost reductions, along with addressing animal health and biodiversity loss.

The study, authored by Dr Asaf Tzachor and Dr Catherine Richards, from the Centre for the Study of Existential Risk (CSER) at the University of Cambridge, in collaboration with PhD student Scott Jeen from the Resource Efficiency Collective at Cambridge, identifies potential "transformative" applications of 'virtual farms' and agrifood value chains. These include: agrochemicals for agricultural production; primary agricultural production; storage and transportation; food processing; distribution and retail; food consumption.

"The potential of virtualised agrifood systems and supply chains is yet to be realised, especially with regards to curbing GHG emissions, food waste and malnutrition," said Dr Richards, who completed her PhD at the Department of Engineering.

"Repurposing Digital Twins for more advanced applications is not a new idea. Although it has already taken off in the context of climate change and extreme weather, for example, the same cannot be said with regards to improving agrifood sector sustainability. This is an area that could really benefit from the live monitoring and comprehensive computational ecosystems that Digital Twins have to offer, enabling the simulation of crops, farms, agricultural equipment, storage facilities, processing factories, and distribution networks. However, Digital Twins do have their limitations, which need addressing, and considerable barriers exist, which are currently limiting the sizeable and meaningful implementation of Digital Twins across the global food sector."

According to their review, there are four factors that threaten to derail future attempts to create 'virtual farms' and agrifood value chains. These are defined as:

- **Digital Twin uncertainty.** Even with sufficient sensor coverage, the Digital Twin can only ever be an approximation of the physical system. Therefore, its state representation and future predictions are uncertain.
- **Technological error.** In practice, sensors can fail. This means unsafe behaviour is likely if reinforcement learning agents are selecting control actions using a model with erroneous sensor data. It is also a barrier to scaled deployment.
- **Human error.** A small notational error in the code of a computation model used for predictive maintenance of an irrigation system, for instance, could affect sound decision making, leading to crop yield failures and resulting in losses.
- **Compatibility difficulties.** There is currently a question mark over the lack of common modelling standards for Digital Twins – so how can they be integrated separately and successfully?

The review also hints at a geographical divide that is creating a barrier to implementation of Digital Twins across the food sector globally. Lower-middle income economies are unable to make use of the technology due to the expertise, methods and infrastructure involved.

"Multidisciplinary collaborations involving computer science, agriculture, food and nutrition experts must be initiated," said Dr Tzachor. "More focus is needed on deploying Digital Twins across the agrifood sector, building inclusivity and developing computer science literacy across the food sector globally, particularly in lower-middle income economies where there is the greatest need; malnutrition is widespread, agricultural productivity is low and food spoilage and waste are high. If the transformation of the agrifood sector with Digital Twins is to be realised successfully and at scale, then we need the technology in place to achieve this via investment in open access and standardised data sets, for example."

Open access paper:
www.eng.cam.ac.uk/digital-twins

→ Electric car charging

Credit: Andrew Roberts via Unsplash

Watching lithium in real time could improve performance of EV battery materials

Researchers have found that the irregular movement of lithium ions in next-generation battery materials could be reducing their capacity and hindering their performance.

The team, led by the University of Cambridge, tracked the movement of lithium ions inside a promising new battery material in real time.

It had been assumed that the mechanism by which lithium ions are stored in battery materials is uniform across the individual active particles. However, the Cambridge-led team found that during the charge-discharge cycle, lithium storage is anything but uniform.

When the battery is near the end of its discharge cycle, the surfaces of the active particles become saturated by lithium while their cores are lithium deficient. This results in the loss of reusable lithium and a reduced capacity.

The research, funded by The Faraday Institution, could help improve existing battery materials and could accelerate the development of next-generation batteries. The results are published in *Joule*.

Electrical vehicles (EVs) are vital in the transition to a zero-carbon economy. Most electric vehicles on the road today are powered by lithium-ion batteries, due in part to their high energy density.

However, as EV use becomes more widespread, the push for longer ranges and faster charging times means that current battery materials need to be improved, and new materials need to be identified.

Some of the most promising of these materials are state-of-the-art positive electrode materials known as layered lithium nickel-rich oxides, which are widely used in premium EVs. However, their working mechanisms, particularly lithium-ion transport under practical operating conditions, and how this is linked to their electrochemical performance, are not fully understood, so we cannot yet obtain maximum performance from these materials.

By tracking how light interacts with active particles during battery operation under a microscope, the researchers observed distinct differences in lithium storage during the charge-discharge cycle in nickel-rich manganese cobalt oxide (NMC).

"This is the first time that this non-uniformity in lithium storage has been directly observed in individual particles," said co-first author Alice Merryweather, from Cambridge's Yusuf Hamied Department of Chemistry. "Real-time techniques like ours are essential to capture this while the battery is cycling."

Combining the experimental observations with computer modelling, the researchers found that the non-uniformity originates from drastic changes to the rate of lithium-ion diffusion in NMC during the charge-discharge cycle. Specifically, lithium ions diffuse slowly in fully lithiated NMC particles, but the diffusion is significantly enhanced once some lithium ions are extracted from these particles.

"Our model provides insights into the range over which lithium-ion diffusion in NMC varies during the early stages of charging," said co-first author Dr Shrinidhi Pandurangi, from Cambridge's Department of Engineering. "Our model predicted lithium distributions accurately and captured the degree of heterogeneity observed in experiments. These predictions are key to understanding other battery degradation mechanisms such as particle fracture."

Importantly, the lithium heterogeneity seen at the end of discharge, establishes one reason why nickel-rich cathode materials typically lose around 10% of their capacity after the first charge-discharge cycle.

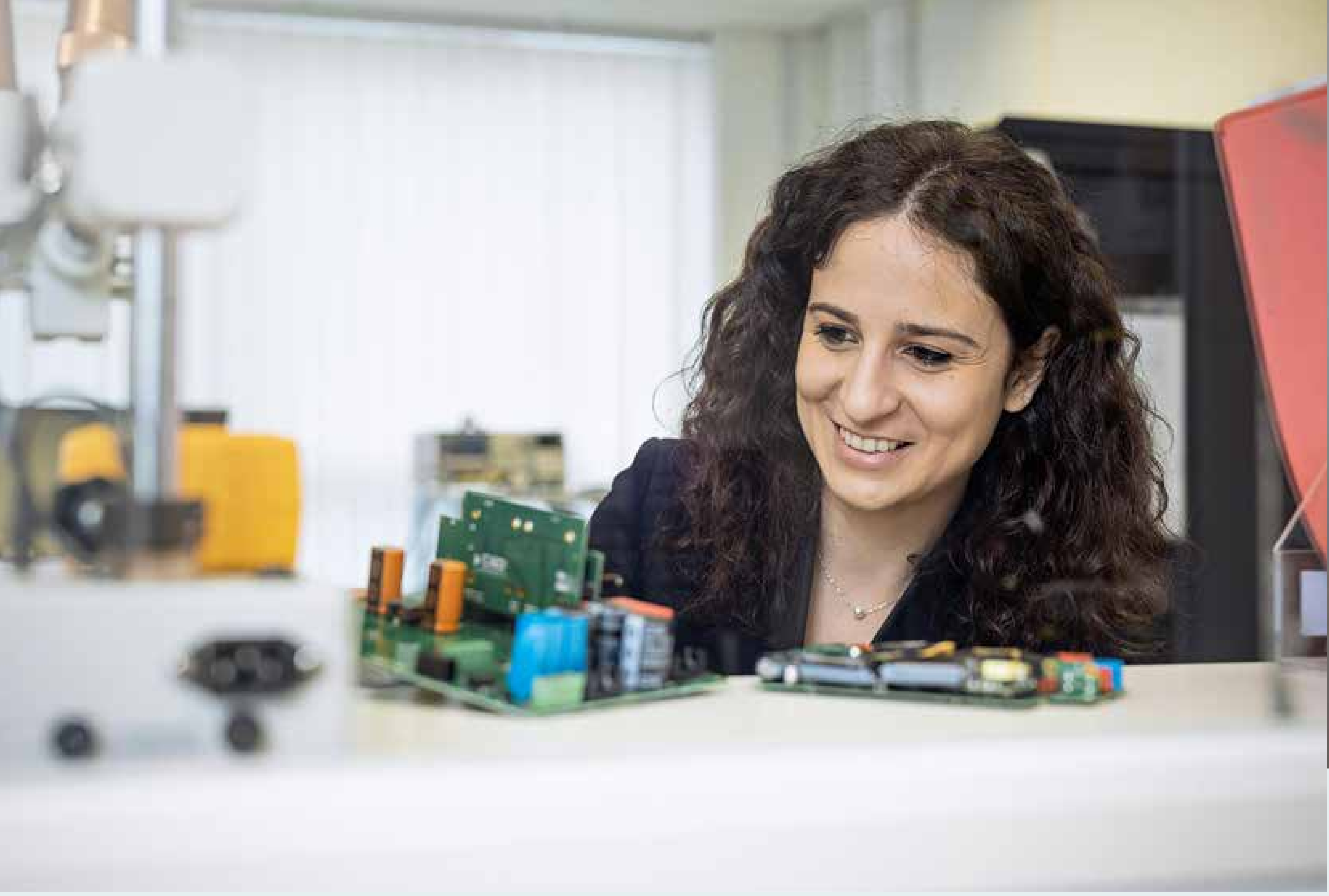
"This is significant, considering one industrial standard that is used to determine whether a battery should be retired or not is when it has lost 20% of its capacity," said co-first author Dr Chao Xu, from ShanghaiTech University, who completed the research while based at Cambridge.

