Cambridge
materialeyes

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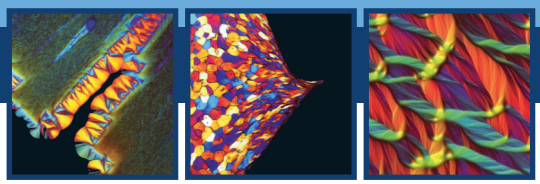


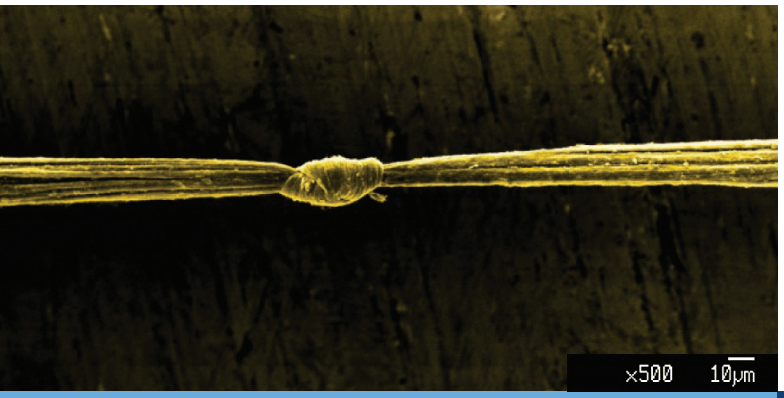
Q-Flo - Spinning a yarn

How did such a striking name, *Q-Flo*, arise? When Alan Windle and colleagues were seeking to set up a spin-out company to develop a significant discovery made in their lab they sought to recognise the outflow of technology from Cambridge University (think "CU" with a hard C). CU-Flo became *Q-Flo* and thus the company name was born. But what was the discovery and why are its prospects so attractive?

The team first developed a method of producing a cloud of loosely entangled, ultra-long nanotubes (each tube about 1 mm long and 10 nm in diameter) – so called "elastic smoke". They then devised a method of spinning fibre from this smoke by taking hold of a part of the cloud with a cold rod (this process works through thermophoresis – more molecules land on a cold surface than leave), attaching that part to a reel and then drawing down the whole cloud to make a yarn-like carbon fibre of oriented nanotubes some million times denser than the smoke. A series of runs on the rig in the Department's process lab can produce about 30 km of fibre, weighing about 1 g, in a day.

The resulting fibre has similar strength and stiffness to conventional carbon fibre but is exceptionally tough (a factor of three better than Kevlar™). Remarkably, it shows 100% "knot efficiency", i.e. a knotted fibre (illustrated) is as strong as an unknotted one, an unusual property, and it bonds efficiently into suitable resin to make fibre composites.

Recently *Q-Flo* has teamed up with *Plasan*, a company based in Israel, with plants in France and the USA, that manufactures composite materials. The partners have set up a joint venture company, *TorTech* to develop materials using *Q-Flo* fibres initially for body armour and related applications. It is expected that items made from these materials, with protective properties at least as good as existing materials, will be much lighter with better environmental resistance. *TorTech* looks forward to its first big challenge, scaling up the production process to make kilograms per hour!



TorTech applications are not the only ones in prospect. *Q-Flo* has retained the rights on other potential uses of this radically new material; for example, there is the possibility of controlling the structure of the nanotube so as to achieve even better electrical conductivity thus opening up the prospect of a replacement for copper in wiring.

Editorial

After much preparation on the West Cambridge site, actual construction of our new building begins in June. It is a privilege to acknowledge further substantial contributions to the cost of the project, from the Ann D Foundation and from the Worshipful Company of Armourers & Brasiers.

Preliminary student returns suggest that the Part II Class in 2011-12 will be our largest in nearly 30 years, continuing the rise noted in issue 20. Can such favourable trends be maintained in an era of rising fees? Cambridge's proposed fee of £9000 pa (for new EU/ home undergraduates from 2012) blends with the crowd; more unusually it was approved by a vote of the Regent House, a governing body with more than 3800 members. An extensive range of support packages will be available (in the form of a bursary or a fee waiver as desired by the needy student). Vice-Chancellor Professor Sir Leszek Borysiewicz notes: "The University of Cambridge is committed to recruiting the brightest and best students irrespective of their background. No UK students should be deterred from applying to the University of Cambridge because of financial considerations and no students should have to leave because of financial difficulties."

We begin to see the effects of tight Research Council budgets, but support from industry (see p. 3 for the opening of our SKF Centre) and the EU is buoyant. Above all, the quality of the Department's research continues to be recognised by appointments and awards. We note in particular the Fellowship of the Royal Society for Sir Colin Humphreys and the award of the Royal Academy of Engineering's President's Medal to Anthony Kelly. Lord Browne of Madingley, who will present Professor Kelly with his award, said: "... his epithet as the 'Father of Composite Materials' is as well-earned as his reputation is global."

Professor Lindsay Greer, Head of Department

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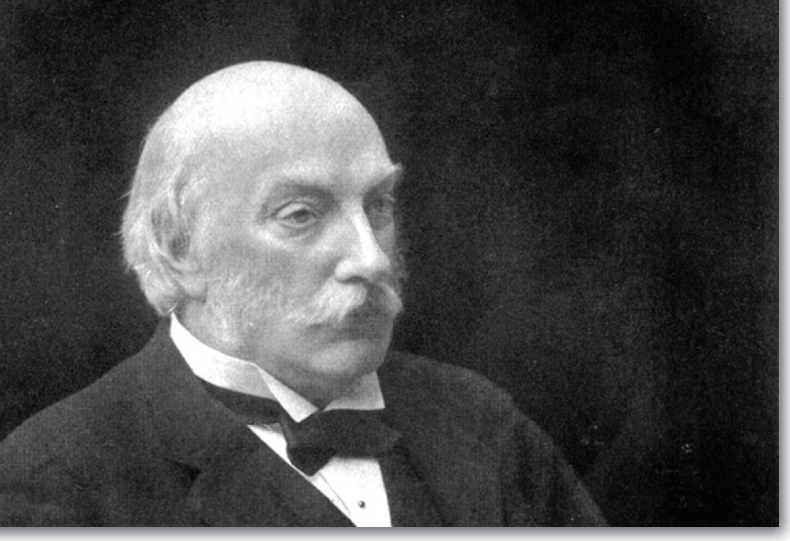
Inside:



Lord Rayleigh: his legacy

Materials scientists and physicists around the world are familiar with the name of Rayleigh. What's more, materials scientists in Cambridge may well find themselves using electron microscopes in the Rayleigh Wing of the Old Cavendish. But who was the Rayleigh whose name is attached to so many significant phenomena as well as to one of the Department's locations on the New Museums Site?

Lord Rayleigh was born John William Strutt in 1842 and succeeded to the title in 1873. He was the third baron in what is currently a succession of six. His contributions to science were immense and covered all fields of physics known in his day. His publications are concerned exclusively with classical phenomena, although, interestingly, several of the analytical techniques he developed are used by quantum theorists today. He was a top mathematics student at Cambridge before he engaged in a mixture of theoretical and experimental work, largely in his private office and laboratory, both of which are extant at the family home in Terling Place, Essex.

Not long after his marriage to Evelyn Balfour (sister of Arthur Balfour who was to become Prime Minister), his health suffered and he took a trip on the Nile to recuperate. During these travels, he wrote almost the whole of the first volume of *The Theory of Sound*, without access to a library. This tome, together with the second volume, became a classic, with the theories and principles expounded in these texts remaining relevant today.

He showed an early interest in photography, which was still in its infancy. One of the things that emerged from these studies was the establishment of a theory for the optical resolution of gratings and prisms. This in turn led to the Rayleigh criterion for resolving power, which is still the basis for the design and performance of many optical instruments.

One of Rayleigh's best known theories concerns the scattering of light by particles of size smaller than the wavelength of the electromagnetic radiation. An expression he derived gave an inverse dependence of the intensity of the scattered light on the fourth power of the wavelength, which means that blue light is scattered about ten times more effectively than red. This explains not only the blue colour of the daytime sky but also the polarisation of scattered sunlight, which it is believed assists birds and insects to navigate.

After succeeding James Clerk Maxwell as Cavendish Professor in the Cambridge University Physics Department in 1879, Rayleigh turned his attention to the establishment of standards of electricity, in particular the ohm and the amp. The apparatus he used stands in the museum of the present-day Cavendish Laboratory. It consists of a current-carrying coil rotating around a small suspended magnet whose deflection produced by the resulting magnetic field was measured with great precision.

The discovery of argon in 1894 provides testimony to Rayleigh's perseverance in pursuing a problem that many experimenters would have dismissed as experimental error. During a series of measurements of the atomic weights of gases, he was puzzled as to why nitrogen extracted from the atmosphere had a density that was one part in 200 greater than that of nitrogen obtained chemically from ammonia. He published a letter in *Nature* inviting explanations but none was forthcoming. Eventually he came up with his own suggestion that air contains a small quantity of a then unknown gas which was heavier than nitrogen. This gas he named argon and eventually, with the help of the chemist Sir William Ramsay, he succeeded in isolating it and measuring its properties.

Rayleigh received the Nobel Prize in 1904. Most of the prize money was used to build a new wing on the (Old) Cavendish Laboratory in central Cambridge in which colleagues in the Department of Materials Science today undertake their own research.

Much of Rayleigh's pioneering work has had a lasting legacy. Apart from the numerous applications of argon, one can point to the use of the Rayleigh criterion in optics, the Rayleigh number in turbulent and laminar fluid flows, and Rayleigh scattering in the operation of microwave windshear sensors.

Rayleigh introduced the concept of surface acoustic waves, which are generated by earthquakes and are of great importance in seismology. Ultrasonic surface waves are used to detect cracks and other imperfections in materials. They are also the basis of electronic components, known as SAW filters, which are commonly used in radio frequency devices, in particular mobile phones.

Rayleigh has been called the last of the great Victorian polymaths. His contributions to science rank with those of Stokes, Kelvin and Maxwell. Although he lived through the time when quantum physics came to the fore and acknowledged, for example, that such concepts were necessary to extend validity of the Rayleigh-Jeans law for black-body radiation spectrum to higher frequencies, he decided to leave such things to younger men!

Acknowledgement: The author would like to express his sincere gratitude to the present Lord Rayleigh for preserving the laboratories used by his great-grandfather and for granting him access to them.

Professor E A Davis
[Following his retirement as Professor and Head of the Department of Physics and Astronomy at the University of Leicester, Professor Davis is now a Distinguished Research Fellow in our Department.]

Fray International Symposium

Derek Fray's many distinguished achievements in basic research in the broad area around chemical metallurgy and in the subsequent creation of spin-out companies will be marked by the *Fray International Symposium* in Cancun, Mexico from 27 November to 1 December this year, with the *Clean Environment* as focal point. The international organisers include Vasant Kumar from our Department. Despite current economic and political difficulties around the world, over 400 abstracts from authors in over 50 countries have already been submitted, and the programme is now taking shape; about 20 short courses will also be offered, including one by Rob Wallach on *Sustainability in Materials Science*. Sponsors include 210 organisations worldwide (a record). Notable keynote speakers from Industry and Academia as well as Law and Politics will be announced shortly, see:

www.flogen.com/FraySymposium

Weak Interfaces and Narrow Lines

Andy Phillipps came up to Downing to read Natural Sciences in October 1987. He was a member of the Part II Class in 1989-90 and then gained a PhD with Bill Clyne, since when his career has developed in surprising ways. "How does he fit it all in?" is the question that most immediately springs to mind on learning of his current appointments, closely followed by "How did he get there from Materials Science?" Answering the second is a matter of historical record, answering the first is beyond the scope of *Material Eyes*!

When he was an undergraduate Andy recalls Bill Clyne describing him as having a "shallow veneer of competence", which Andy says was both perceptive and accurate. Stung into action, he surprised everyone, including himself, by obtaining a First. Elated by unexpected success, he stayed in the Department to work for a PhD, also with Bill Clyne. His project, sponsored by Bill Clegg (then at ICI), involved developing and testing a model for the fracture behaviour of ceramic laminates in bending. It built on the observation that some natural materials (for example marine shells) consist of layers of brittle ceramic separated by weak organic interfaces capable of deflecting cracks and so increasing the toughness. The project proved very successful and the model has wide applicability; pursuing it further might well have led Andy into an academic life, but the experience of working alongside industry during his PhD had persuaded him to look elsewhere, and he joined the Development and Technology Centre of the *Cookson Group*, subsequently moving to *BOC Semiconductor Division* as Development Manager. Stimulated by this taste of management but puzzled by some of the decisions he observed, he decided to study for an MBA, entering INSEAD in 1998 supported by a Sainsbury Management Fellowship.

Up to this point Andy's career trajectory had followed the pattern of other potentially high-flying industrial materials scientists, but all was to change. Acquiring what he describes as a memorably modest grade in his entrepreneurship module at INSEAD, Andy decided to build on this solid foundation by starting his own business. Instead of returning to the materials industry he and a cousin set up *Active Hotels Limited*, doing so, as it turned out, shortly before the collapse of the dot-com boom. Happily, the business survived the crash – Andy attributes this to a combination of terror, luck and good advice – and went on to become one of the largest hotel booking companies in Europe, gathering a number of awards along the way, before being acquired by *Priceline International,* of which Andy became CEO. Leaving the company in a very flourishing state at the end of 2005, he became chairman of another reservations company, *Top-table*, guiding it through a period of rapid growth before it was sold to *Open-table* in 2010. Since 2006 Andy has also developed several wider interests ranging from *I_2O Water*, a company that aims to reduce leakage and energy consumption in water distribution networks, through *Greentraveller* and *Reevoo.com* to *Albion Ventures Development VCT*, as well as to teaching and advising at INSEAD and LBS. Perhaps inevitably there have been downs as well as ups, a notable down being the disastrous purchase of a floristry chain that went rapidly into administration. Reflecting on his overall progression one discerns a connecting thread: efficient and effective use of the internet.

Spare time is not something that Andy has in abundance, but when he does he likes to escape to his home in Norfolk and above all to indulge his passion for windsurfing, at which he describes himself as "consistently inept". At other times he obeys orders from his wife and small children and chases errant chickens back to their pen.

Thus since graduating just over 20 years ago Andy has had – and continues to have – a very active and wide-ranging career. He looks back with pleasure on his time in the Department and passionately believes that the mental disciplines learnt from doing a PhD have proved immensely valuable in business. Asked what advice he would offer to current undergraduates he says "There's a narrow line between self-confidence and delusion, and learning to recognise it is a life-long task".

More Efficient Use of Nuclear Power

To make best use of nuclear power plants the neutrons emitted in fission should be used to create more fission, not absorbed in control rods. This means operating at full power for as much of the time as possible, even if more power is produced than is being called for by the grid; other means must be found to use the surplus. In the past this has been achieved by enormous pumped-storage schemes. Now a very different approach is being developed by an international collaboration of our Department, MIT in the USA and Tsinghua University in China (see figure). This will involve a high temperature electrolyser/fuel cell (HTEFC), a highly efficient, reversible fuel cell. When demand from the grid is low, the cell will create hydrogen and carbon monoxide ("syn-gas" fuel) and oxygen by co-electrolysis of water and carbon dioxide, when demand is high it can be reversed to operate as a fuel cell providing additional electrical power. Thus the system is capable of recycling carbon dioxide instead of creating more. To produce a working system many challenges must be overcome. The Cambridge research, led by Paul Bristowe, will make use of his extensive experience in computational modelling to provide insights into the stability and degradation of target electrode materials, enabling accelerated design of superior materials.

Characterisation of surface structure and chemistry, and reactions on oxide materials (MIT)

Computational modelling of surface reactions and transport, and materials design at the atomic level (Cambridge)

Electrochemical testing, process modelling of co-electrolyzer for performance optimization of the HTEFC (Tsinghua)

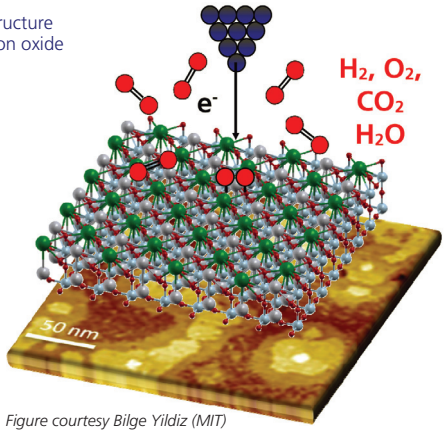


Figure courtesy Bilge Yildiz (MIT)

Inauguration of the SKF UTC

The agreement between SKF and the University to create a University Technology Centre for Steels in the Department and under the direction of Professor Harry Bhadeshia was reported in Issue 19 of *Material Eyes* and research has already been initiated. To mark this significant development a meeting was held on 9 June attended by representatives from SKF, led by Tom Johnstone, President and CEO, and Alan Begg, