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# DEPARTMENT OF ENGINEERING NEWS



UNIVERSITY OF CAMBRIDGE

# In this issue



Cover image: Guy Martin on site at the Wall of Death where he attempted to break a world speed record live on Channel 4. Credit: Ryan McNamara/Channel 4


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# Welcome

**The upcoming book by Haroon Ahmed, *Cambridge Engineering: The First 150 Years*, is nearing completion. Spanning the breadth of research and the history of the Department and looking toward the future, the book commemorates the achievements of all of the notable figures who have studied, researched and worked in Cambridge to advance the field of engineering.**

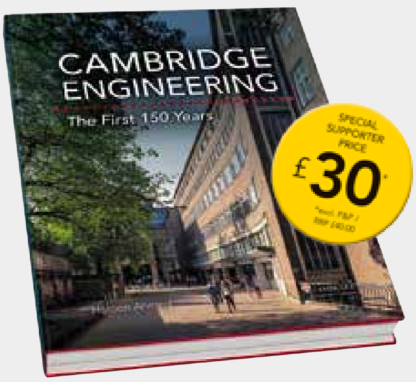
Turning through the pages of the book, I was struck by the many contrasts and parallels I find between the current Department and its history. We have always emphasised greatness, of course, but it's clear that our focus on excellence won't slow down any time soon!

A very striking contrast is seeing the increasing diversity of the students and researchers as we move through history. There is a photograph of a large classroom here in the Department, taken in the 1920s, with only three female students grouped together at the front; the remainder of the 100 or so students were all male. Our current undergraduate intake includes 28% women, which is a great improvement, even though we still have some way to go.

The Department's Women in Engineering initiative has grown substantially, conducting frequent outreach events and lectures within the Department. This newsletter highlights this initiative – in an interview with Dr Jenni Sidey, a recently appointed University Lecturer, on page 10 and a recap of a poster competition to raise awareness of women engineers on page 11.

As you read through this edition of the newsletter, I invite you to consider supporting the Department with your preorder of the *Cambridge Engineering book*. More than 600 people have already preordered and will have their names (or someone of their choice) printed in the List of Supporters.

**Professor David Cardwell FREng**




## Cambridge Engineering The First 150 Years

Preorder the book today to save £10 on the published price. Until 30 November 2016, you may have your name (or a name nominated by you) printed in the book as an enduring record of your links with Cambridge Engineering.

### How to preorder

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Ryan McNamara/Channel 4

# Science behind remarkable new Wall of Death motorcycle world record

**Dr Hugh Hunt, Reader in Engineering Dynamics and Vibration, writes about his experiences consulting for a Channel 4 programme about the infamous Wall of Death in *The Conversation*.**

The Wall of Death has been the most enigmatic dare-devil motorbike stunt for more than 100 years. Motorcyclists ride around the inside of a vertical wall, rather like a huge barrel, at speeds of around 30mph. Most Wall of Death "drums" are about 32 feet (10 metres) in diameter.

It was thought that no one has ever ridden the Wall of Death any faster than 45mph, but during the record attempt, experienced motorcyclist Guy Martin attempted to reach 80mph, a speed which would completely smash existing records. So how did he do? And how on Earth can a motorcycle ride around a vertical wall?

## The G-force awakens

The limiting factor for speed on the Wall of Death is human physiology. When riding the wall, you are subject to high acceleration – or G-force. Under these conditions, blood drains away from your brain and eyes, much as water is flung out of clothes during the spin cycle of a washing machine. It leads to tunnel vision, temporary blindness, difficulty breathing and eventually unconsciousness.

When you're riding the Wall of Death the centrifugal force pushes you outwards and then friction holds you up. Imagine the wall was wet and slippery – you'd slide right down. That's why it was very important that the wall was kept dry and free from dust and drops of oil. Clearly, the wall has to be built indoors and we needed a very big hangar for that.

The training for a high-G environment involves flights in stunt aircraft. During those Guy found himself passing out at around 7G – and it doesn't bear thinking about what would happen if consciousness was lost when riding a motorbike at 80mph on the wall.

## So how fast can you go?

Let's assume that Guy doesn't want to exceed 7G (remember that he'd be experiencing the extreme forces for far longer than someone on a rollercoaster – and having to control a motorbike, too) and that he wants to ride at 80mph. Using Newton's differential calculus, it turns out that the centrifugal G-force increases with the square of your speed and decreases in proportion to the Wall of Death's diameter.

This means, for example, that if you travel at 80mph on a 10-metre wall you'd experience 25G of centrifugal force – certain death. But on a bigger wall, say 40 metres in diameter, you'd experience 6.4G – just about within the physiological limit.

With the maths in mind, a huge Wall of Death was constructed especially for Guy's record attempt. It was 37.5 metres in diameter and quite a dramatic sight. It was constructed out of upturned shipping containers, welded together and lined with timber. A refuge for paramedics was constructed in the centre so if anything went wrong, medical help could be summoned in a matter of seconds.

Guinness World Records was present to officiate – and required a speed over 60mph in either one of two attempts. In his first attempt, Guy achieved 72mph and there was much celebration. But during his second attempt (on his own home-made bike), he reached 78mph, smashing his own record.

If anyone is going to break Guy Martin's record of 78mph then they will have to build a wall at least as big as the Lincolnshire one. In training, Guy thinks he once reached a peak of 85mph but he backed off quickly as he was blacking out at this speed. Perhaps on a bigger wall a new record will be set, but building a bigger wall is quite an undertaking. I think the record is safe for a few years.

***Guy Martin's Wall of Death: Live* can be seen on Channel 4's catchup service.**
www.channel4.com/programmes/guy-martins-wall-of-death-live

# Sir James Dyson opens invention powerhouse at the University of Cambridge

Credit: Morgan Sindall

**The engineering hub focuses on advances including smart infrastructure, electric vehicles and efficient internal combustion systems.**

Sir James Dyson opened some of the world's most advanced engineering facilities at the University of Cambridge in May – giving the institution's students and academics the space and means to prototype, invent and collaborate on cutting-edge research.

The development has been funded by an £8m donation from the James Dyson Foundation – the largest gift ever received by the Department.

The Dyson Centre for Engineering Design is the focal point for teaching Cambridge students about the design process, providing specialised printing machinery, scanners, lasers and routers. It provides space for over 1,200 engineers to conduct their project work. An open plan design encourages the sharing of ideas and a collaborative environment. Student led projects housed within the centre include solar powered electric racing cars, vehicles engineered for arctic ice, quad-rotor drones and helium balloon spaceflight systems.

A separate new four-storey building, the James Dyson Building for Engineering, houses postgraduate researchers and supports world leading research in areas including advanced materials, smart infrastructure, electric vehicles and efficient internal combustion systems. A bridge link offers easy access to testing laboratories housing world-class fluid dynamics machinery, aerodynamics equipment and areas for aeroacoustics analysis.

The building itself is as smart as the minds it houses: fibre-optic sensors in the foundation piles, concrete columns and floor sections offer live data, about temperatures and strain – providing a picture of how the building is behaving. The result is a building that's more of a living creature than a passive block of material.

Research undertaken in the hub will build on a rich tradition of invention: Cambridge alumni include internal combustion pioneer Harry Ricardo and jet engine inventor Frank Whittle.

The Department is located at the heart of the Cambridge cluster, Europe's largest technology cluster, which employs around 57,000 people in more than 1,500 technology-based firms, which have combined annual revenue of over £13 billion. Cambridge has created over 1,500 spin-out companies over the last decade, with a 97.4% five year survival rate, compared to 44.6% nationally.

Sir James said: "Developing the intellectual property that will help Britain succeed in the global technology race depends on applying our brightest minds to ambitious and exciting research projects. I'm hopeful that this new space for Britain's best engineers at the University of Cambridge will catalyse great technological breakthroughs that transform how we live".

Vice-Chancellor of the University of Cambridge, Professor Sir Leszek Borysiewicz, said: "The research taking place in this building exists at the very cutting edge of engineering excellence. Allied to new ideas generated within the Dyson Centre, this will produce not only world-changing discoveries and inventions, but the future generations of engineers the world requires to address the major challenges of the 21st century."

Head of the Department of Engineering, Professor David Cardwell, said: "Collaboration is at the heart of solving global engineering challenges and the new James Dyson Building brings brilliant researchers from across disciplines together with industrial practitioners to serve our cities, transportation and energy systems with novel techniques.

"The adjoining Dyson Centre for Engineering Design enables students to express their creative talents and test their engineering skills using high-tech and diverse machining and prototyping equipment. Here we will also welcome schoolchildren to see engineers at work and captivate the next generation of competent engineers. An updated and redesigned Engineering Library will guarantee flexible spaces for collaborative as well as silent work spaces for our students and researchers."

Professor Dame Ann Dowling, President of the Royal Academy of Engineering, said: "Academic rigour must meet with practical invention. The Dyson Engineering Design Centre and the James Dyson Building for Engineering bridge the gap, encouraging engineers to apply their minds to creatively experiment and try new things."

Credit: Shutterstock

# Dreaming big with biomimetics

## Could future buildings be made with bone and eggshells?

**Dr Michelle Oyen, Reader in Bioengineering for the Biomechanics Group, writes for *The Conversation* on how researchers are looking for ways to make new materials inspired by nature.**

In 2007 alone, steel and concrete were each responsible for more $CO_2$ emissions than the entire global aviation industry. Before reaching the construction site, both steel and cement must be processed at very high temperatures – and this takes a lot of energy. So how can we reduce our dependence on these "dirty" materials, when they play such a crucial role in construction?

### Copying life

Could the answer lie in developing new materials that are inspired by nature? This idea started to gain traction in the research community in the 1970s and really exploded in the 1990s, with the development of nanotechnology and nanofabrication methods. Today, it forms the basis of a new field of scientific research: namely, "biomimetics" – literally "copying life".

Biological cells are often referred to as "the building blocks of life", because they are the smallest units of living matter. But to create a multi-cellular organism like you or me, cells must clump together with a support structure to form the biological materials we're made of, tissues such as bone, cartilage, and muscle.

In order to make biomimetic materials, we need to have a deep understanding of how natural materials work. We know that natural materials are also "composites": they are made of multiple different base materials, each with different properties. Composite materials are often lighter than single component materials, such as metals, while still having desirable properties such as stiffness, strength and toughness.

### Making biomimetic materials

Materials engineers have spent decades measuring the composition, structure and properties of natural materials such as bone and eggshell, so we now have a good understanding of their characteristics.

For instance, we know that bone is composed of hydrated protein and mineral, in almost equal proportions. The mineral confers stiffness and hardness, while the protein confers toughness and resistance to fracture. Although bones can break, it is relatively rare, and they have the benefit of being self-healing – another feature that engineers are trying to bring to biomimetic materials.

Like bone, eggshell is a composite material, but it is around 95% mineral and only 5% hydrated protein. Yet even that small amount of protein is enough to make eggshell very tough, considering its thinness – as most breakfast cooks will have noticed. The next challenge is to turn this knowledge into something solid.

There are two ways to mimic natural materials. Either you can mimic the composition of the material itself, or you can copy the process by which the material was made. Since natural materials are made by living creatures, there are no high temperatures involved in either of these methods. As such, biomimetic materials – let's call them "neo-bone" and "neo-eggshell" – take much less energy to produce than steel or concrete.

In the laboratory, we have succeeded in making centimetre-scale samples of neo-bone. We do this by preparing different solutions of protein with the components that make bone mineral. A composite neo-bone material is then deposited from these solutions in a biomimetic manner at body temperature. There is no reason that this process – or an improved, faster version of it – couldn't be scaled up to an industrial level.

Of course, steel and concrete are everywhere, so the way we design and construct buildings is optimised for these materials. To begin using biomimetic materials on a large scale, we'd need to completely rethink our building codes and standards for construction materials. But then, if we want to build future cities in a sustainable way, perhaps a major rethink is exactly what's needed. The science is still in its infancy, but that doesn't mean we can't dream big about the future.

www.eng.cam.ac.uk/profiles/mlo29

➔ The Oatley family in front of the garage


# Student projects find a home as new Oatley Garage opens

**Student projects such as Full Blue Racing and Cambridge University Eco Racing have had to build in any area they could find – with no easy storage solutions for cars between competitions – until a generous donation from the Oatley family provided a dedicated space for these projects.**

The Oatley Projects Garage was officially opened in a ceremony on 15 February by benefactors Geoff and Jean Oatley. Also present were son Joe Oatley, Department of Engineering graduate (1987) and now CEO of Cape plc., international provider of support services to the energy and mineral resources sectors; Joe's wife Jane, graduate of the Department of Veterinary medicine; and several other family members.

The garage's electric door opened to reveal 'Evolution' the Eco Racing Team's solar car, recently returned from the World Solar Challenge in Australia, alongside the Full Blue Racing Team's FBR16 (Formula 1 car). The student team members were able to thank Geoff and Jean personally, and explain how valuable the new garage is to their projects; this is their first ever garage area on site – it will save the project teams huge amounts of time and money.

The Oatley grandchildren Sam, Sophie and Patrick tried out both cars and later built their own mini solar cars in the Dyson Centre for Engineering Design under the supervision of Outreach Officer Maria Kettle.

Several members of the Department of Engineering were present at the opening, including Professor David Cardwell (Head of Department), Mr Philip Guildford (Director of Research), Dr Claire Barlow, Dr David Cole, Dr Paul Heffernan, Dr Richard Roebuck, Dr Hugh Shercliff, Dr Ronan Daly, Dr Simon Guest and Tom Ridgman, as well as representatives from student teams Full Blue Racing and Cambridge University Eco Racing.

"We wanted to thank the Engineering Department at Cambridge for what they did for our son, Joe, setting him on a brilliant career path," said Geoff and Jean. Their gift not only provides for the cutting-edge garage-cum-workshop for student projects but enables the Department's outreach work with the local community.

The Department of Engineering hosts or is associated with a number of student-led societies in addition to Full Blue and Eco Racing, such as Cambridge University Spaceflight, the Cambridge Autonomous Underwater Vehicle Team, Engineers Without Borders, the ecohouse initiative, Cambridge University Autonomous Flight and Cambridge University Entrepreneurs. More information about the Department's student-led societies can be found at the URL below.

> "We wanted to thank the Engineering Department at Cambridge for what they did for our son, Joe, setting him on a brilliant career path.
>
> Geoff and Jean Oatley

➔ teaching.eng.cam.ac.uk/content/student-led-societies

**Photo gallery of the opening of the Oatley Projects Garage at:**
www.flickr.com/photos/cambridgeuniversity-engineering/albums/72157663344154403


ALUMNI UPDATE

# PhD student Sakthy Selvakumaran is on the Forbes 30 under 30 list

**PhD student Sakthy Selvakumaran, a Chartered Civil Engineer, is on the Forbes 30 under 30 list Europe 2016.**

The Forbes inaugural 30 Under 30 Europe list looks at the brightest and most talented under-30-year-olds who are already shining in their chosen career and changing our world.

Sakthy, at the time of being shortlisted, was an Innovation Engineer with civil engineering contractor Laing O'Rourke. Laing O'Rourke and National Physical Laboratory are currently sponsoring her to do an Industrial Case PhD at the Department. During her time at Laing O'Rourke, Sakthy was in the Engineering Excellence Group, and spent time on site helping to deliver the ExCeL Footbridge. She previously worked on the project leading on its design in her role as a Design Engineer for Ramboll.

She developed and ran an education initiative with Serious About Youth (SAY) called 'Construkt' on behalf of Institution of Civil Engineers (ICE) who founded this scheme. She is now influential in the further development of the scheme to enable young people to better understand different career pathways, and is engaging with additional companies and institutions to encourage them to become involved.

Sakthy is pleased at the recognition that becoming chartered has meant for her saying: "I'm proud to be a Chartered Civil Engineer. It recognises that you have reached a marker in your career that indicates that your peers in the wider profession trust you to act as a professional engineer, to represent the profession. It's by no means a mark that states that you've learned all you need to know about being a Civil Engineer, but I like that because it means that you're always learning new things and coming with new ideas."

Sakthy says she's still not sure who put her name forward and only found out she had been nominated when someone contacted her on behalf of Forbes to say that she had been shortlisted. As part of becoming one of the '30 under 30' she has been invited to a Summit in April along with other members on the list.

A keen writer on her experiences, she has written articles in a several magazines and also has a blog slot for the Huffington Post.

Sakthy graduated with an engineering degree from the Department (2006-2010) and has since worked as a civil and structural engineer in design consultancy and contracting applications across multiple roles and countries (including UK, Canada, Sri Lanka, Peru and Spain). Significant projects include the design and construction of ExCeL Bridge, (a 34 metre long bridge installed as part of the construction of the new Crossrail station at Custom House, linking the station with ExCeL London), inspection design and assessment of various rail bridges owned by Network Rail, the design of various UK highway bridges and civil infrastructure, and the design of a tunnel and approach structures in Gibraltar. In 2013 she was asked to join the Engineering Excellence Group of Laing O'Rourke, working on developing new design solutions and technologies to change the way infrastructure is designed, constructed and maintained. She re-joined the Department in 2015 to undertake a PhD in Engineering.

> I'm proud to be a Chartered Civil Engineer. It recognises that you have reached a marker in your career that indicates that your peers in the wider profession trust you to act as a professional engineer, to represent the profession.
>
> Sakthy Selvakumaran

www.eng.cam.ac.uk/profiles/ss683
www.huffingtonpost.co.uk/sakthy-selvakumaran
www.say-youth.org/home


Credit: Iwan Baan

# Venice Architecture Biennale 2016

**Entitled 'Reporting From The Front', the Venice Architecture Biennale 2016 is intended by director Alejandro Aravena to offer a new perspective on global issues.**

Dr Matthew DeJong and his research group are involved in two projects that are exhibited at the Venice Biennale from 28 May to 27 November, 2016. One is entitled 'Beyond Bending', which uses various visual and constructed elements to advocate for the logic of compression-only forms, not only because of their uniquely expressive aesthetics but also because of their potential to achieve efficiency and stability while reducing material waste. The other project is entitled 'Droneport', a full-scale masonry shell prototype to highlight one module of the larger Droneport project in Africa, an initiative which seeks to create a network of drones to transport essential items to areas that lack access to roads.

### 'Beyond Bending' – Learning from the past to design a better future

"Beyond Bending' is a joint project led by the Block Research Group at ETH Zurich in collaboration with Professor John Ochsendorf at MIT, Dr Matthew DeJong at the University of Cambridge, and with The Escobedo Group.

The exhibition takes inspiration from master builders who have discovered expressive forms through the constraints of economy, efficiency and elegance, not in spite of them. For example, the fan vaults of King's College Chapel were constructed of unreinforced stone just over 500 years ago. They span 12.7 m with complex curvature and a minimum thickness of only 10 cm. Though the stone vaults are cracked in places, they have stood through the centuries without steel reinforcement.

Building on this tradition, the project team has developed new computational tools and expertise, and makes use of advancing technology, to push the boundaries of compression-only forms. Within the exhibition, two smaller prototype structures aim to show how traditional floor systems made from tile masonry are extremely structurally efficient, and how these floor systems could be reimagined with 3D printed unreinforced concrete that saves 70% of the material compared to typical concrete floor slabs. Meanwhile, a third structure, the Armadillo Vault, stretches the imagination of what is possible with unreinforced dry-stone construction. The vault has a minimum thickness of 5 cm, with a maximum span of approximately 16 metres. Novel computational form-finding techniques developed by the Block Research Group enabled the geometry, while Dr DeJong and PhD student Anjali Mehrotra played an important role in the engineering design through computational modelling. Construction of the shell was made possible by The Escobedo Group, modern-day master masons based in Texas, USA.

### 'Droneport'

The Droneport prototype, a full-scale earthen masonry shell that has been built on site, exemplifies one module of the future Droneport project in Africa. The Droneport project is led by the Norman Foster Foundation, while the prototype shell was designed in collaboration with Foster + Partners, Ochsendorf, DeJong & Block and the Block Research Group, ETH Zurich. The shell was primarily funded by the Lafarge-Holcim foundation.

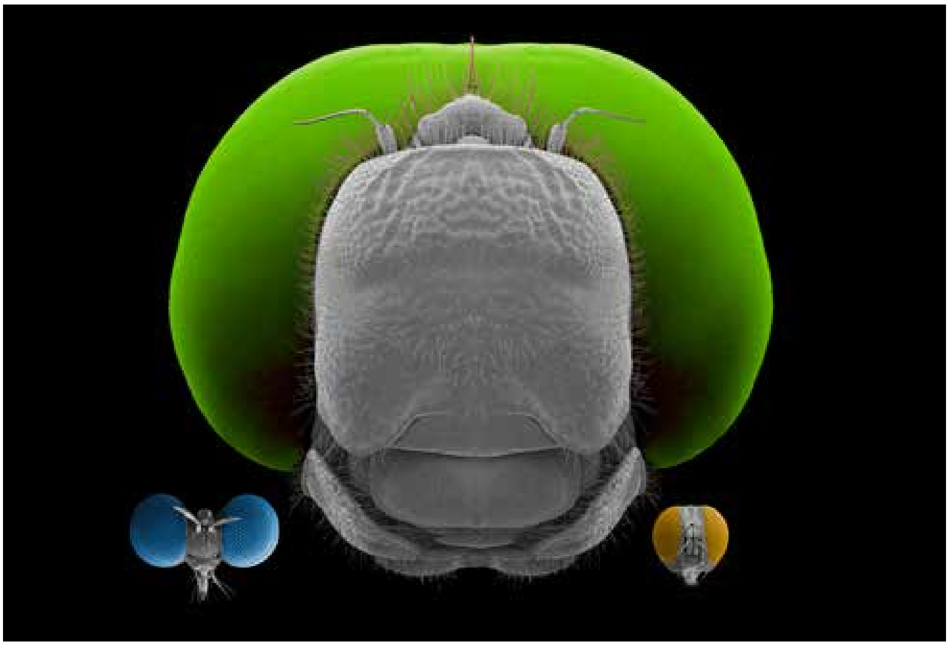
The project aims to create a network of drones to deliver medical supplies and other necessities to areas that are difficult to access due to a lack of roads or other infrastructure. The Droneports will be built not only to act as small airports for the drones but also as civic buildings, fulfilling important social and cultural roles in the communities. The ambition is that every small town in Africa and in other emerging economies will have its own Droneport by 2030.

The prototype presented at the Venice Biennale is a first iteration to test the key engineering and architectural elements of such a building. The essential characteristic of the tile vault is again an efficient structural form to minimise materials. However, the efficient design also enables the structure to be built without formwork. Only fibre-glass splines are used to guide the mason; the structure is self-supporting during the entire construction process, which minimises costs.

> I am very excited to be involved in these projects that apply years of research to tackle engineering challenges.
>
> Matthew DeJong

www.eng.cam.ac.uk/profiles/mjd97

➔ A dragonfly has a larger brain than a robber fly or a killer fly, but what are the trade-offs?



Credit: Sam Fabian

# Think small

# **Diminishing returns in neuroscience**

**Cambridge researchers are studying what makes a brain efficient and how that affects behaviour in insects – including the aptly named killer fly.**

As in economics, there is a law of diminishing returns in neuroscience – doubling the investment going in doesn't equal double the performance coming out. With a bigger brain comes more available resources that can be allocated to certain tasks, but everything has a cost, and evolution weighs the costs against the benefits in order to make the most efficient system.

"Larger brains are specialised for high performance, so there's a definite advantage to being bigger and better," says Professor Simon Laughlin of the Department of Zoology, whose research looks at the cellular costs associated with various neural tasks. "But since most animals actually have very small brains, there must also be advantages to being small."

So does size matter? "When an animal is limited, is it because their neural system just can't cope? Or is it because they're actually optimised for their particular environment?" asks Dr Paloma Gonzalez-Bellido from the Department of Physiology, Development and Neuroscience.

Dragonflies are among the largest flying insects and hunt smaller insects such as mosquitoes while patrolling their territories. They have changed remarkably little in the 300 million years since they evolved – most likely because they are so well optimised for their particular environmental niche. "Other researchers have found that dragonflies are capable of doing complex things like internally predicting what their body is going to do and compensating for that – for instance, if they're chasing a target and turn their wings, another signal will be sent to turn their head, so that the target stays in the same spot in their visual field," says Gonzalez-Bellido.

Gonzalez-Bellido also studies the killer fly, or *Coenosia attenuata*. These quick and ruthless flies are about four millimetres long, and will go after anything they think they can catch – picky eaters they are not. However, the decision to go after their next meal is not as simple as taking off after whatever tasty-looking morsels happen to fly by. As soon as a killer fly takes off after its potential prey, it exposes itself and runs the risk of becoming a meal for another killer fly.

To help these predacious and cannibalistic flies eat (and prevent them from being eaten), they need to fly fast and to see fast. Insects see at speeds much higher than most other animals, but even for insects, killer flies and dragonflies see incredibly fast, at rates as high as 360 hertz (Hz) – as a comparison, humans see at around 60 Hz.

By making the 'pixels' on their photoreceptors (the light-sensitive cells in the retina) as narrow as possible, killer flies trade sensitivity for resolution. In bright light, they see better than their similar-sized prey, the common fruit fly. However, the cap on sensitivity and resolution imposed upon killer flies by their tiny eyes means that they can only see and attack things that fly close by.

In the early 2000s, Laughlin determined the energy efficiency of single neurons, by estimating the numbers of ATP molecules – the molecules that deliver energy in cells – used per bit of information coded. To do this he compared photoreceptors in various insects. Laughlin and his colleagues found that photoreceptors are like cars – the higher the performance, the more energy they require, and costs rise out of proportion with performance.

### Engineering an optimal system

Researchers in the Department of Engineering are taking the reverse approach to answer questions about how the brain works so efficiently by looking at systems from the top down. "If you reverse engineer an animal's behavioural strategy by asking how an animal would solve a task under specific constraints and then work out the optimal solution, you'll find it's often the case that animals are pretty close to optimal," says Dr Guillaume Hennequin, who looks at how neurons work together to produce behaviour.

Hennequin studies how brain circuits are wired in such a way that they become optimised for a task: how primates such as monkeys are able to estimate the direction of a moving object, for example. "How brain circuits generate optimal interpretations of ambiguous information received from imperfect sensors is still not known," he says. "Coping with uncertainty is one of the core challenges that brains must confront."

Different animals come up with their own solutions. Both dragonflies and killer flies have systems that are optimal, but optimal in their own ways. It's beneficial for killer flies to be so small, since this gives them high manoeuvrability. Dragonflies can do things that killer flies can't, but their size means they can't turn or stop on a dime, like a killer fly can.

"By answering some of the questions around efficiency in brain circuits, large or small, we may be able to understand fundamental principles about how brains work and how they evolved," says Laughlin.

➔ www.eng.cam.ac.uk/profiles/gjeh2

# Women in Engineering

## An interview with Dr Jenni Sidey

**Dr Jenni Sidey spoke with the Women in Engineering team about her career and her future. Since this article's original publication, Jenni has been appointed University Lecturer in Internal Combustion Engines for the Energy Group.**

### How did you get into Engineering?

At school I was always interested in the sciences, particularly maths and physics. I enrolled in the Mechanical Engineering course at McGill University and had a wonderful thermodynamics instructor. I did an honours project on alternative energy in his lab, which stemmed into an interest in combustion research.

### What are you doing now and what are your plans for the future?

I came to the University of Cambridge in 2011, working towards a PhD with Professor Nondas Mastorakos. I am now a Research Associate in Experimental Turbulent Combustion and Nondas acts as my Principal Investigator. I am currently applying for various academic positions, hoping to continue a career in research and teaching. Although my research takes priority, I'm finding that it's important to consider the level of support offered to female academics in engineering at each institution I apply to.

### What motivates you?

I love teaching and have particularly enjoyed the outreach work I have had the privilege of being involved in during my time in Cambridge. After the first year of my PhD, I realised that I hadn't done much outreach work since leaving McGill. I was encouraged by Maria Kettle, the Department's outreach officer, and Dr Michelle Oyen to help start Cambridge Robogals. Robogals is an international, not-for-profit, student-run organisation that aims to increase female participation in Engineering, Science, and Technology through fun and educational initiatives aimed at girls in primary and secondary school. I worked with two undergraduates, Ester Sidebottom and Carly Brooker. Together we organised and ran a number of local events www.eng.cam.ac.uk/news/robogals and were invited to help out with the BBC Make it Digital Campaign in the summer of 2015. We ran events around the UK with the BBC team, teaching people of all ages how to program.

Ester is now in the final year of her degree in the Department of Engineering and is running regular Robogals events, including two family workshops during the Cambridge Science Week.

### What has helped your career – fellowships, support from the Department, inspirational teachers and colleagues?

I'm fortunate to have had excellent supervisors who have always been extremely supportive. They have helped me to build a network of female engineers both within the Department and in our greater field of research. Women within the Department, including Professor Ann Dowling, have taken the time to give me advice about an interviews and job prospects. When I was preparing for a lecture for my first academic job interview, I received an enormous amount of support and feedback from both my supervisor and other professors in my division.

### How have you overcome challenges and knockbacks in your career?

Women are still under-represented in engineering, so without a good support network, it can be quite isolating. Although the Engineering Department is generally very supportive  I occasionally come across negative or misogynistic comments or more subtle forms of sexism. In order to try and improve things, I strive to be honest about these attitudes to facilitate discussions on these topics. We must talk about things if we want to encourage other women to enter and stay invested in engineering fields. Two years ago, I joined the Department's Athena Swan Committee to try and encourage and participate in such discussions.

### How have you managed to balance family life and other interests with your career?

Although I've not yet been faced with the task of balancing family responsibilities and my career, the Department has encouraged me to pursue my outreach work and has offered flexibility whenever I've needed it.

### Do you have any role models?

Absolutely – Jackie Chen is certainly a role model of mine. She is a phenomenal combustion scientist at Sandia National Labs in California. She is confident and incredibly accomplished.

### Do you have any advice for women who are considering pursuing a career in Engineering?

My advice is to seek out supportive people who trust in you and your abilities, which should come solely from the value of your work. This solid backing of friends and colleagues will allow you to pursue whatever career you may want to achieve.

www.eng.cam.ac.uk/profiles/jams4
www.robogals.org
www.facebook.com/CambsRobogals


# Women in engineering celebrated with inaugural competition

**The Inspirational Women Engineers competition celebrating women in the field was held at the Department of Engineering. The winners were announced at an event during a lunchtime champagne reception.**

The competition was run by the Athena Swan team in order to raise awareness of the many amazing women engineers, past and present, and to help inspire others to pursue study and careers in engineering. Nearly all the engineering portraits that hang around the Department of Engineering are of male engineers; displaying the winning entries will help to redress the balance and counteract the 'stereotype threat' effect for the many women now studying and working in the department.

The competition attracted 60 nominations of women from all over the world and all engineering disciplines – from over 2000 years ago up to the very current achievements of Department of Engineering alumna Ruth Buscombe. Ineligible for nomination were women currently working or studying in the department, as this would have made judging an impossible task.

The quality of entries was excellent, and with so many interesting stories the judging panel found their task very difficult. After some discussion, first prize was awarded to Vere Whittome for his nomination of Margaret Hamilton.

Using one of the first chip-based computers with only 64k of memory, Margaret successfully wrote the code which enabled humans to land on the moon. Through her scientific papers and the work of the company she later founded she also made important contributions to ideas about fault-tolerance and reliability.

Vere, an undergraduate engineer in the Department, was presented with his prize of an iPad by Professor Dame Ann Dowling, who also presented gift tokens for chocolate to the twenty runners up. Dame Ann, former Head of Department and Professor in the Energy, Fluid Mechanics and Turbomachinery division, now serves as President of the Royal Academy of Engineering.

The winning and shortlisted entries (a short bio, a photo of the engineer and the reasons for nominating them) have been produced as posters and are on display in the Engineering Library. After the initial display, the posters will be framed and shown around the Department's various buildings. The 60 total entries have also been bound together in a booklet which is available at the link below.

There is already interest in running the competition again, and the hope is this will become an annual event.

> The quality of entries was excellent, and with so many interesting stories the judging panel found their task very difficult.

**To complement the competition posters we are currently seeking profiles of women engineers (staff, students and alumna) of the Department, to inspire potential women applicants by showing that women are forging successful paths in all branches of engineering and at every level. If you are interested in providing a profile (see the link below) or wish to know more, please email Madeline McKerchar at mjm61@cam.ac.uk.**

**www-womeninengineering.eng.cam.ac.uk/inspiring/index**

**The booklet of entries is available online at**
www-womeninengineering.eng.cam.ac.uk/news/compbooklet

# Institute for Manufacturing
## Design Show 2016

The Manufacturing Engineering Tripos (MET) provides engineering students with the management competence, business acumen and interpersonal and organisational skills they need to become world-class leaders.

Over the last year, teams of three or four MET students have completed a major design project to develop a new product with real business potential. Having first identified a customer need, they have researched the market, developed original design concepts and created a full business plan. The projects have generated some exciting new ideas and innovative technology.

### BrekTech Wafflestation

**The BrekTech Wafflestation is a revolutionary continuous flow waffle production device for commercial use, with potential industrial scalability options.**

Aimed at small to medium-scale commercial catering, the Wafflestation enables a less laborious continuous approach to waffle production. The team identified an opportunity to challenge the existing standards of the traditional waffle iron that is currently used for both home and mass production – and introduce an automated solution for smaller firms that would not have previously considered this approach.

The Wafflestation's core competency revolves around its two counter rotating silicon belts. The belts both support and shape the batter throughout the cooking process. Batter is dispensed from a hopper at a carefully controlled rate before being conveyed through the heating chamber.

### Crispeasy

**Crispeasy is a compact appliance that produces delicious spiral potato crisps in the comfort of your own home. The powerful oven and automated slicing system make baking crisps easier than ever.**

Crispeasy offers a fast and simple solution. The machine uses an automated slicing system that cuts half a potato at a time into a spiral. The spiral then moves into a powerful oven powered by four heating elements, which allows the process to be completed in under 15 minutes. The oven also contains a pump-powered oiling system that aims to balance the healthiness and crispiness of the snack.

↑ Bottle Brick

### AdaptaMould

**AdaptaMould is an innovative way to rapidly create moulds for use in vacuum forming. The system uses a series of pins, electro-mechanically controlled to create the desired shape.**

3D printing is bringing rapid prototyping to the mass market. Vacuum forming, where a sheet of heated plastic is pulled down over a mould and then a vacuum applied to produce a shaped plastic piece is not as quick or easy as 3D printing. The process of creating the mould can take up to a week, as they are normally made from wood and require careful sanding to make the correct shape. The team aimed to greatly increase the speed of this process.

The concept of AdaptaMould is to feed a CAD model into our product, which will then create a vacuum forming mould within minutes.

### BRICK-E

**BRICK-E is a robot designed to reduce the skilled labour requirement in brick laying. With this semi-automated device, unskilled workers can construct brick walls autonomously at low cost. Unlike existing brick laying robots, BRICK-E completes all tasks required to build a straight wall by travelling on top of the wall. This allows it to be cheaper, lighter and more compact.**

In the UK, there is expected to be a shortage of 244,000 brick layers by 2020. In Australia, the shortage has driven up the cost of labour to an average of $100,000 a year. Using BRICK-E to replace a skilled worker with an unskilled worker, even at current wages, will result in substantial cost-savings.

The robot will lay both cement and bricks requiring the worker to simply perform a set up and feed supplies. At a length of 80cm and weighing less than 25kg, a single worker can position BRICK-E with ease. By using a unique spacing structure, BRICK-E is able to bypass the traditional constraints on build speed imposed by cement drying. Carrying the load through the spacers rather than the cement, a given construction project can progress at a rate much beyond the typical 6 rows per day. As such, not only will it be cheaper, but also faster than relying on traditional work methods.

### PolyPack

**PolyPack is an innovative solution to creating beautiful, sturdy and environmentally sustainable packaging. The packaging consists of a soft fibrous**

↑ BRICK-E


↑ PolyPack

**interior transitioning to a hard plastic shell to provide twofold protection.**

PolyPack currently uses shredded PET – sourced from plastic bottles – as a raw material with which to create this pioneering packaging product, but could potentially use other plastics.

The method involves two processes to transform shredded PET to fibres to packaging. The initial process – inspired by candy floss machines – heats a spinning bowl and softens the shredded plastic to be forced through a row of holes. This creates fibres that offer impact resistance and thermal insulation. The secondary process involves filling a heated mould with the candyfloss like material. With careful control of process parameters a hard outer shell is produced with an optimum thickness to balance the requirements of structural rigidity and finish against those of efficient material use and interior cushioning.

## Paperbot

**Paperbot is a unique new take on the paper mache formula. It aims to layer newspaper and glue on a rotating mould to build up a product, such as a lampshade. Paper mache is usually a messy and time consuming process, but with this machine the process can be dramatically improved, particularly for large scales.**

Paper has been around for over 2000 years and is amazing material but it consumes trees that we cannot afford to lose. So we must recycle it but, unfortunately, after 4-6 times the fibres become too short or weak and the paper quality goes down. Upcycling is a popular new concept employed by Paperbot to make a valuable and lasting product by reusing paper without having to break down the fibres again.

The Paperbot machine begins with a hopper of paper and a reservoir of glue. Using a motor, gravity glue is applied to the paper and dropped on to a mould. An innovative positioning system is at the heart of the system that moves the glue feeder back and forth along the mould.

## Bottle Brick

**Bottle Brick – a small-scale community PET bottle recycling solution. It recycles and reforms waste plastic bottles into building bricks for the developing world, eliminating use of concrete and reducing landfill waste.**

Bottle Brick introduces a novel process of reforming a waste PET drinks bottle into a stackable, interlocking, tessellating shape which may be used as a structural brick. The team identified an existing practice in some developing countries such as Nicaragua and Nigeria whereby bottles are removed from local landfill sites, filled with mud and stacked as building blocks, held together with mortar. The result is a robust housing structure. Having seen this they questioned how the process might be improved. The team set themselves the challenge of making this production process cheaper, easier and even more environmentally friendly. The existing 'bottle wall' requires at least 25% concrete in volume. Not only is concrete expensive, it is non-renewable, non-recyclable and its manufacture contributes to 5% of global $CO_2$ emissions. And so we sought to minimise or eliminate the use of concrete.

The team have developed a vessel for the process of heating and blow moulding a bottle at 14 bar through manual labour with the use of a bicycle pump and then cooling the bottle. The output is a well-defined, intricate brick which successfully stacks in a honeycomb formation, significantly reducing the required volume of concrete. The working prototype successfully provides 'proof of concept' and is designed to be easily scalable in order to produce bottles in larger quantities. The rate of production of one bottle is 6 minutes. Scaling to 10 units would allow a rate of production of 100 bottles per hour.

The organisation would be run as a not-for-profit social enterprise, distributing this product through existing charitable organisations to areas which may benefit from this practice. To our knowledge there is currently no other company which recycles bottles by directly re-blow-moulding them.

## Fruiticle

**Fruiticle manufactures customisable icicles to be used as drinks coolers in high-end cocktail bars.**

The user can create straight or 'wavy' icicles from a piece of fruit at its core, and place the icicle directly into the customer's glass. The cocktail market is predicted to grow by 50% between 2013 and 2017, and is being guided by the desire for cocktails to be 'instagrammable', with cocktail bars focusing more attention on presentation. The product is automatic, self-contained, and easy to use. It consists of two conjoined units: a freezer section where the icicles are grown, and a fridge section where the water is kept cool. The skewered fruit is placed in the freezer across a rack, which can be rotated to create curves in the growing icicles. The rotation is controlled by a stepper motor in a pre-programmed cycle. Water for the icicle is delivered via a feed system designed for the optimum drip rate for icicle formation.

## Rotoform

**Rotoform uses an innovative rotational moulding machine to produce hollow fibreboard products from a sawdust mixture. Rotational moulding is widely used in plastic manufacturing, with the ability to form thin hollow products allowing lightweight and novel designs. The team has adapted this technology, using an original machine to maximise spinning speeds.**

Combining this capability with the use of sawdust allows Rotoform to produce a similar range of fantastic products but using eco-friendly fibreboard materials. Using sawdust is part of what makes Rotoform unique. Sawdust is a waste material – 0.4 million tonnes are produced and disposed of every year. Rotoform takes this sawdust and enables the production of eco-friendly products. Achieving the rotational speeds necessary to use the viscous sawdust mixtures was the most significant challenge the team had to overcome. Traditional rotational moulding machines reach rotational speeds of 60 rpm. Rotoform has designed a more rigid machine, which employs powerful motors allowing stable, high speed rotation.

Development of the optimal mixture required lengthy testing, but the ideal ratios of fibres, PVA and water were finally found. This allowed the team to minimise drying times and maximise the strength of the fibreboard.

**Demonstration videos of all of the 2016 Design Show projects can be found on the Department's YouTube channel:**
www.eng.cam.ac.uk/Youtube

➔ Visualisation of Silicon Microgravity's sensing technology in a borehole

# Cambridge spin-out secures $3m to improve oil recovery efficiency

**Silicon MicroGravity (SMG), a newly-formed University of Cambridge spin-out that has developed a novel sensor technology used by oil companies to enhance oil recovery, has received initial funding of $3 million from Imperial Innovations Group plc (AIM: IVO, 'Innovations') and Cambridge Enterprise, the commercialisation arm of the University of Cambridge, together with grant funding from the UK Government.**

SMG's sensors, developed in partnership with BP, are sensitive enough to measure one billionth the level of Earth's gravity and are small and robust enough to be sent deep into boreholes to distinguish oil from water.

Once the position of water is established and tracked, reservoir engineers can mitigate the potentially damaging results of water reaching a production well. SMG estimates that the technology could improve yields on conventional reservoirs by up to 2 percent, representing significant increases in production and revenues.

A team of Cambridge scientists, led by Dr Ashwin Seshia of the Department of Engineering, has been working closely with BP to develop the sensors.

Design work began in 2010 and has resulted in several generations of prototypes providing experimental validation of the underlying device approach. A successful test of the technology was conducted in 2012 prompting BP to fund a follow-on project to address further optimisation and pursue large-scale manufacture of the sensors. SMG was formed in 2014 to accelerate the development of the product and develop a service that can capture and analyse data on behalf of oil companies. The first field trial in a production well is scheduled for 2017.

Innovations led the funding round alongside Cambridge Enterprise, which also invested and licensed the technology to SMG. SMG is also being supported through the Institution of Mechanical Engineers' Stephenson Fund, a private investor, InnovateUK and the Natural Environment Research Council (NERC), which have awarded a substantial grant.

SMG's advisory board includes Kevin Dodds, General Manager of ANLEC in Australia, and Professor Roger Howe from Stanford University.

Dr Ashwin Seshia, co-founder of Silicon Microgravity, said: "The SMG devices advance the frontiers of gravity sensor technology building upon several years of University research and innovation. SMG brings together a leading international team of experts to address the next phase of technology translation and we are looking forward to working collaboratively with our partners to deploy these tools widely."

Paul Vickery, Chairman and co-founder of Silicon Microgravity, said: "I am very excited to form this new company based on a long standing collaboration between Cambridge University and BP. We have created a compelling business plan, raised a sizable initial investment and formed a credible global team to launch the company. I look forward to building a business that can help oil companies enhance oil recovery from their major assets."

Akira Kirton from BP Ventures said: "Water management is an increasingly important issue for BP and the whole industry, so we are excited about the potential for SMG's technology to help us pinpoint where water is within a reservoir and enable us to take mitigating action. This collaboration fits perfectly with BP Ventures' strategy of investing in new technologies that can be rapidly field tested and deployed."

> "
> We are delighted that Dr Seshia's unique technology is being commercialised by SMG. We are very excited by the market opportunity and we are keen to support future progress.
>
> Julian Peck

Stephen Tetlow MBE, Chief Executive of the Institution of Mechanical Engineers, said: "We are excited to be supporting such an exciting and cutting-edge technology. The Institution's Stephenson Fund aims to fulfil the Institution's original purpose to give an impulse to invention and also help companies overcome the investment hurdle between Research and Development and bringing a product to market.

"This innovation could revolutionise oil well recovery and is an example of exactly the sort of innovation we are committed to supporting."

➔ www.eng.cam.ac.uk/profiles/aas41

ALUMNI UPDATE

# Alumna Anya Jones Receives Presidential Early Career Award

**President Barack Obama has named alumna Anya Jones a recipient of the Presidential Early Career Award for Scientists and Engineers (PECASE), the highest honour bestowed by the US Government on science and engineering professionals in the early stages of their independent research careers.**

"These early-career scientists are leading the way in our efforts to confront and understand challenges from climate change to our health and wellness," President Obama said "We congratulate these accomplished individuals and encourage them to continue to serve as an example of the incredible promise and ingenuity of the American people."

Anya, whose PECASE nomination was sponsored by the US Department of Defense, has been a member of the Aerospace Engineering faculty at the University of Maryland since 2010. She earned her doctorate in experimental aerodynamics from the University of Cambridge, her Master of Science in aeronautics and astronautics from the Massachusetts Institute of Technology, and a dual bachelor's degree from Rensselaer Polytechnic Institute in aeronautical and mechanical engineering.

Speaking about Anya, her supervisor here at the Department of Engineering Professor Holger Babinsky, said "Anya, first came to know of the Department when she was involved, as a Masters student at MIT, in the Silent Aircraft Initiative. She came to know us from the various team meetings and decided to pursue a PhD here.

"Anya worked on an experimental investigation into flapping wing aerodynamics. This research was part of a wider NATO effort to better understand how small birds and insects can produce the necessary force to keep flying. Anya designed and built a completely new experiment in our water tunnel which has since been copied by many other research groups around the world. One of her papers was at one point in the top three most cited articles in a major journal: 'Experiments in Fluids'. Her PhD research was a stunning success, it led to a follow-on NATO research effort (which used Anya's work as a starting point) and rather unusually she was hired straight into a tenure-track post at the University of Maryland despite having no post-doctoral experience. This is very rare, but their confidence was confirmed by her subsequent success in generating new grants and prizes.

"All of the above is even more remarkable when one considers that Anya is also a double blue. She first represented Cambridge in fencing and was part of the 2010 blue boat. In my experience it is exceptionally rare for anyone to be able to row at the standard needed to make the boat race and do a PhD in Engineering. If she hadn't told me I would have never even noticed that she was in the squad – it never affected her work in any way."

Darryll J. Pines, Clark School Dean and Nariman Farvardin Professor of Engineering said "Dr. Jones' unmistakable leadership in our field so early in her career gives me great hope for the future of engineering and our country."

Anya is chair of a NATO Research Technology Organization task group on gust response and unsteady aerodynamics and an associate fellow of the American Institute of Aeronautics and Astronautics (AIAA). She also serves as a member of the AIAA Applied Aerodynamics Technical Committee, the University of Maryland Energy Research Center, and the Maryland Robotics Center, is a faculty advisor to the UMD Women in Aeronautics and Astronautics, and serves on the Raising Excitement for Science Engineering and Technology (RESET) board of directors.

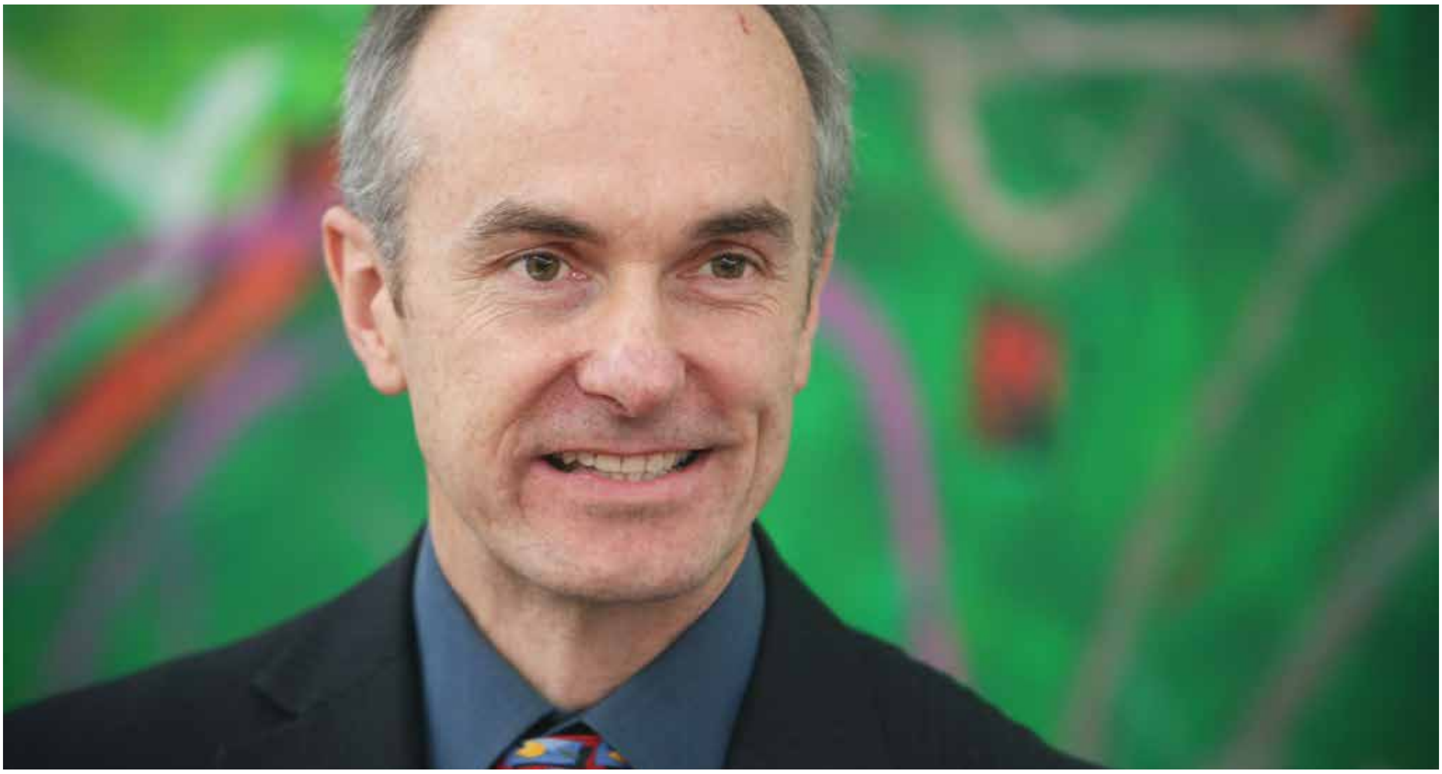
Speaking about her time here at Cambridge Anya said, "My PhD studies at the Department of Engineering were an enjoyable and fulfilling experience throughout. The research I began at the Department formed the foundation for much of my current work and for this recent award. I am exceptionally grateful to the Department of Engineering, Holger, and all of my colleagues at Cambridge who were instrumental in setting me on a path to a successful scientific career, and look forward to continuing to work with them in the future."

> These early-career scientists are leading the way in our efforts to confront and understand challenges from climate change to our health and wellness.
>
> President Obama

She received the National Science Foundation Faculty Early Career Development (CAREER) program award for research to improve the safety, reliability, and efficiency of air vehicles by gaining a deeper understanding of the physics of the large flow field disturbances encountered in high winds and gusty flight environments.

Anya has developed unique experimental capabilities at the University of Maryland to allow for the exploration of the interaction between a wing and a large, well-characterized gust in a repeatable and controlled environment. By modeling this interaction both experimentally and analytically, her research offers a new approach to validating classical aerodynamic theories and a new framework for physics-based models of separated flow.

The PECASE awards, established by President Clinton in 1996, are coordinated by the Office of Science and Technology Policy within the Executive Office of the President. Awardees are selected for their pursuit of innovative research at the frontiers of science and technology and their commitment to community service as demonstrated through scientific leadership, public education, or community outreach.



# Professor Sir David MacKay 1967–2016

**We are saddened by the loss of Professor Sir David MacKay, Regius Professor of Engineering, who lost his battle against stomach cancer on 14th April 2016. He was 48 years old.**

As a scientist, he made contributions to a wide range of fields, including metallurgy, information theory, machine learning, human-computer interaction and sustainable energy. His fundamental contributions to information theory and machine learning include the development of Bayesian methods for artificial neural networks. His detailed book *Information Theory, Inference, and Learning Algorithms* (2003) was an instant classic and is still widely read in the field. He believed in open access at an early stage and as a consequence his book has always been available for free on his website.

He cared deeply about education. He taught mathematics at the African Institute for Mathematical Sciences in Cape Town, South Africa and he was a popular lecturer at the Department of Physics where for many years he taught dynamics, computing, information theory, pattern recognition and neural networks, and materials, electronics, and renewable energy.

His passion for information theory, education and outreach lead to the invention of Dasher, an information-efficient text entry method for people with disabilities, which allows users to communicate with any muscle. Dasher is free software and currently maintained by volunteers at Google.

His commitment to science outreach and his long-standing interest in the environment resulted in the book *Sustainable Energy – Without the Hot Air* (2009). The book achieved widespread acclaim – *The Economist* described it as a tour de force, and it was favourably reviewed in *Science*, *The Guardian*, and many other newspapers, specialist journals and blogs. As with his previous book, *Sustainable Energy* was released for free on the web. Nine months after the publication of *Sustainable Energy* he was appointed Chief Scientific Adviser in the Department of Energy and Climate Change (DECC) for a five-year term. At DECC he and his colleagues developed the 2050 Energy Calculator, which was released as free software and has been adapted by several other countries.

David read Natural Sciences at Trinity College, Cambridge, and received his PhD from California Institute of Technology for his work in Professor John Hopfield's research group on Computation and Neural Systems. After his PhD he was the Royal Society Smithson Research Fellow at Darwin College, where he was later elected Official Fellow. He was a Lecturer, Reader and Professor of Natural Philosophy at the Department of Physics where he started and led the Inference Group. After his service to the government he returned to Cambridge in 2013 as the inaugural Regius Professor of Engineering in the Department of Engineering.

He was a Fellow of the Royal Society, the Institute of Physics, the Institution of Civil Engineers, and Darwin College, Cambridge. In 2012 he was elected Honorary Fellow of Trinity College, Cambridge. He was knighted in the 2016 New Year Honours for his services to scientific advice in government and science outreach.

His battle against cancer was bravely chronicled on his blog. The range of his world-leading research was remarkable and were it not for his early death he would surely continued to have had, a strongly positive influence on both academic research and public policy for several decades. We will remember him as an intelligent, principled, enthusiastic and engaging colleague who left us with an inspiring legacy. He is survived by his wife Ramesh and their two young children, Torrin and Eriska.

David MacKay, born 22 April 1967, died 14 April 2016.

itila.blogspot.co.uk/


# Hackathon unleashes the power of wearables

**The Cambridge University Engineering Society (CUES) has held its first-ever Hackathon. Organised in collaboration with ARM, participants had the opportunity to use ARM microcontrollers, sensors and other products in the mbed system to design their creations. The event drew in more than 100 students not only from engineering but from many disciplines across the University.**

The theme of the Hackathon was wearables. Teams were instructed to develop an electronic wearable product within 24 hours that uses the ARM mbed platform.

First prize went to Tomas Cerskus, Quang Ha and Josiah Yan for their Rowbot Personalised Rowing Device. They developed a miniature wireless device that attaches near the rower's wrist and streams real-time acceleration data to a mobile phone. The device can both analyze data by itself and give personalized advice, or can be used by the team coach to track the performance of the team.

The second-place team built what they called Internet of Decks – lights that can be attached to clothes which beat in time to music. Team members George Fortune, Agnes Cameron and Jamie Wood embedded light-emitting diode strips in a dress that flash in a range of patterns based on signals from a beacon and an app that users download to their phones.

Other creations included

- Smart Bin, a waste bin with flex sensors to measure weight and light sensors that detect when the bin is full
- Childcare, a set of bracelets for children and their parents that buzz if a child gets too far, alerting the parents
- Sygnal, a bracelet that provides information (such as the time) via vibration without you having to check your watch or retrieve your mobile
- Panic Button, a small button you press when you're feeling unsafe that alerts nearby Facebook friends to alert them of the danger
- Slipper Alarm Clock, an alarm clock embedded within a pair of slippers that only shuts off when the user puts the slippers on.

"I would like to see more such events, both as an ex-student and an ARM employee," said Leo Zhou, one of the ARM engineers who assisted with the Hackathon. "It really engages enthusiastic students and gets them into electronics and programming."

Students also participated in similar design challenges at the Open Technology Week which took taking place in the Department of Engineering's James Dyson Building 9–15 June. It included the Open Technology for Development Make-a-thon, which encouraged students to solve design problems from international development and humanitarian contexts. Interdisciplinary undergraduate teams competed over five days using open-source technologies to learn, explore and innovate through challenges put forward by the Centre for Global Equality.

> “It really engages enthusiastic students and gets them into electronics and programming.
>
> Leo Zhu

developer.mbed.org/blog/entry/CUES-Hackathon-Wrap-Up

# Consortium scores €9 million for textile nanofibre research

**The Department of Engineering will coordinate a new €9 million European Commission-funded project on technical textiles.**

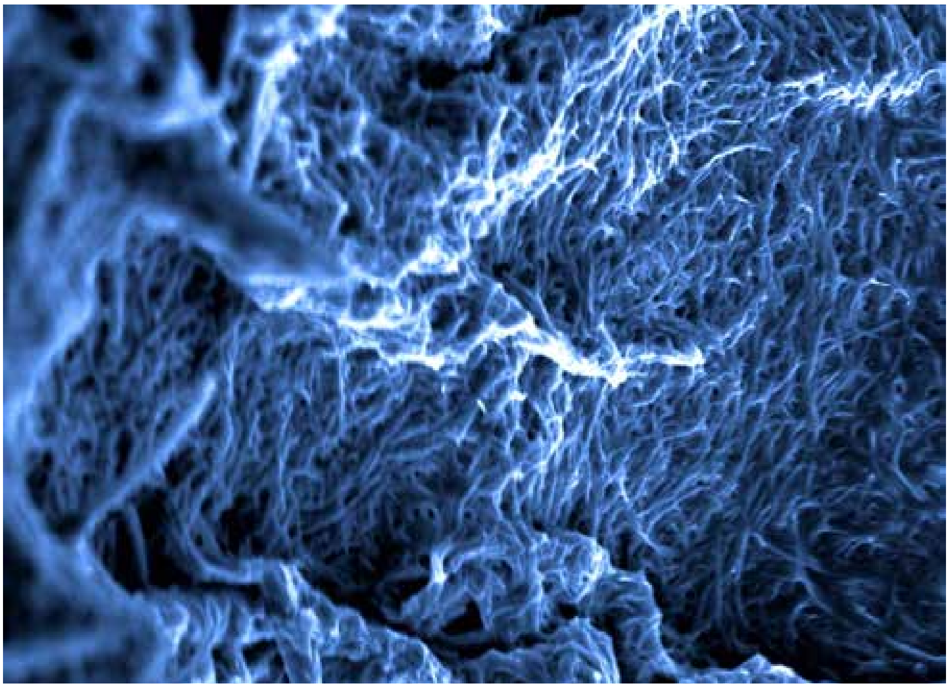
The fibre-based materials for non-clothing applications consortium involves 14 partners from the UK and Europe in a 4-year innovation action activity with the purpose to mature technologies from a technology validated in a lab to a technology demonstrated in a relevant environment.

The project is founded upon previous research activities and demonstrated proof of concepts and laboratory prototypes of fibre electronic components. These include fibre-stretchable electrodes and conducting fibres, fibre-light emitting devices, fibre-field effect transistors and silicon embedding fibres, fibre-piezo harvesters, fibre-sensors, and fibre-energy storage. The activities have been incubated for almost a decade in Europe, Korea and the UK. A pioneering team of scientists who initiated the work at Samsung Advanced Innovation Technologies (SAIT) are now part of the consortium, including the coordinator of 1D-NEON project and Professor of Electrical Engineering Jong Min Kim.

Professor Kim said: "I have seen this field evolving in the last decade and feel that timing is opportune to bring this wonderful innovation to the market and to the community. I have the privilege to lead this unique consortium which is poised to revolutionise electronics manufacturing and bring added value to the field of technical textiles."

Professor Kim is Professor of Electrical Engineering in the Department. Prior to his arrival at Cambridge, he was Professor at Oxford University and Senior Vice President of Samsung Electronics and SAIT in charge of leading innovations including organic light-emitting diode and quantum dot displays, fibre electronics and graphene technologies.

Dr Luigi G. Occhipinti, Exploitation and Business Development Manager and work-package leader for Exploitation and Dissemination, said: "The 1D-NEON project represents a unique opportunity to bring innovation in technical textiles by embedding electronic, sensing and energy functionalities into active fibres. The new manufacturing platform will use processes widely adopted by the textile industry, from multi-layered fibre extrusion to weaving, knitting or braiding techniques, in order to make circuits and multifunctional systems that are intrinsically flexible and stretchable."



Credit: Christoph Meier

↑ Nanofibre mesh

Dr Occhipinti is a member of the Department of Engineering and is also the National Outreach Manager of the EPSRC Centre for Innovative Manufacturing in Large-Area Electronics.

Professor Arokia Nathan, a work-package leader in 1D-NEON for Design and Modelling, said: "This project represents a stepping stone to bring further innovation on e-textiles for the University of Cambridge and the UK. We are looking to establish a strong network in the UK to support the field and work with other centres of excellence in the UK and with the textile industry to provide the UK with yet another opportunity to become world leader in the field of e-textiles for smart wearables. We look forward to creating a Future Manufacturing Hub in Fibre Electronics in the UK and towards a global centre of excellence in textiles, together with the combined effort of the University of Manchester and other academic and industrial research centres active in the UK."

> "I have seen this field evolving in the last decade and feel that timing is opportune to bring this wonderful innovation to the market and to the community.
>
> Jong Min Kim

Professor Nathan holds the Chair of Photonic Systems and Displays in the Department of Engineering. He leads a multi-disciplinary research group whose primary focus is on the heterogeneous integration of materials and processes, sensors, energy harvesting and storage devices including wireless power, signal processing and radio frequency wireless communications pertinent to wearable systems. The laboratory has world-leading expertise in systems integration and has pioneered many important areas related to circuits and systems and computer-aided design, including compensation of materials deficiencies by electronics.

"The key objective of a Future Manufacturing Research Hub in this area will be to create a bridge between the electronics and textile industries and help build UK leadership in this multidisciplinary field by developing new added value products such as stretchable, wearable and cloud-connected smart textiles," said Brian J. McCarthy, who leads the Knowledge Transfer Network on Textiles in the UK.

1d-neon.eu

# Trimble partnership will advance engineering and construction technologies

**The Department's Construction Information Technology Laboratory, part of the Laing O'Rourke Centre for Construction Engineering and Technology, will partner with California-based technology firm Trimble to collaborate on research to advance technology development in the engineering and construction industries.**

Trimble's contribution includes a sponsorship programme which will focus initially on

- conducting research to potentially improve safety, reduce costs and increase predictability and operational efficiency across the construction sector
- providing educational and professional development to encourage and champion construction information technology research in academia and industry
- accelerating the advantages of building information modelling and the use of computer vision and augmented reality technologies to simplify many common construction problems in practical applications.

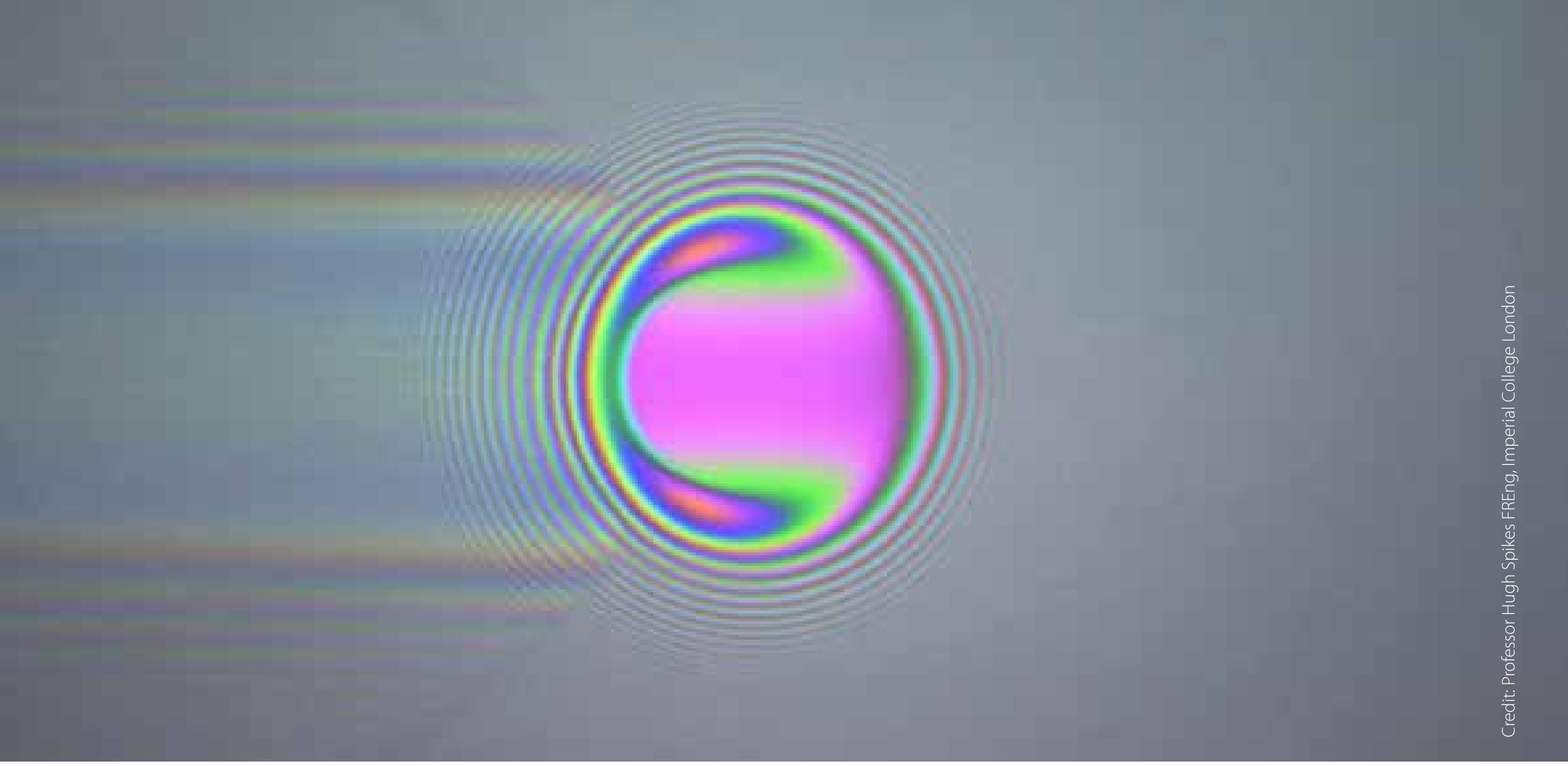
"The research interests between the University of Cambridge Construction Information Technology Laboratory in the Laing O'Rourke Centre and Trimble are truly aligned," said Bryn Fosburgh, sector vice president at Trimble. "Working closely with the research teams at Cambridge, our goal is to foster innovation and enable academic research in information technologies that can affect and transform the way the industry designs, builds and operates buildings and infrastructure."

Professor Campbell Middleton, Head of the Laing O'Rourke Centre, said, "The construction sector is undergoing rapid transformation as a result of the revolution in digital engineering. Cambridge University has a wide portfolio of research projects which aim to solve problems in the construction sector. This exciting new partnership with Trimble will enable us to work together to push forward our agenda to develop new, transformative tools and technologies to deliver a much safer and more productive construction industry and help build the infrastructure on which the well-being of society depends."

"This exciting new partnership with Trimble will enable us to work together to push forward our agenda to develop new, transformative tools and technologies to deliver a much safer and more productive construction industry and help build the infrastructure on which the wellbeing of society depends.

Campbell Middleton

www.construction.cam.ac.uk




↑ **Thin lubricant films play an important role in reducing friction and wear. Here coloured interference fringes outline the circular contact patch, 270 µm in diameter, in the oil film between a steel ball and a flat surface.**

# 50 years of tribology – or should it be 523?

Tribology, the science of friction, lubrication and wear, is a key enabling technology that is involved in nearly all mechanical systems. 2016 has marked a milestone for the subject, being the 50th anniversary of the word 'tribology' which was celebrated with several events including a reception at Buckingham Palace. Ian Hutchings, GKN Professor of Manufacturing Engineering at Cambridge, has written an article for the Royal Academy of Engineering's magazine *Ingenia* that highlights the achievements we have made over the past 50 years.

The Cambridge connection to the subject dates back to the key work of Philip Bowden and David Tabor from the 1940s to the 1980s (though Bowden died in 1968), initially as part of the Department of Physical Chemistry, and then in the Cavendish Laboratory. Within the Department of Engineering very important work was done by Ken Johnson (who died last year) and Jim Greenwood (now Emeritus Reader).

Advances in tribology have demanded the skills of mechanical engineers, materials scientists, physicists and chemists, and have underpinned much of the world's engineering progress. Tribology is very often associated with bearing design, but its reach extends to all aspects of modern technology in which surfaces move against each other, even to apparently surprising areas such as hair conditioners and cosmetics. Many would also include the field of surface engineering – modifying or coating a surface in order, for example, to achieve lower friction or greater wear resistance. Aero-engines, road vehicles and railways, artificial hip and knee joints, computer hard disk drives and toothbrushes all benefit from the pervasive underpinning science of tribology, and Ian argues that the essential elements of tribological understanding should lie at the core of the education of every engineer. For more than 20 years, he and John Williams have run an annual short course on the subject for industry that regularly attracts 30-40 delegates from all over the world.

We have known for a long time that Leonardo da Vinci made the first quantitative studies of friction about 500 years ago. But it was only after a detailed chronological study of his notebooks, also carried out by Ian Hutchings, that we can now identify Leonardo's very first statement of the laws of friction. In an article which has received a lot of publicity, Ian has shown that a tiny page in a notebook preserved in the Victoria and Albert Museum in London contains the very first record of these key findings, expressed in both words and drawings in 1493. Interestingly, the page had been commented on much earlier by art historians who were interested in a sketch of a woman's head; the material on friction below it on the same page was referred to as 'irrelevant notes and diagrams in red chalk'. Ian's work has shown for the first time that Leonardo's studies of friction extended over more than 20 years, and that even with his limited understanding of mathematics and mechanics he incorporated his empirical knowledge of friction into models for several mechanical systems. Although his work had no influence on the development of the subject over the succeeding centuries, Leonardo da Vinci holds a unique position as a pioneer in tribology.

www.ingenia.org.uk/Ingenia/Articles/1009
www.eng.cam.ac.uk/news/leonardo-da-vinci-first-systematic-study-friction

**Ian Hutchings discusses his discovery of Leonardo da Vinci's friction studies**

# Smart glass goes from clear to opaque and back again – 27 million times

**A smart material that switches back and forth between transparent and opaque could be installed in buildings or automobiles, potentially reducing energy bills by avoiding the need for costly air conditioning.**

Imagine a glass skyscraper in which all of the windows could go from clear to opaque at the flick of a switch, allowing occupants to regulate the amount of sunlight coming through the windows without having to rely on costly air conditioning or other artificial methods of temperature control.

Researchers in the Department have developed a type of 'smart' glass that switches back and forth between transparent and opaque, while using very low amounts of energy. The material, known as smectic A composites, could be used in buildings, automotive or display applications.

Working with industrial partners including Dow Corning, the Cambridge researchers have been developing smectic A composites over the past two decades. The team, based at the Department's Centre for Advanced Photonics and Electronics (CAPE), has made samples of smectic A based glass, and is also able to produce it on a roll-to-roll process so that it can be printed onto plastic. It can be switched back and forth from transparent to opaque millions of times, and can be kept in either state for as long as the user wants.

"In addition to going back and forth between clear and opaque, we can also do different levels of opacity, so for example, you could have smart windows in an office building that automatically became more or less opaque, depending on the amount of sunlight coming through," said Professor Daping Chu, one of the developers of smectic A technology.

The main component of the developed composite material is made up of a type of liquid crystal known as a 'smectic' liquid crystal, which is different from a solid crystal or a liquid.

The simplest definition of a crystal is a solid in which the atoms form a distinct spatial order. A liquid crystal, such as those that are used in many televisions, flows like a liquid, but has some order in its arrangements of molecules. The liquid crystals used in televisions are known as nematic crystals, where the molecules are lined up in the same direction, but are otherwise randomly arranged.

In a smectic liquid crystal, the molecules have a similar directional ordering, but they are also arranged in stacked layers which confines the movement of ionic additives. When a voltage is applied, the liquid crystal molecules all try to align themselves with the electric field, and the material they are embedded in (glass or plastic) will appear transparent.

When the direction of the voltage is slowly changed, the ionic additives disrupt the layer structure of the smectic liquid crystals, which has the result of making the glass or plastic panel appear milky. Increasing the frequency of the voltage causes the movement of the ionic additives to freeze out and then switches the plastic or glass panel back to transparent. These transitions happen in a fraction of a second, and when the voltage is switched off, the material will remain either transparent or opaque until the user wants it to switch again, meaning that unless the material is actively switching states, it requires no power.

Possible applications for smectic A composites include uses in the construction, advertising and automotive industries. For example, it could be applied to glass buildings in order to regulate the amount of sunlight that could get through, or it could be used as a 'sunroof' in a car that could be switched back and forth between transparent and opaque.

The work has been patented, and is being commercialised by Cambridge Enterprise, the University's commercialisation arm, with a major industrial partner through a technology framework transfer agreement.

The original motivation behind the development of smectic A was to develop a type of low-power electronic signage, of the type commonly seen at bus stops, that would use low amounts of energy, and would not fade in bright sunlight.

The original form of smectic A was based on organic materials, but the newer version is silicon-based. One sample of smectic A in a lab at CAPE has been switched back and forth between opaque and transparent more than 27 million times, switching once per second for several years.

"The earlier glass-based samples we produced worked well, but there was a challenge in making them in sizes larger than a metre square," said Chu. "So we started making it in plastic, which meant we could make bigger samples, and attach it to things like windows in order to retrofit them. This would reduce the effects of solar radiation, since the energy is being scattered rather than absorbed."

Chu's team is also working on other possible applications for smectic A and related technologies, including the possibility of a transparent heat controllable window and non-intrusive public information messaging system.

www.eng.cam.ac.uk/profiles/dpc31

# UK steel can survive if it transforms itself, say researchers

**A new report claims that British steel could be saved, if the industry is willing to transform itself.**

The report, by Professor Julian Allwood, argues that in order to survive, the UK steel industry needs to refocus itself on steel recycling and on producing products for end users. He argues that instead of viewing Tata Steel's UK exit as a catastrophe, it can instead be viewed as an opportunity.

Allwood's report, *A bright future for UK steel: A strategy for innovation and leadership through up-cycling and integration*, uses evidence gathered from over six years of applied research by 15 researchers, funded by the UK's Engineering and Physical Sciences Research Council (EPSRC) and industrial partners spanning the global steel supply chain.

"Tata Steel is pulling out of the UK, for good reason, and there are few if any willing buyers," said Allwood, from Cambridge's Department of Engineering. "Despite the sale of the Scunthorpe plant announced earlier this week, the UK steel industry is in grave jeopardy, and it appears that UK taxpayers must either subsidise a purchase, or accept closure and job losses.

"However, we believe that there is a third option, which would allow a transformation of the UK's steel industry."

Instead of producing new steel, one option for the UK steel industry is to refocus itself toward recycling steel rather than producing it from scratch. The global market for steel recycling is projected to grow at least three-fold in the next 30 years, but despite the fact that more than 90% of steel is recycled, the processes by which recycling happens are out of date. The quality of recycled steel is generally low, due to poor control of its composition.

Because of this, old steel is generally 'down-cycled' to the lowest value steel application – reinforcing bar. According to Allwood, the UK's strengths in materials innovation could be applied to instead 'up-cycle' old steel to today's high-tech compositions.

According to Allwood, today's global steel industry has more capacity for making steel from iron ore than it will ever need again. On average, products made with steel last 35-40 years, and around 90% of all old steel is collected. It is likely that, despite the current downturn, global demand for steel will continue to grow, but all future growth can be met by recycling our existing stock of steel. "We will never need more capacity for making steel from iron ore than we have today," said Allwood.

Apart from the issue of recycling, today's UK steel industry focuses on products such as plates, bars and coils of strip, all of which have low profit margins. "The steel industry fails to capture the value and innovation potential from making final components," said Allwood. "As a result, more than a quarter of all steel is cut off during fabrication and never enters a product, and most products use at least a third more steel than actually required. The makers of liquid steel could instead connect directly to final customer requirements."

These two opportunities create the scope for a transformation of the steel industry in the UK, says the report. In response to Tata Steel's decision, UK taxpayers will have to bear costs. If the existing operations are to be sold, taxpayers must subsidise the purchase without the guarantee of a long term national gain. If the plants are closed, the loss of tax income and payment of benefits will cost taxpayers £300m-£800m per year, depending on knock-on job losses.

Allwood's strategy requires taxpayers to invest in a transformation, for example through the provision of a long term loan. This would allow UK to innovate more than any other large player, with the potential of leadership in a global market that is certain to triple in size.

He singles out the example of the Danish government's Wind Power Programme, initiated in 1976, which provided a range of subsidies and support for Denmark's nascent wind industry, allowing it to establish a world-leading position in a growing market. Allwood believes a similar initiative by the UK government could mirror this success and transform the steel industry. "Rapid action now to initiate working groups on the materials technologies, business model innovations, financing and management of the proposed transformation could convert this vision to a plan for action before the decision for plant closure or subsidised sale is finalised," he said. "This is worth taking a real shot on."

www.cam.ac.uk/system/files/a_bright_future_for_uk_steel_2.pdf

# Honours, awards and prizes

**Professor Dame Ann Dowling OM DBE FREng FRS**, President of the Royal Academy of Engineering, has formally joined the highly prestigious Order of Merit.

Dame Ann is the first female engineer to join the Order of Merit (OM), which only has 24 living members at any time. She is only the tenth woman in over 100 years to join the OM, following in the footsteps of some uniquely accomplished women from politics, science and the arts.

**Professor Norman Fleck**, head of the Department's Materials Engineering Group and Director of the Cambridge Centre for Micromechanics, has received a €2.5 million grant from the European Research Council (ERC) to advance his engineering work on advanced structural materials.

IDBE
Masters Programme

We are delighted to announce that the established and world-leading **Interdisciplinary Design for the Built Environment (IDBE)** masters course for built environment professionals, run by the Departments of Engineering and Architecture for over twenty years, is being revised, revitalised and enhanced. The new course will be designed to take advantage of the many exciting new initiatives in infrastructure and the built environment in both departments. All potential applicants are invited to apply in 2017.

**Professor Lord Mair**, head of the Department of Engineering's Centre for Smart Infrastructure and Construction (CSIC), made his maiden speech to the House of Lords.The speech, which was part of a wider debate about the High Speed Rail Bill (London – West Midlands), made an impressive case for investment in infrastructure and research to secure a stronger future economy and stimulate growth. Lord Mair championed the role of innovation in engineering and smart infrastructure suggesting the benefits and commercial opportunities that investment in science and technology will bring.

**Stefania C. Radopoulou** has been awarded a Fiatech Outstanding Student Research Project prize for her work in developing road infrastructure sensor systems in vehicles.Stefania is a PhD student in the Construction Information Technology Laboratory, part of the Laing O'Rourke Centre for Construction Engineering and Technology in the Department of Engineering. Her research objective is to create a novel framework that, when combined with low-cost vehicle sensors into a system, is able to detect the type, location, and severity of defects and damages on road assets for condition assessment purposes.

**Dr Dick Fenner** and Dr Feriha Mukuve have been awarded the Senior Moulton Medal for 2015 by the Institution of Chemical Engineers (IChemE) for a paper on "Scale variability of water, land and energy resource interactions and their influence on the food system in Uganda" and published in the *Journal of Sustainable Production and Consumption*.

The work is forward looking on a very topical issue of sustainability facing many countries. The authors have produced a very well written and clearly presented piece of work making it ideal for others to replicate and use in future work.

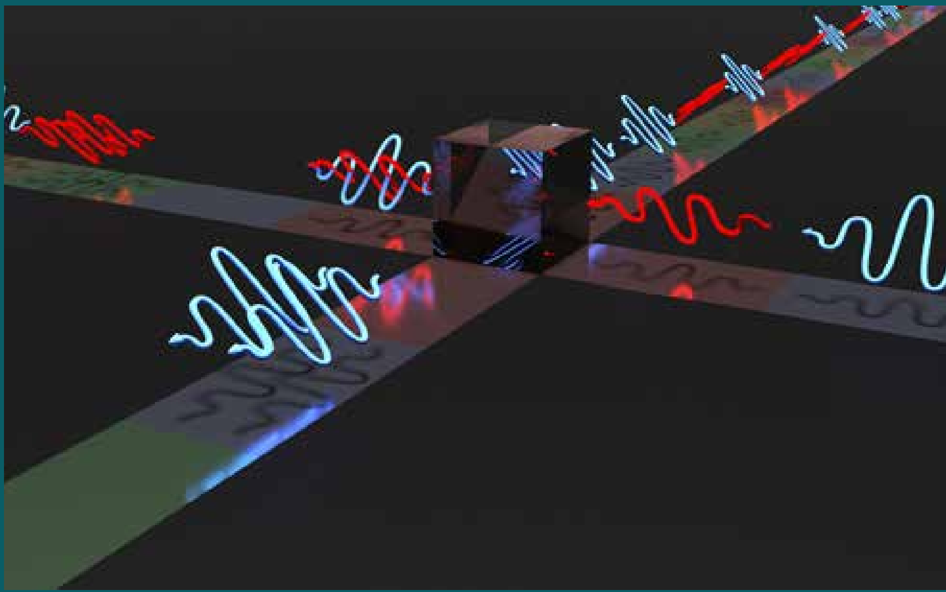
The paper looks at future resource pathways, and describes a resource analysis in relation to Uganda's 2012 and 2050 agricultural resource demand at national, district and local scales.

**Dr Mark Ainslie**, Research Fellow in the Bulk Superconductivity Group of the Department of Engineering, recently presented his research to Parliament. A King's College Junior Research Fellow and a Royal Academy of Engineering Research Fellow, Mark was shortlisted from hundreds of applicants to take part in SET for Britain, a poster competition in Westminster for early-stage and early-career researchers. Mark's poster featured his research on compact and energy-efficient superconducting electric machines using high-temperature superconductors.

The Materials Research Society (MRS) has recognised **Professor Andrea Ferrari**, Director of the Cambridge Graphene Centre, as a 2016 MRS Fellow. Professor Ferrari was cited "for seminal research on Raman spectroscopy of carbon materials and leadership role in the development of graphene and other two-dimensional materials in Europe and worldwide." The honour of MRS Fellow is bestowed upon outstanding members of the organisation in recognition of their sustained and distinguished contributions to the advancement of materials research.

MEng Student **Srikanth Madabhushi** wins the best Dissertation Award from British Geotechnical Association (BGA). The British Geotechnical Association (BGA) gives out annually the best Dissertation in any MSc or MEng program in the UK. Srikanth Madabhushi won the prize for his MEng dissertation titled "Investigating the Deformation Mechanisms beneath Shallow Foundations" supervised by Dr Stuart Haigh, who is a Senior Lecturer at the Department.

# Laser technique promises super-fast and super-secure quantum cryptography



Credit: Lucian Comandar

**A new method of implementing an 'unbreakable' quantum cryptographic system is able to transmit information at rates more than ten times faster than previous attempts.**

Researchers have developed a new method to overcome one of the main issues in implementing a quantum cryptography system, raising the prospect of a useable 'unbreakable' method for sending sensitive information hidden inside particles of light.

By 'seeding' one laser beam inside another, the researchers, from the University of Cambridge and Toshiba Research Europe, have demonstrated that it is possible to distribute encryption keys at rates between two and six orders of magnitude higher than earlier attempts at a real-world quantum cryptography system. The results are reported in the journal *Nature Photonics*.

Encryption is a vital part of modern life, enabling sensitive information to be shared securely. In conventional cryptography, the sender and receiver of a particular piece of information decide the encryption code, or key, up front, so that only those with the key can decrypt the information. But as computers get faster and more powerful, encryption codes get easier to break.

Quantum cryptography promises 'unbreakable' security by hiding information in particles of light, or photons, emitted from lasers. In this form of cryptography, quantum mechanics are used to randomly generate a key. The sender, who is normally designated as Alice, sends the key via polarised photons, which are sent in different directions. The receiver, normally designated as Bob, uses photon detectors to measure which direction the photons are polarised, and the detectors translate the photons into bits, which, assuming Bob has used the correct photon detectors in the correct order, will give him the key.

The strength of quantum cryptography is that if an attacker tries to intercept Alice and Bob's message, the key itself changes, due to the properties of quantum mechanics. Since it was first proposed in the 1980s, quantum cryptography has promised the possibility of unbreakable security. "In theory, the attacker could have all of the power possible under the laws of physics, but they still wouldn't be able to crack the code," said the paper's first author Lucian Comandar, a PhD student at Cambridge's Department of Engineering and Toshiba's Cambridge Research Laboratory.

However, issues with quantum cryptography arise when trying to construct a useable system. In reality, it is a back and forth game: inventive attacks targeting different components of the system are constantly being developed, and countermeasures to foil attacks are constantly being developed in response.

The components that are most frequently attacked by hackers are the photon detectors, due to their high sensitivity and complex design – it is usually the most complex components that are the most vulnerable. As a response to attacks on the detectors, researchers developed a new quantum cryptography protocol known as measurement-device-independent quantum key distribution (MDI-QKD).

In this method, instead of each having a detector, Alice and Bob send their photons to a central node, referred to as Charlie. Charlie lets the photons pass through a beam splitter and measures them. The results can disclose the correlation between the bits, but not disclose their values, which remain secret. In this set-up, even if Charlie tries to cheat, the information will remain secure.

↑ **Depiction of indistinguishable photons leaving through the same output port of a beam splitter**

MDI-QKD has been experimentally demonstrated, but the rates at which information can be sent are too slow for real-world application, mostly due to the difficulty in creating indistinguishable particles from different lasers. To make it work, the laser pulses sent through Charlie's beam splitter need to be (relatively) long, restricting rates to a few hundred bits per second (bps) or less.

The method developed by the Cambridge researchers overcomes the problem by using a technique known as pulsed laser seeding, in which one laser beam injects photons into another. This makes the laser pulses more visible to Charlie by reducing the amount of 'time jitter' in the pulses, so that much shorter pulses can be used. Pulsed laser seeding is also able to randomly change the phase of the laser beam at very high rates. The result of using this technique in a MDI-QKD setup would enable rates as high as 1 megabit per second, representing an improvement of two to six orders of magnitude over previous efforts.

"This protocol gives us the highest possible degree of security at very high clock rates," said Comandar. "It could point the way to a practical implementation of quantum cryptography."

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