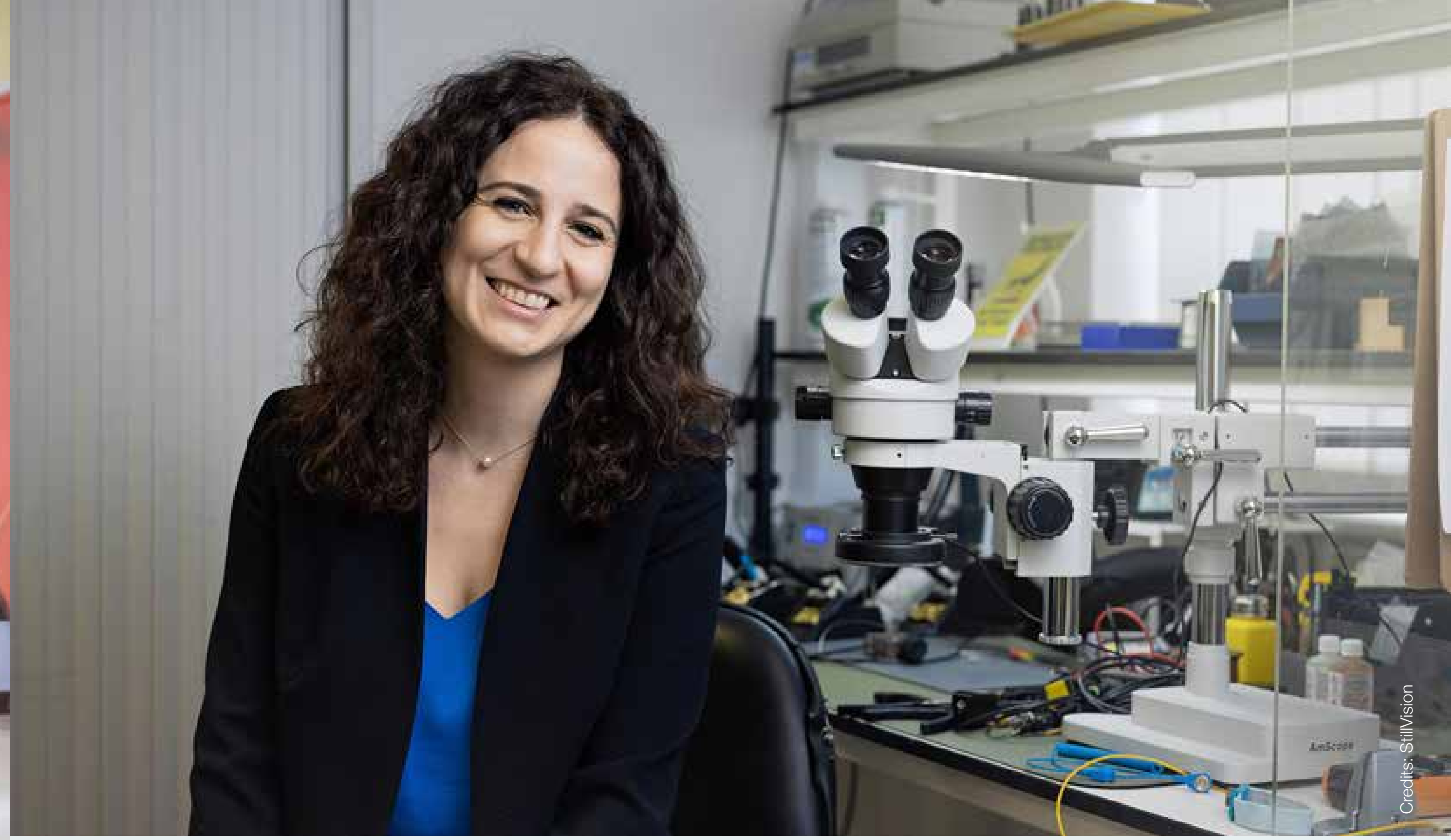
The researchers are now seeking new approaches to increase the practical energy density and lifetime of these promising battery materials.

The research was supported in part by the Engineering and Physical Sciences Research Council (EPSRC), part of UK Research and Innovation (UKRI). Alice Merryweather is jointly supervised by Professor Dame Clare Grey and Dr Akshay Rao, who are both co-authors on the current paper.

Written by Sarah Collins

Open access paper:
www.eng.cam.ac.uk/ev-battery





Credits: StillVision

ALUMNI UPDATE

Powering a green revolution

Alumna, engineer, founder and CEO of Cambridge GaN Devices, Dr Giorgia Longobardi, was a Royal Academy of Engineering Young Engineer of the Year in 2019 and has been the winner of numerous accolades including *Business Weekly*'s Woman Entrepreneur of the Year in 2021.

Based on Dr Longobardi's original research, Cambridge GaN Devices (CGD) has developed a range of power devices using the energy-efficient semiconductor gallium nitride (GaN), heralding a new era of greener electronics.

"As our lives becomes increasingly digital, our need for more energy-efficient ways to power them becomes ever more pressing. Swapping gallium nitride for silicon in electronics will save up to 50% of the energy used in everything from fast-charging our phones to running the vast data centres that keep our digital world turning."

Why gallium nitride? I came to Cambridge initially as an Erasmus student and was given a choice of topics to research. One was silicon power devices, which the group in the Department of Engineering already knew a lot about. The other was the energy-efficient 'material of the future' which I would be the first in the group to work on. Of course, I chose the latter. I like a challenge!

It was particularly difficult because I was having to learn English at the same time. But somehow, I got through and as soon as I finished, I was given the opportunity to continue my research as a PhD student, this time working in collaboration with a major semiconductor company, NXP (now called Nexperia).

You got your PhD. Then what? I could see the potential for GaN, so I applied for EPSRC Follow-on Funding which gave me a year to start bridging the gap between the research and commercialisation.

After that, I was awarded a Junior Research Fellowship at Gonville and Caius College which was perfect: it gave me the flexibility to pursue my own research – and to really think. I had so many ideas during that time and the College was so supportive.

What about founding a company? When did you start to think that might be a good idea? When I applied for the Junior Research Fellowship, my application was based on the idea of spinning out a company. To be honest, I didn't have any real idea of what it meant and what it would take to do it.

During my Fellowship, I continued to work with industry, consulting with two of the main semiconductor companies, Infineon and Vishay, getting good market knowledge and insight.

I founded the company in 2016, with my PhD supervisor – and serial entrepreneur – Professor Florin Udrea.

This all seems like a very smooth path? Yes and no. After raising the first £20k by winning the Cambridge Enterprise post-doc competition in 2016, I pitched to Cambridge Enterprise again, this time for a Fast50 £75,000 convertible loan. On the same day, I also told them, "I'm going to go to Japan for a year".

I had been offered a fellowship by the Japanese Society for the Promotion of Science. For me, it was an amazing opportunity. Cambridge is fantastic but I needed to see something different. And this was the moment in my life when it would be possible, before partners, families or companies could get in the way.

I managed to convince Cambridge Enterprise that it would be beneficial for the company – which it was.

In what way? We all talk about the need for diversity and the importance of listening to other people's ideas and perspectives. It was only when I went to Japan that I properly understood the difference between cultures. In Europe, we have so much in common. But this was totally different.

And that lesson informs everything I do. There are 32 people at CGD at the moment and 19 different nationalities.

What about gender diversity? Your board members are all male, bar one. Yes – because all the investors are men. It has not been a problem in that the board is very supportive. But I do think it is a challenge, if you are in a meeting, whether with your board, your customers or your own staff, and you are different from everyone else around the table.

That is why I am involved in lots of activities to promote STEM subjects to young women such as the Global Semiconductor Alliance's Women in Leadership Initiative.

Has being in Cambridge helped you achieve your goals? There are so many helpful people and programmes here. Cambridge Enterprise was hugely important in the early stages when I didn't know how to file a patent or how to pitch to investors.

Having Florin as my co-founder was also important. He has five spinouts now and back then it was two or three. He made me believe it was possible.

I must also mention the Royal Academy of Engineering SME Leaders' programme which gave me £10,000 to spend on training courses and meant I was able to do a finance course, which was invaluable.

Where is CGD now? At a very exciting time. We have launched our product range and have rebranded. We are coming out to the world.

Our first focus is the consumer electronic market, but over the next two years, we will have products for industrial and data centre markets. By 2025, we will have entered the automotive market with transistors that can be used in onboard chargers for electric vehicles.

For me, it's all about leadership rather than making money, about the impact our technology can have. GaN is the most energy-efficient semiconductor and if our technology is used by data centres, it will save more than nine million tonnes of $C0_2$ emissions, equivalent to the greenhouse emissions from more than 20 million barrels of oil consumed. That's our ambition.

And we are growing fast. By the end of 2023, there should be 100 of us.

How are you finding scaling up? Anyone who says this is not a challenge, is lying. It's a challenge personally, and for the company. You have to adapt to whatever stage you are at and hire the right people to cover the aspects that can no longer be your primary focus. Understanding that this is necessary and letting those parts of the business go is vital.

Of course, the CEO gives the direction, but the people you hire are the key to the company's success. It is not about telling them what to do, it is making sure they share their ideas. If you do that, you can create an avalanche of innovation. It's beautiful.

Written by Sarah Fell

camgandevices.com

Professor Jacques Heyman FREng awarded Sir Frank Whittle Medal

↑ Professor Jacques Heyman (right) receiving the Sir Frank Whittle Medal from Sir Jim McDonald, President of the Royal Academy of Engineering

Professor Jacques Heyman, formerly Head of the Department and a leading figure in church architecture and restoration, was presented with the Royal Academy of Engineering's Sir Frank Whittle Medal in recognition of his outstanding career in structural design.

Named after Britain's jet engine genius, the Sir Frank Whittle Medal is awarded to an engineer resident in the UK whose outstanding and sustained achievements have had a profound impact on their engineering discipline.

For nearly 70 years, Professor Heyman has made vital contributions to structural engineering. His highly original research found that the design theorems developed to understand the plastic behaviour of steel structures, could also be applied to masonry structures. This resulted in a paradigm shift in the understanding of structural behaviour and design and provided new insight into historical structural masterpieces, justifying the intuition of the great builders and engineers of the past.

Focusing on masonry structures, Professor Heyman used his deep knowledge of the architectural history of masonry construction, coupled with his own field observations and his research, to become the foremost authority on cathedrals.

Movements of foundations or abutments in historic stone buildings produce patterns of fine cracks that can be 'read' to deduce what is causing the problem. He has advised on the safety of masonry vaults in many iconic structures, including Westminster Abbey, King's College Cambridge, St George's Chapel Windsor, as well as Ely and Worcester Cathedrals.

From Gothic cathedrals to steel skyscrapers, Professor Heyman's research has not only guided the design and repair of countless historic constructions around the world, but paved the way for new low-carbon vaulted structures made from local materials. His work has inspired generations of structural engineers and others working in masonry, as well as those who seek to build modern structures with more efficient use of resources.

Professor David Muir Wood FREng FRSE, Emeritus Professor of Geotechnical Engineering at the University of Dundee, said: "Professor Heyman's profound knowledge of matters concerning masonry construction, together with forensic case studies of reported distress and failure, have often led him to become the international 'engineer of choice' for solving structural masonry problems."

> "Professor Heyman's profound knowledge of matters concerning masonry construction, together with forensic case studies of reported distress and failure, have often led him to become the international 'engineer of choice' for solving structural masonry problems.
>
> Professor David Muir Wood FREng FRSE

→ Professor Graham Pullan, Director of the EPSRC CDT FPP, engages the attendees of the annual Women in Aerospace gathering

Women in Aerospace

Annual gathering

The fourth annual Women in Aerospace event has been held at the Whittle Laboratory and Newnham College. With more than 80 women in attendance, this has been the largest gathering to date, hosted by the EPSRC Centre for Doctoral Training (CDT) in Future Propulsion and Power (FPP).

The event provided an opportunity for women from varying backgrounds, disciplines and careers to discuss the importance of diversity in the aviation industry and how it can help transform the sector to one that works better for people and the planet.

Of those in attendance, 36% were engineering degree undergraduates from the CDT partner universities (Cambridge, Oxford and Loughborough) and also from other leading universities around the country (Bath, Durham and Imperial College). PhD students, and women from industry, government and academia, were also in attendance.

The event began with a panel session chaired by Dr Maria Vera-Morales, Senior CDT Fellow, and included Grazia Vittadini, Chief Technology Officer at Rolls-Royce; Carrie Lambert, Head of Sustainability at Reaction Engines; and Dr Grace Belshaw, EPSRC Portfolio Manager for Fluid Dynamics and Aerodynamics.

The topics discussed included the challenges and opportunities of the aviation sector, and the obstacles faced by women in engineering and STEM (science, technology, engineering, and mathematics) disciplines. The panellists shared their journeys to the leading roles they play today. Current CDT FPP students prepared questions to the panel. Attendees asked questions that covered everything from the challenges faced by being the only female worker in the room, to the motivations behind career moves.

Dr Belshaw stressed the importance of doctoral training centres such as the CDT FPP in training future engineers to be resilient and adaptive to change in order to tackle the key challenges that we will face over the next 10 to 15 years.

Looking to the future

After the panel, Professor Graham Pullan, Director of the EPSRC CDT FPP, highlighted the breadth of topics covered by the CDT in response to the changing landscapes in both propulsion and power sectors. The CDT FPP – a collaboration between the University of Cambridge, University of Oxford and Loughborough University in association with Rolls-Royce, Mitsubishi Heavy Industries, Siemens and Dyson and funded by the EPSRC – is the leading centre for research into sustainable propulsion and power, providing training in the key skills that engineers will need to become the leaders of the future.

Attendee Dr Shini Somara said: "This CDT event highlighted for me how far trailblazing women have come, how empowered we are now, and the exciting challenges faced by incredibly talented women who are bold, brilliant and determined to take care of our aerospace future. I see diversity, equality and inclusion increasing each year in this cutting-edge field and it's really encouraging – well done CDT, a powerful force in engineering!"

The afternoon concluded with a tour of the Whittle Laboratory, as well as an opportunity to hear about the plans for the National Centre in Propulsion and Power that will be housed in the New Whittle Laboratory.

Inspiring the next generation

The pinnacle of the event was a keynote speech, introduced by Professor Dame Ann Dowling, Deputy Vice-Chancellor and Emeritus Professor of Mechanical Engineering at the University of Cambridge, and given by Grazia Vittadini.

Grazia said: "The aviation sector is at a crossroads, achieving net zero is non-negotiable. But no one person can push the levers to get there. Everyone must work together, from policymakers to academia to industry. It will require diverse skills that can accelerate innovation. Let's find unity in diversity, it is our greatest strength, and it will power this transition. Be as bold as you can be in the face of challenge. Don't just walk through open doors, but hold them open for those behind. It is only through this, that we will be able to create an environment that benefits everyone."

Professor Rob Miller, Director of the Whittle Laboratory, said: "Getting to net zero in both the aerospace and energy sectors requires a mix of talented engineers who are diverse not only in terms of engineering discipline, but also in background, experience and perspective."

Speaking after the event, Professor Dowling said: "I was struck by how much the event – and the group – has grown since 2017. Aviation plays an important role in bringing people together from around the world but is one of the hardest sectors to decarbonise. The creativity and innovation that these women bring are essential to meeting our net zero goals."

www.turbocdt.org
whittle.eng.cam.ac.uk

➜ The experimental setup showing UAV (drone) monitoring and improved estimations of particle dispersion from maritime emissions

Monitoring maritime emissions at land and sea using drones and handheld particle sensors

Cambridge engineers have used drones, handheld particle sensors and a new modelling framework to measure, map and characterise harmful shipping emission particles at both land and sea. It is the first time that multi-characteristic particle measurements – including lung deposited surface area (LDSA), black carbon, and particle number – have been performed in this way, and it is hoped that this research will inform environmental initiatives and support efforts to clean up the maritime sector.

Particulate matter (PM) is a harmful pollutant commonly found in emissions. When inhaled, it can cause serious health problems, and it is also known to have a negative impact on the climate. Efforts to regulate the maritime sector have resulted in a call for new knowledge and methods to characterise the evolution of maritime particle emissions dispersing in port areas.

With this in mind, Cambridge researchers ran experiments at the Port of Rafina, in Greece. Land- and drone-based measurements involving five passenger ferries, primarily idling at port, were conducted over a period of seven days in port-side locations (using low-cost, handheld sensor technology), and at-sea at various locations (using a novel instrument set-up mounted on a drone). The drones entered emission plumes, capturing real-time data close to the emission source (passenger ferries). This was achieved in two ways: by slowly ascending and descending through the plume, and by holding a steady position for 10 minutes, at a constant height of 10 metres, approximately 130 metres from ground-based sensors as the ferry accelerated past.

The study has broken new ground; it is the first time that drones have been used for monitoring multiple particle characteristics within plumes in the near field of emissions sources at-sea, in a real-world setting. The findings are reported in the journal *Atmospheric Environment*.

Experimental observations revealed the differences in particle characteristics. Multiple particle sensors were used to measure more than one particle metric to better understand particle evolution in a maritime plume. These were:

- LDSA – a metric related to the ability of the particle to penetrate the lungs
- Black carbon – a component of PM, the air pollutant
- Particle number – a parameter to measure the number of solid particles emitted by an engine.

Whereas other studies have used drones flying behind ships, none have used more than one particle instrument. By using all three of these characteristics (LDSA, black carbon, and particle number), the researchers can gain valuable information on how the plume is dispersing. This would not have been possible to determine, if only one of the metrics was being measured.

Further still, the research team were able to predict the three-dimensional evolution of particle characteristics by coupling a Gaussian plume dispersion model and a new modelling approach, known as the Incompletely Stirred Reactor Network (ISRN). The aim is to enhance the accuracy of predictive pollutant dispersion methods by taking into account physiochemical transformations of evolving particles within plumes in a computationally affordable way.

From the land-based measurements, researchers found that LDSA averages, which are influenced by particle number and size, increase up to 20 times above background levels as an emission plume progresses downwind. In comparison, black carbon concentrations, which are dominated by mass, are approximately 12 times higher than the background concentration. Particle instruments were positioned in two locations: port-side, and the balcony of the only hotel within the port. The former was five metres above sea-level, 175 metres from the ferry docking area, and adjacent to the only road entering/exiting the port, and the latter was 250 metres from the ferry docking area.

"Interestingly, peak black carbon and LDSA concentrations at our port-side and hotel balcony locations are comparable to exposure levels in underground mining, depending on the location in the mine, and almost twice as high as airport taxiway personal exposure," said Dr Molly Haugen, Senior Research Associate in Emissions Measurement, and first author of the paper. "These measurements were taken as ferries arrived into the port."

➜ Standing alongside the drone, from left, Dr Savvas Gkantonas, Professor Epaminondas Mastorakos, Professor Adam Boies and Dr Molly Haugen

The researchers found that the LDSA to black carbon ratio at the hotel balcony location increased by an order of magnitude, meaning that the LDSA rises significantly faster than the black carbon concentration. A similar relationship is shown at the port-side location, with increased LDSA to black carbon ratios when maritime emissions are present, specifically for gas turbine engines[1]. In both cases, the difference in background particle concentrations from steady traffic in the area is insignificant when maritime emissions are present, say the researchers.

When comparing land- and drone-based particles, particle number and LDSA measurements exhibited greater differences than black carbon relative to the plume's location. Land-based sensors have approximately 50% lower LDSA and particle number concentrations, whereas black carbon was about equal.

Particle instruments placed in a third land-based location, directly on the dock, showed that the smaller particles emitted in this area are not being captured in black carbon concentrations. This was not the case with LDSA measurements however, which showed a significant impact from maritime emissions.

"These measurements, taken in different sampling locations, should reinforce why dual monitoring of black carbon and LDSA are so imperative," said Dr Haugen. "The implications of regulating and monitoring black carbon alone, could pose a threat to public health, as these smaller particles being emitted are not captured in black carbon measurements, and have an increased possibility of entering and remaining in exposed lungs. Therefore, maritime vessels could adhere to PM standards while continuing to have high LDSA averages, or smaller particles, leading to unknown health and environmental repercussions."

Dr Savvas Gkantonas, Research Associate in Numerical Simulations in Turbulent Combustion, and paper co-author, added: "We are interested in developing a model to understand how the aerodynamics of the ferries – and turbulence – affect all kinds of chemical or physical transformations occurring within an exhaust plume. This is not only related to particulate matter emissions but also gaseous pollutants, such as NOx. Eventually, all this knowledge could help improve air quality modelling on a coastal, national or even global scale. However, it is also not hard to imagine a future 'policing' application, where a port officer uses a handheld sensor or a drone to measure a pollutant and then plugs the data into a code that identifies an illegal polluter a few kilometres away."

The researchers are thankful for the support they received for this work. The local authorities (Athens Airport Air Traffic Control, Mayor of Rafina, Coast Guard and Port Authority) embraced this campaign and are keen to continue the dialogue on these measurements.

The research was carried out by the Department of Engineering, University of Cambridge, and the Cambridge Centre for Advanced Research and Education in Singapore (CARES), from a grant issued by the National Research Foundation (NRF), Prime Minister's Office, Singapore, under its Campus for Research Excellence and Technological Enterprise (CREATE) programme. Special thanks to Mr Peter Benie for leadership with the electronics and software of the sensors.

The project was originally planned to be deployed in Singapore, in 2020, for fieldwork. Due to the COVID-19 pandemic, fieldwork was carried out in Europe instead. However, it is hoped that the Singapore fieldwork plans will be able to recommence in 2023, subject to licenses.

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> Peak black carbon and LDSA concentrations at our port-side and hotel balcony locations are comparable to exposure levels in underground mining, depending on the location in the mine, and almost twice as high as airport taxiway personal exposure.
>
> Dr Molly Haugen

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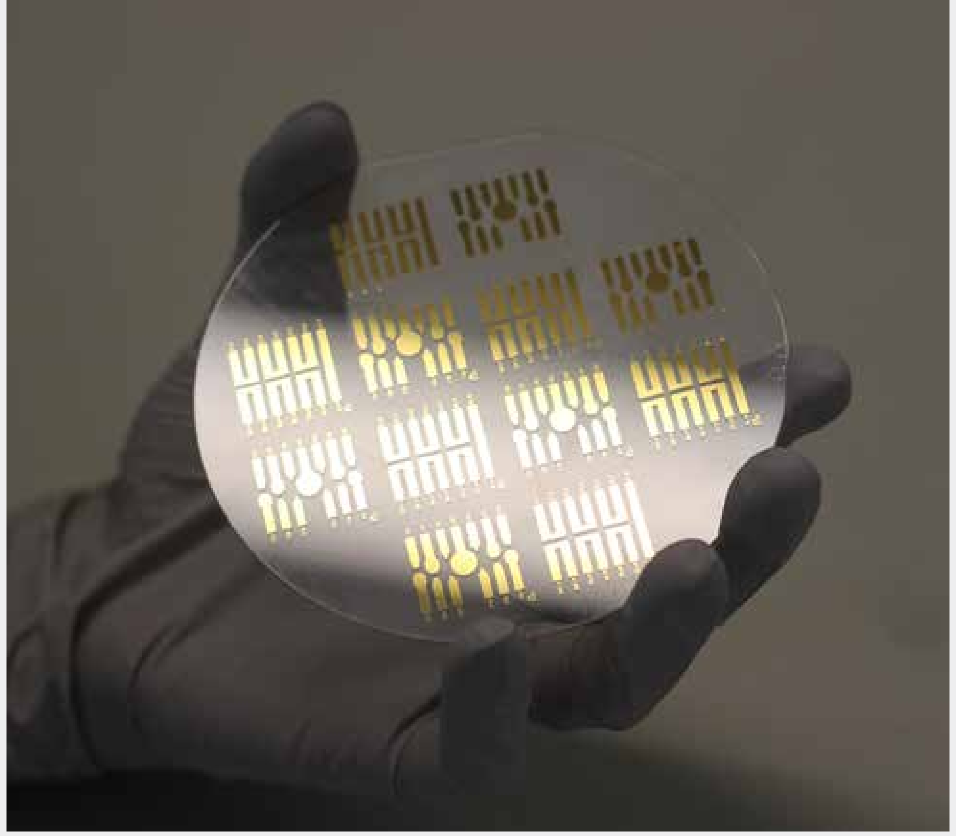
[1] Whereas the gas turbine-propelled ferries did not have black plumes spewing from their stack pipes, the diesel ferries did – this visible difference was corroborated with the measurements made.

Watch the drone in action:
youtu.be/NQHKPtPm68g
Open access paper:
www.eng.cam.ac.uk/maritime-emissions
www.cares.cam.ac.uk



Credit: Ben Woodington

Miniaturised biosensors for minimally invasive implants

A new method for the miniaturisation of biosensors will enable new possibilities for minimally invasive implants. The miniaturised transistors are fabricated on thin, flexible substrates, and amplify biosignals, producing currents more than 200 times larger than analogous alternatives.

Diagnosing and monitoring diseases often rely on the detection of molecules called "biomarkers". However, the detection of such biomarkers need periodic blood draws, which are expensive, time consuming, require specialised equipment, and provide no continuous data. To avoid this, and provide real-time biomarker detection, Professor Kevin Plaxco's team at the University of California Santa Barbara pioneered the development of implantable aptamer-based sensors. These devices are electrochemical sensors based on DNA and they successfully track small molecules in real time.

A key step to translate these sensors to real-life applications in the clinic is to make them as small and minimally invasive as possible. To solve this miniaturisation challenge, researchers at Cambridge[1] teamed up with the Plaxco Lab to discover a way to combine aptamer-based sensors with an amplifying transistor platform. Together, they developed biosensors based on organic electrochemical transistors (OECTs), which maintain high performances of the aptamer sensors even when shrunk to quite small dimensions. The results are reported in the journal *Science Advances*.

Research student Sophia Bidinger, lead author of the paper, said: "This work is an important step towards creating better tools for healthcare providers. With this type of sensor, physicians will be able to gain unprecedented real-time data for tracking their patients' health."

Previous aptamer sensors were made of thin, millimeters-long wires. In contrast, the new transistor biosensors are so small that they are barely visible to the naked eye. This technology will be useful for medical applications that require sensors in delicate areas. For example, such a minimally invasive sensor could enable implantation in the brain – an ideal region to track biomarkers linked with mental disorders, such as depression.

Paper co-author Professor Tawfique Hasan said: "There is a huge market opportunity for continuous molecular monitoring. Besides glucose, there are not very many commercially available sensors. More tools for supporting continuous, in vivo sensing will save lives."

The cross-disciplinary research team will now explore possible next directions of this work. For example, another benefit of signal amplification is improved lifetime, so the sensor can operate for longer without being replaced. Each of these improvements is one step closer to deployment in humans for tracking anything from drugs to hormones to neurotransmitters.

Paper co-author Professor George Malliaras added: "The most exciting aspect of this work is that it could be used to detect virtually any small molecule. This will help doctors gain much more patient specific insight than ever before."

> "With this type of sensor, physicians will be able to gain unprecedented real-time data for tracking their patients' health."
>
> Sophia Bidinger

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[1] From the Electrical Engineering Division, Department of Engineering, and the Department of Physics.

Open access paper:
www.cambridgeroadmapping.net
ee.eng.cam.ac.uk

Cambridge spin-out BKwai enables construction industry to work smarter

Credit (right): scottimage – stock.adobe.com

Launched in 2019 by alumna Sakthy Selvakumaran, BKwai is a software platform that provides data insights to support construction site teams and help asset owners better interpret large volumes of sensor data.

The software provides valuable data analysis by incorporating data from multiple sources, including existing sensors, environmental data and new and emerging data sets, such as satellite radar used to monitor millimetre-scale displacements over wide geographical areas, and is designed to extract information from large-scale datasets where little related knowledge exists. By using different sources of data, and combining them, the platform can exploit a range of insights, spot trends and flag unusual behaviours.

The idea for the company came from insights and problems identified by Sakthy during her time working in design and construction roles within industry. BKwai incorporates some of the multimodal data analysis algorithms and satellite monitoring work progressed during her PhD, during which she was affiliated to the Cambridge Centre for Smart Infrastructure and Construction (CSIC) and the Laing O'Rourke Centre for Construction Engineering and Technology.

The beginnings of the platform were developed using data from a pilot study on the Thames Tideway Central site. BKwai's first product was in use on live construction sites by January 2020 and the company, now a CSIC Industry Partner, is currently engaged by a number of construction organisations including Thames Tideway, Laing O'Rourke, Kier, WSP and Highways England.

Addressing industry challenges

Global infrastructure in many countries is ageing and performing beyond its design life and intended capacity. Construction is an industry that is experiencing a period of rapid digitisation in the UK. Faced with the climate emergency and extreme weather events, the built and natural environment is under increasing strain and resilient infrastructure is needed to provide services on which society depends. Government targets for net zero require the built environment sector to better understand the condition of existing assets and maintain them using minimal resources.

Assessing the condition of some assets can be difficult: logistical challenges make the visual inspection of remote and hard-to-access assets expensive and potentially hazardous. New construction projects must ensure safe environments and understand and monitor the short- and long-term environmental impact of a site.

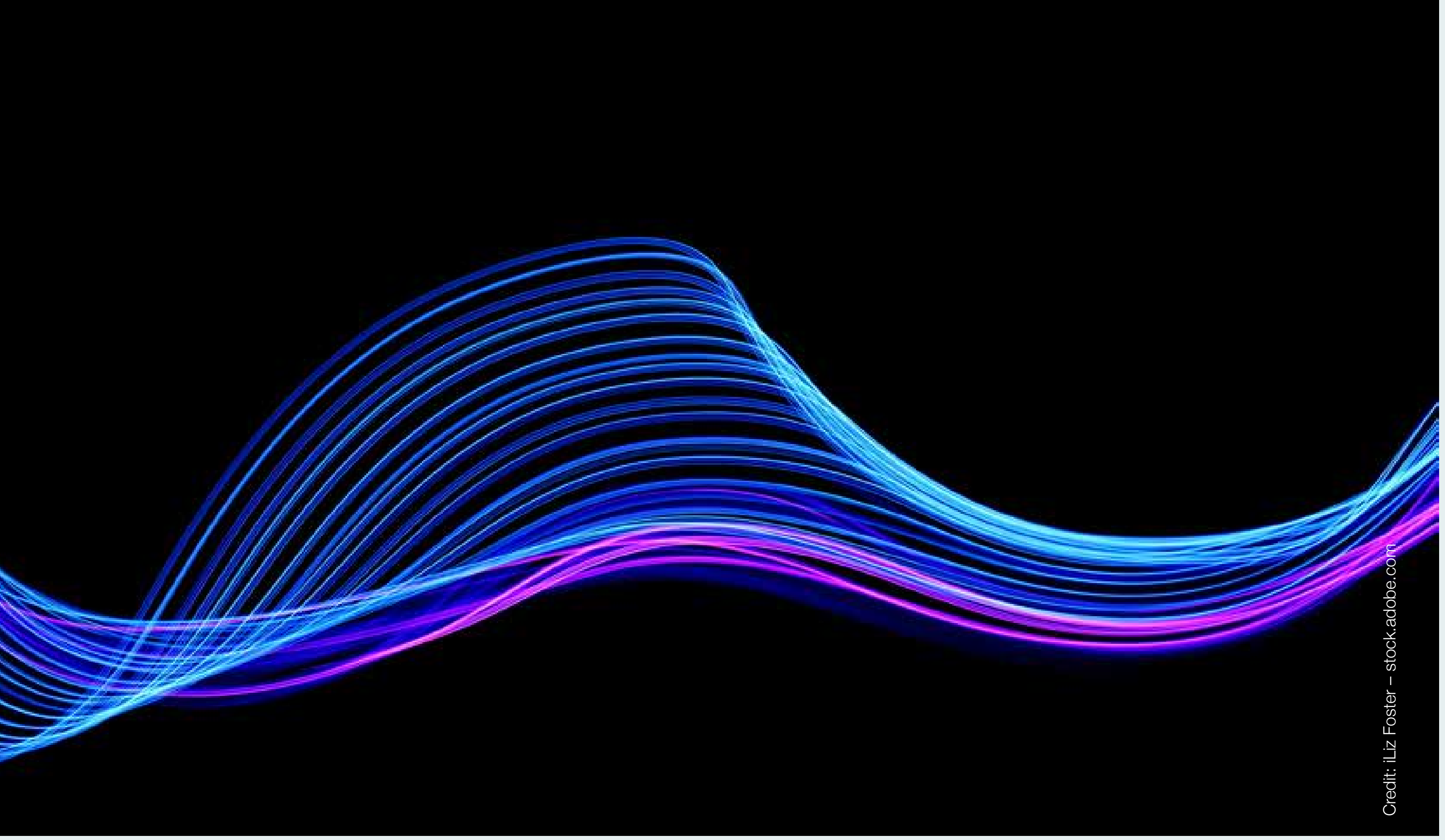
"The proliferation of new sensors and satellite technology has the potential to fuel a revolution in the way the built environment can be monitored. Data can be used to make smarter, safer, sustainable and efficient decisions across all aspects of the process – from planning to construction to operation and maintenance," said Sakthy, now an Engineering Fellow based in the Department's Civil Engineering Division. "In an industry rooted in spreadsheets and manual interventions, it becomes impossible to sift through such volumes and find key insights and values. One sensor or source of information does not fix all problems – the industry is crying out for better tools to help understand the complex challenges facing our built environment and provide data-driven engineering insights."

Looking ahead

Data is radically transforming construction and asset management and the BKwai platform provides industry with better tools to interrogate datasets. AI learning architectures have been developed to enable BKwai products to intelligently analyse petabytes of data and find answers to large, multi-variate problems within seconds.

Jennifer Schooling OBE, Director of CSIC, said: "The construction and infrastructure industries are sitting on huge amounts of data that they are currently unable to gain long-term insights from – most data is looked at once and then archived. BKwai's platform creates a real opportunity to learn far more about our infrastructure assets and construction processes, and extract the value from this rich but under-utilised asset."

www.bkwai.com



Credit: iLiz Foster – stock.adobe.com

Smart lighting system based on quantum dots more accurately reproduces daylight

Researchers have designed smart, colour-controllable white light devices from quantum dots – tiny semiconductors just a few billionths of a metre in size – which are more efficient and have better colour saturation than standard LEDs, and can dynamically reproduce daylight conditions in a single light.

The researchers, from the University of Cambridge, designed the next-generation smart lighting system using a combination of nanotechnology, colour science, advanced computational methods, electronics and a unique fabrication process.

The team found that by using more than the three primary lighting colours used in typical LEDs, they were able to reproduce daylight more accurately. Early tests of the new design showed excellent colour rendering, a wider operating range than current smart lighting technology, and wider spectrum of white light customisation. The results are reported in the journal *Nature Communications*.

As the availability and characteristics of ambient light are connected with wellbeing, the widespread availability of smart lighting systems can have a positive effect on human health since these systems can respond to individual mood. Smart lighting can also respond to circadian rhythms, which regulate the daily sleep-wake cycle, so that light is reddish-white in the morning and evening, and bluish-white during the day.

When a room has sufficient natural or artificial light, good glare control, and views of the outdoors, it is said to have good levels of visual comfort. In indoor environments under artificial light, visual comfort depends on how accurately colours are rendered. Since the colour of objects is determined by illumination, smart white lighting needs to be able to accurately express the colour of surrounding objects. Current technology achieves this by using three different colours of light simultaneously.

Quantum dots have been studied and developed as light sources since the 1990s, due to their high colour tunability and colour purity. Due to their unique optoelectronic properties, they show excellent colour performance in both wide colour controllability and high colour rendering capability.

The Cambridge researchers developed an architecture for quantum-dot light-emitting diodes (QD-LED) based next-generation smart white lighting. They combined system-level colour optimisation, device-level optoelectronic simulation, and material-level parameter extraction.

The researchers produced a computational design framework from a colour optimisation algorithm used for neural networks in machine learning, together with a new method for charge transport and light emission modelling.

The QD-LED system uses multiple primary colours – beyond the commonly used red, green and blue – to more accurately mimic white light. By choosing quantum dots of a specific size – between three and 30 nanometres in diameter – the researchers were able to overcome some of the practical limitations of LEDs and achieve the emission wavelengths they needed to test their predictions.

The team then validated their design by creating a new device architecture of QD-LED based white lighting. The test showed excellent colour rendering, a wider operating range than current technology, and a wide spectrum of white light shade customisation.

> “The ability to better reproduce daylight through its varying colour spectrum dynamically in a single light is what we aimed for. We achieved it in a new way through using quantum dots. This research opens the way for a wide variety of new human responsive lighting environments.
>
> Professor Gehan Amaratunga

The Cambridge-developed QD-LED system showed a correlated colour temperature (CCT) range from 2243K (reddish) to 9207K (bright midday sun), compared with current LED-based smart lights which have a CCT between 2200K and 6500K. The colour rendering index (CRI) – a measure of colours illuminated by the light in comparison to daylight (CRI=100) – of the QD-LED system was 97, compared to current smart bulb ranges, which are between 80 and 91.

The design could pave the way to more efficient, more accurate smart lighting. In an LED smart bulb, the three LEDs must be controlled individually to achieve a given colour. In the QD-LED system, all the quantum dots are driven by a single common control voltage to achieve the full colour temperature range.

“This is a world-first: a fully optimised, high-performance quantum-dot-based smart white lighting system,” said Professor Jong Min Kim from Cambridge’s Department of Engineering, who co-led the research. “This is the first milestone toward the full exploitation of quantum-dot-based smart white lighting for daily applications.”

“The ability to better reproduce daylight through its varying colour spectrum dynamically in a single light is what we aimed for,” said Professor Gehan Amaratunga, who co-led the research. “We achieved it in a new way through using quantum dots. This research opens the way for a wide variety of new human responsive lighting environments.”

The structure of the QD-LED white lighting developed by the Cambridge team is scalable to large area lighting surfaces, as it is made with a printing process and its control and drive is similar to that in a display. With standard point source LEDs requiring individual control this is a more complex task.

The research was supported in part by the European Union and the Engineering and Physical Sciences Research Council (EPSRC), part of UK Research and Innovation (UKRI).

Putting the user at the centre: The future of digital health apps

Eighty per cent of health apps fail to deliver their intended impact. Second-year Institute for Manufacturing (IfM) PhD student Devmalya (Dev) Sarkar tells us why he wants to help firms change this, using need-driven and empathic approaches to innovation.

While digital health innovations such as health apps are not a utopian cure-all, they can help. These innovations offer a range of possibilities: immediate access to health services beyond physical locations, health promotion support, targeted disease management, and cost-effective data collection and processing.

Dev explains: “When applied correctly in a context-appropriate manner, health apps can promote better patient experience and treatment outcomes. However, four in every five health apps fail, often because they don’t adequately consider their users’ reality. Firms struggle to identify user needs early in the ‘fuzzy’ front end of the innovation process.

“An overly technology-driven focus often fails to account for real-world complexities, such as understanding users, their behaviours and, most importantly, their unmet needs. This then limits design quality and overall downstream acceptance of the app. Firms typically incorporate user feedback no earlier than concept development, later in iterative solution refinement, or worse, after the solution has been developed. Unsurprisingly, inherent bias accumulates and results in something that users cannot relate to.”

Dev is therefore looking to help guide firms to improve their user-centric innovation ability by reducing uncertainty in identifying users’ needs early in innovation.

Dev says his research will contribute to the IfM’s unifying vision of ‘manufacturing a better world’, alongside ongoing contributions in the Institute to improve affordable and accessible healthcare. These include Professor Ronan Daly’s and his team’s work on identifying existing technologies, such as mobile phone touchscreens for diagnostic and therapeutic purposes; the IfM’s Cambridge Service Alliance’s work on a patient-centric, wearable-based therapeutic intervention (and its business model framework) for childhood cancer; and the IfM Engage’s work with the The William Templeton Foundation for Young People’s Mental Health on addressing early intervention and self-care needs in young people’s mental health.

↑ This image was created with the assistance of DALL.E2

→ NanoFutures Scholars pictured with programme coordinator James Dolan (front, far right).

Pioneering new approaches to postgraduate widening participation

The UKRI CDT in Nanoscience and Nanotechnology (NanoDTC) ran a postgraduate widening participation internship programme called NanoFutures Scholars. The programme pioneers new approaches to postgraduate widening participation by exposing students with only limited prior research experience to cutting-edge interdisciplinary research.

The NanoDTC was established in 2009 and is a world leader in postgraduate research and education for accelerating the discovery cycle of functional nanotechnologies and materials. Based across the Departments of Engineering, Physics, Chemistry, and Materials Science and Metallurgy, the group bridges groundbreaking fundamental science toward industrial device integration, and drives technological innovation via a strongly interdisciplinary approach. With many industry interactions, and a number of spin-outs, the group have evidenced success in traction for novel nanomaterials and devices.

In the summer of 2022, the NanoDTC welcomed its first cohort of NanoFutures Scholars – undergraduate students that the NanoDTC identified as the future of nanoscience and nanotechnology research. Two of the scholars are at the Institute for Manufacturing (IfM), part of the Department of Engineering. Through the NanoFutures Scholars internship programme, one of the first of its kind in the University, the NanoDTC is leading the Physical Sciences and Engineering at Cambridge in pioneering new approaches to postgraduate widening participation. By exposing students with only limited prior research experience to the cutting-edge interdisciplinary research within the NanoDTC community, together with its extracurricular programming, NanoFutures Scholars provides interns with the knowledge, experience and confidence to make successful applications for postgraduate study. The NanoDTC is led by its Director Stephan Hofmann, Professor of Nanotechnology in the Department of Engineering. Other members of the Department sit on the Management Committee, including Professor George Malliaras, Professor Tawfique Hasan, and Professor Michael De Volder.

The NanoDTC is an interdisciplinary centre for doctoral training which sits between and across all of the physical science and engineering departments in the University. Each student funded through the NanoDTC is co-supervised by two or more academics from different departments and disciplines, and many students end up supervised or co-supervised by academics in the Department of Engineering.

The NanoDTC provides high-quality, advanced-level training through the (Master of Research (MRes) first year of the 1+3 MRes+PhD programme) to students who are then fully funded to undertake their PhDs in different departments across the University, including Engineering.

Thanks to the generosity of a college donor, scholars were accommodated free of charge at Selwyn College. The scholars, all second and third year undergraduates from universities across the UK, spent eight weeks in Cambridge spread across the Departments of Engineering, Physics, Chemistry, and Materials Science and Metallurgy, supervised and mentored by early career researchers in the NanoDTC.

These members of the NanoDTC, many of whom themselves come from under-represented backgrounds, helped co-design the NanoFutures Scholars programme, ensuring the support and participation of the whole NanoDTC community. Interns tackled a range of challenging projects including the manufacture of luminous polymer waveguides, the mechanical study of micro-algae hydrogels, and the analysis of fluorescent polymer nanoparticles for cancer therapy.

Scholars integrated into the NanoDTC community by joining the weekly NanoDTC journal club, broadening their academic networks and gaining confidence discussing and presenting on technical research-level topics. Interns sponsored by the School of Physical Sciences also joined the NanoFutures Scholars extracurricular programme. The carefully curated research culture of the NanoDTC, widely recognised around the University as welcoming, inclusive, and supportive, and replicated within NanoFutures Scholars for the benefit of all participating interns, is an invaluable vehicle to help support the University's postgraduate widening participation aims.

→ nanodtc.cam.ac.uk/nanofutures-scholars

→ Katy Cartlidge

Credit: Charlotte Hester

Undergraduate project
Can an 'ice volcano' help to regenerate sea ice?

For her fourth year project, undergraduate Katy Cartlidge has evaluated whether a proposal known as the 'ice volcano' has the means to restore Arctic sea ice. Katy used theoretical modelling and experimental analysis to assess the feasibility and sensitivity of an 'ice volcano' to its environment, at a time when Arctic summer sea ice is declining at an alarming rate due to climate change.

The project titled *Ice Thickening – Climate Repair* investigated the use of the 'ice volcano' method to increase Arctic sea ice production in the winter. This method involves pumping seawater over a floating conical buoy, where it then freezes in the cold Arctic atmosphere to generate a growing cone of ice. A slotted pipe allows water to be pumped higher as the ice builds up. Once a height of three metres has been achieved, scientists say the newly-formed ice is likely to survive a summer melting season and become valuable 'multi-year ice', surviving at least two summers' melt.[1] This is a desirable outcome: thicker, stronger multi-year ice that is present in the summer, providing its benefits year-round.

Arctic sea ice has numerous benefits, such as: inhibiting methane release from permafrost melt; increasing the proportion of incoming solar radiation that is reflected; maintaining global currents that mediate weather patterns in the Northern hemisphere; and providing a habitat for polar wildlife. Scientists say that if current rates of ice decline are sustained, an ice-less summer will be seen in the Arctic within the next decade.

"A significant benefit of the 'ice volcano', in comparison to other proposed geoengineering projects, is that it merely augments a natural activity and does not introduce any unfamiliar chemicals or processes into the environment," said Katy.

Katy developed a simplified, two-dimensional model to predict the behaviour of an 'ice volcano' for fresh water at its freezing temperature and also fresh water above its freezing temperature. This was then followed by experimental analysis, using a narrow channel that maps onto the two-dimensional model. The experiments were conducted in a walk-in freezer with a temperature of –18°C. Water, of varying temperatures and salinities (fresh water and water at the salinity of Arctic seawater), was pumped through the channel over a layer of cold 'original ice' and allowed to freeze or cause melting. The resulting change in ice thickness was then calculated.

Both theoretically and experimentally, the results were promising for water at its freezing temperature: ice formed readily and uniformly all along the channel, indicating an 'ice volcano' could be successful and uniform. Experimental ice build-up exceeded theoretical predictions for both fresh and salt water, potentially due to heat fluxes from the air that were neglected in the model.

However, results were less encouraging for water entering the channel above its freezing temperature. It was found that this results in a substantial loss of ice near the inlet, even for water just a few degrees above its freezing temperature, although ice is still created further down the channel. In the context of the 'ice volcano', this insinuates that the region of ice surrounding the pipe could be completely eroded within a few hours, creating an 'ice doughnut', unless the water is within a very narrow margin of its freezing temperature.

Katy said: "When working in such a unique and fragile environment as the Arctic, it is necessary to take extreme care.

"Extensive trials in Arctic conditions, such as those that I carried out in the walk-in freezer, would be undertaken before contemplating any tests in the Arctic itself. The potential impact on ecosystems, climate and wildlife would be carefully evaluated at each stage, the formal approval process including ethics and stakeholder engagement for even small-scale field work would be exhaustive, and the experiments would be halted if unforeseen negative effects were observed."

Katy is supervised by Dr Shaun Fitzgerald, Teaching Fellow in Engineering and Director of Research at the Centre for Climate Repair at Cambridge. The Centre is working in affiliation with Cambridge Zero at the University of Cambridge to safeguard our planet from the disastrous effects of global warming.

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[1] Peter Wadhams. *Ice in the Ocean*. Gordon and Breach Science Publishers, London, 2000.

→ www.climaterepair.cam.ac.uk
www.zero.cam.ac.uk


Credit: iStock

New postgraduate courses to enable innovation in the healthcare sector

The Healthcare Innovation Programme is a set of three successive part-time courses designed to fit with the demands of full-time employment, leading to PgCert, PgDip and Master of Studies qualifications.

The objective of the Programme is to provide knowledge and understanding of the healthcare system and the technologies applicable to this sector, giving students the expertise and skills needed to innovate successfully in healthcare.

The course is suitable for those with a background in medicine, engineering or a related area.

The Healthcare Innovation Programme is delivered through a combination of face-to-face sessions requiring attendance in Cambridge, online sessions, and self-directed learning, and is supported through a virtual online environment.

Students will be equipped with the skills necessary to understand how biomedical engineering impacts upon populations, health conditions and clinical outcomes, and learn how to work across the boundaries of engineering, design and healthcare in an effective manner.

The Programme is structured such that students can progress from the Postgraduate Certificate in Healthcare Innovation (PgCert), through the Postgraduate Diploma in Healthcare Innovation: Engineering, Systems and Improvement (PgDip) and then on to the Master of Studies in Healthcare Innovation: Engineering, Systems and Improvement (MSt) in a flexible manner, enrolling each year for the corresponding award if they choose to progress, with breaks allowed along the way.

The main driving force of this Programme is the ambition to enhance the ability of people to innovate in the healthcare sector, requiring a challenging set of skills and knowledge. Innovators in healthcare are presented with many barriers to the implementation of their ideas, from technical difficulties, regulatory and environmental sustainability concerns to a multitude of difficulties in navigating the NHS and wider healthcare system. Subsequently, a great many of these ideas fail. Hence there is a need to interweave the development of new technologies with the surrounding healthcare system to allow them to be deployed widely and to operate successfully. This course aims to help innovators to engage with the practicalities of applying these technologies in the healthcare ecosystem.

"The challenges of innovation in healthcare span both technical issues and navigating the complexities of the healthcare system. I am very excited to be launching this suite of courses, which will provide people wanting to work in this sector with the broad range of skills needed to succeed in helping to improve people's health," said Michael Sutcliffe, Professor of Biomedical Engineering.

The Programme is targeted at both mid-career and new graduates who wish to develop their knowledge and skills in the healthcare innovation field. The part-time nature of the courses is designed to fit around the demands of full-time employment. The courses are broadly based and inter-disciplinary and students from any technical or healthcare-related discipline are welcomed.

It is expected that an applicant's first degree will be in a subject relevant, or related to, life sciences, medical sciences, computation or engineering, but other backgrounds will be considered. The courses are structured to accommodate a range of backgrounds, but enthusiasm for learning new methodologies, technologies and approaches to healthcare innovation will be important.

The course is a collaboration between the Department of Engineering and the Department of Public Health and Primary Care.

For more information about The Healthcare Innovation Programme of courses and how to apply, visit the Healthcare Innovation: Engineering, Systems and Improvement website healthcare.eng.cam.ac.uk

The deadline for 2023 applications was 17 April 2023, but any readers keen to apply for the September 2023 intake should email the course administrator: healthcare-course-admin@eng.cam.ac.uk to see if space is still available.

ALUMNI UPDATE

Meet the team on a mission to supercharge your sustainability efforts

Credit: Alectro

→ Alectro co-founders Tim Geller (Darwin College) on the left, and Bertie Ivory-Peters (Downing College)

Alumni Tim Geller and Bertie Ivory-Peters first met on the Department's MPhil programme in Nuclear Energy and soon realised that they shared a common goal: to help reduce the speed and impact of climate change. In 2019, the two joined forces to found Alectro – an on-demand software platform providing insight to organisations on the extent of their carbon emissions.

Alectro's vision is to encourage every business and employee to take responsibility for improving their own carbon footprint. To help with this process, Tim and Bertie have developed a Virtual Sustainability Office® platform, providing companies and employees with the tools they need to successfully deliver a comprehensive net zero strategy. The platform consists of a text-based algorithm that takes a bottom-up approach to analysis. It takes historical data, makes trend-based predictions and auto-generates data in real time. Employees also have access to the platform, providing them with a breakdown of their own individual impact and opportunities to actively engage in their employer's sustainability strategy.

With more than 40 clients spanning three continents, Tim and Bertie are enjoying a period of rapid expansion. Here they share their story.

Our vision is to empower every employee to become a 'climate champion'. Employees can play an active role in helping their company drive towards net zero for this generation and the next. Our platform enables employers to provide a tangible benefit for each employee and tackle their own sustainability agendas at the same time. If companies act on agendas at a minimum of board level, the sustainability agenda can be brought into all business decisions. Our platform assists in this process by providing easy-to-use measurement tools, as well as empowering all employees to contribute to, learn about, and challenge the company's sustainability agenda moving forward.

From the electricity used to heat buildings to the coffee people drink at work, analysing and interpreting this data can help companies and organisations to supercharge their sustainability strategies. With the help of a bottom-up, text-based algorithm, our platform enables companies to dynamically see the direction that their emissions are moving in, without having a time burden attached or a need for constant administration. Our platform recognises items on a line-by-line basis including expenses and other raw-data sources such as asset lists and cloud computing uptimes, rather than by overall spend data. This means that companies can start making informed and detailed decisions that impact their value chain in specific areas. For example, when looking at air travel, our text-based model can recognise a specific route or class of flight, in addition to the total cost and distance travelled. This provides a more accurate understanding of what that distance travelled actually is, and the associated impact of flight class, therefore allowing a company to understand the breakdown of the tonnes of carbon dioxide equivalent and target specific reductions from a few very carbon intense flights, rather than from a blanket reduction.

Without the MPhil in Nuclear Energy, we would not have started Alectro. We both chose to study this topic, because we wanted to contribute to reducing the speed and impact of climate change. One of the best aspects of the MPhil is the ability to customise it to the outcomes that you want. The core modules gave us hard technical skills, but also delivered softer skills like presenting and debating. The elective modules allowed both of us to tailor the experience to exactly what we were interested in.

We met sharing a common goal, bonded through shared interests, and launched Alectro with the skills we developed in Cambridge. The MPhil gave us the deep technical skills needed to tackle industry-leading problems. We wrote our theses on scenario analysis and energy modelling to 2050, and the challenges facing global energy collaboration – topics that directly translate to the work we now do at Alectro. The MPhil itself is fascinating, challenging and engaging. It pushed us hard and the sense of achievement at the end was phenomenal. If you are thinking about applying, absolutely do!

alectro.io

Tokyo TECH and Cambridge: research exchange and collaboration

Credit: Left – Tokyo TECH. Right – Sir Cam

A long-running student exchange programme set up by the Department of Engineering and the Tokyo Institute of Technology has gone from strength to strength.

The Tokyo TECH – Cambridge Summer Exchange Research Programme (SERP) provides opportunities for graduate students to take part in research exchange and collaboration. The programme, established in 2005, offers several months of overseas study under faculty supervision.

To mark the success of the 2022 SERP, an online workshop was held, attended by more than 100 faculty members and students from both universities.

An opening address was given by Philip Guildford, Chief Operating Officer of the Department of Engineering. He noted that Cambridge's Department of Engineering was created in 1875 and Tokyo TECH originated just six years later in 1881 – they were born when engineering emerged from the Industrial Revolution as an academic discipline. Professor James Alfred Ewing worked in Tokyo from 1878 to 1882, teaching engineering and undertaking research, before he returned to the UK to become the Head of Engineering at Cambridge. The bond between engineering in Tokyo and Cambridge has been strong throughout this history and continues to the present day.

Also giving an opening address was Professor Hidetoshi Sekiguchi, Dean of the School of Materials and Chemical Technology at Tokyo TECH, who echoed the importance of the ongoing relationship and the potential for its future.

There were SERP presentations from Tokyo TECH students who studied abroad at Cambridge last summer. They included:

Naoki Tano, Master's student, who visited Professor Iida's Bio-Inspired Robotics Lab (BIRL).

He shared details of his research looking at soft robotics, particularly the "relationship between deformable mesh structure and sensitivity in gelatin strain sensors".

Naoki said: "I worked on the morphology of flexible strain sensors for soft robot applications. It was a valuable experience for me to be able to devote three months to my research with colleagues from different backgrounds, who are outstanding in their research. If you have any doubts about studying abroad, I encourage you to take the first step and challenge yourself."

Touta Kobayashi, Master's student, who visited Professor Nedunchezhian Swaminathan's lab in the Department's Division of Energy, Fluids and Turbomachinery.

He shared details of his research on machine learning for fluid dynamics.

Touta said: "Fluid flow simulation using machine learning is important and it is widely used to help reduce development costs and improve equipment efficiency. In Professor Swaminathan's lab, I have researched a data augmentation method suitable for predicting physical phenomena to obtain a wide range of training data. I believe that this will lead to highly accurate simulations that can be adapted under a wide range of conditions. During this study abroad programme, I was able to broaden my international perspective by interacting with fabulous students and conduct research activities under the guidance of my host supervisor. I feel that it has greatly changed the range of my career considerations."

Yoshiki Kawai, Master's student, who visited Professor Tawfique Hasan's NanoEngineering Research Group at the Cambridge Graphene Centre.

He shared details of his research on "nanotechnology collaboration – nanofibers and graphene".

Yoshiki said: "Since I have been working on one-dimensional (1D) nanomaterials in Professor Matsumoto's laboratory at Tokyo TECH, I decided to study abroad and join Professor Hasan's group due to my research interest of 2D nanomaterials. While in his group, I tried to fabricate ambient-dried 3D printed graphene oxide aerogels. This research field has huge potential for paving the way for designing many types of new energy devices such as supercapacitors and batteries using these aerogels as the electrode materials. Overall, I was pleased to work in a different research field and discuss the results with excellent researchers. This research experience has broadened my knowledge and given me a global perspective."

Summing up the workshop, Professor Fumiya Ida said: "Every year, Tokyo TECH supports its postgraduate students for a three-month research visit to Cambridge, benefiting not only the visiting students themselves, but also the research labs in Cambridge. The Tokyo TECH students are highly trained and skilled due to the education system in Japan, which offers longer research experiences at Bachelor's and Master's degree level than in the UK.

"This exchange opportunity allows us to run research projects, often leading to impressive outcomes, such as technical publications achieved during the three-month period of the student's visit. Many Cambridge academics and students expressed their interest in visiting Tokyo TECH to help strengthen Cambridge's collaborative contributions there."

Honours, awards and prizes

The Princess Royal Silver Medal

Alumna Heba Bevan OBE, CEO and founder of UtterBerry Ltd – a patented, wireless sensor system that consists of a collection of miniature, artificially intelligent, ultra-low-power sensors – has been presented with The Princess Royal Silver Medal.

It is one of the Royal Academy of Engineering's most prestigious individual awards and celebrates an outstanding personal contribution made to UK engineering by an early- to mid-career engineer resulting in market exploitation. UtterBerry Ltd's technology has been used in a variety of major national infrastructure projects, including London's Crossrail and Thames Tideway.

New RAEng Fellows

Professors Mark Girolami and Epaminondas Mastorakos have been announced as Fellows of the Royal Academy of Engineering (RAEng) in recognition of their outstanding and continuing contributions to the profession.

Professor Girolami (pictured right) is a globally-renowned and inspirational research leader whose expertise uniquely spans the main data science and AI disciplines of computing science, statistical science, applied mathematics, and engineering.

Professor Mastorakos's research aims to provide theories and background knowledge for combustion physics, with a focus on how flames behave in gas turbines and diesel engines.

Philip Leverhulme Prize winner

Professor John Orr has been announced as a winner of the 2022 Philip Leverhulme Prize, securing £100,000 to advance his research in the field of construction and structural engineering. He will specifically use the prize money to continue his work on reducing whole life embodied carbon of built assets in support of the UK's net zero carbon ambitions.

The Prize, awarded by the Leverhulme Trust, will build on the outputs of Professor Orr's recent research projects, including the UKRI-funded Automating Concrete Construction (ACORN) and the EPSRC-funded Minimising Energy in Construction (MEICON).

Professor elected IFAC Fellow

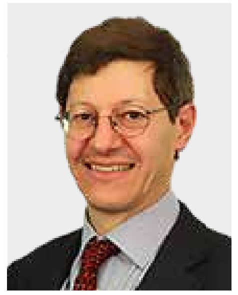
Professor Malcolm Smith has been elected to a Fellowship of the International Federation of Automatic Control (IFAC) *"for contributions to robust control and network synthesis and for the invention, development, and application of the inerter"*.

His election brings the number of IFAC Fellows in the Cambridge Control Group to four, alongside Keith Glover, Jan Maciejowski and Rodolphe Sepulchre.

Enrichment Placement Award

PhD student Maximilian Elsen has been granted a place on The Alan Turing Institute's 2022/23 Enrichment scheme. His research focuses on the identification and classification of climate change mitigation technologies from patent data.

Maximilian, who is from the Institute for Manufacturing (IfM), part of the Department of Engineering, joins 43 new Enrichment Placement students from a wide range of disciplines. He has secured a nine-month Enrichment Placement Award at the Turing's headquarters in London. There he will explore green technologies based on patented inventions.



Presidential Prize

The Centre for Sustainable Road Freight has won the inaugural IEEE ITSS Presidential Prize for Sustainability in Transportation.

The Centre, a collaboration between Cambridge, Heriot-Watt and Westminster Universities and a consortium of industry partners, has been recognised *"for its multinational, multistakeholder, multidisciplinary, high-impact research into decarbonising road-freight"*.

Professor David Cebon, Director of the Centre (pictured), said: "It is a great honour to receive this important award from the IEEE. It was only possible because of the sustained effort, innovation and teamwork of the academics, researchers, students and industrial partners in the Centre for Sustainable Road Freight."

→ Cambridge bakery Fitzbillies

Credit: Sam A. Harris

The Students, The Bakers, The Chelsea Bun Makers...

Despite a few challenging years as a result of COVID-19, 100-year-old Cambridge bakery Fitzbillies has emerged triumphant, with the help and insights of a group of Institute for Manufacturing (IfM) students.

Current owners Alison Wright and Tim Hayward (who relaunched the bakery in 2011 after it closed as a result of bankruptcy) manage the business, which consists of a café behind the cake shop in Trumpington St, a second branch in Bridge St and a larger off-site bakery.

However, the COVID-19 pandemic threw the bakery an unexpected curveball, abruptly forcing the shop and cafés to close and leaving the team with no choice but to reconsider the way they did business.

Armed with a newly improved website, some unexpected thinking time and a renewed focus and desire to see online offerings grow, Alison was delighted when IfM Industrial Tutor Vanessa McNiven contacted her to ask if she would consider having a group of Industrial Systems, Manufacture and Management (ISMM) students come to Fitzbillies for their industrial placement.

Every year, 40 students from across the globe complete the MPhil which is a one-year postgraduate programme designed to help prepare students for careers in industry.

Two groups of students from the 2021-22 cohort were placed at Fitzbillies – an unlikely choice, perhaps, for an industrial placement, given the bakery's size and lack of 'traditional' manufacturing processes.

However, the ISMM focuses on the entire value chain of manufacturing, not just production; and smaller-sized businesses like Fitzbillies can provide just as much value to students as would larger factory-based settings.

Sales up by 30%

The first group of ISMM students were tasked with helping Fitzbillies to explore the value of their online potential, something that Alison knew was needed but simply hadn't had the luxury to devote proper headspace to.

Student Hassan Yusuf explains how the students encouraged the bakery to have a complete rethink about the way their website was structured:

"We did a survey, and the majority of customers (67%) weren't aware Fitzbillies even had an online store, so our first task was increasing awareness of this. We also encouraged the bakery to flip their website, so the focus was on their online product offerings. We also suggested that they make much more use of the shopping features of their social media accounts, and we identified Cambridge alumni as a key new audience for them to market to."

Alison said: "The students pointed out to us that our website positioned us as mainly two cafés in Cambridge, with an online shop function attached, so it was all pretty much oriented to the café (opening times, menus, etc). Flipping it around has been transformational. It was a real light-bulb moment for us."

Alison explains how, thanks to these changes, as well as a social media revamp and an advert taken out in the alumni magazine, *CAM*, online product sales grew by 30%:

"We have achieved much more than we ever would have done under our own steam. It has given us a new focus and a new lease of life when we really needed it."

A few months later, students Ben Purkis and Mark Taylor were tasked with improving suspected day-to-day inefficiencies, sourcing as much information as possible about the operational setup, as well as doing number-crunching.

By using a string model to measure exactly how far someone had to walk to make an item, they then created a Lego model of how the bakery could potentially be reorganised to optimise performance. A new product-pricing model identified products that could be wound out of production (which helped increase manufacturing efficiency as well as profitability), and by developing an econometric forecasting model to help the bakery cope with busier periods they helped the business to cut waste.

Alison said: "We have reorganised the bakery, implemented a newly reviewed pricing model and are using the extremely accurate forecasting model. The students have helped us to transform our online business."

Read the full story at:
www.ifm.eng.cam.ac.uk

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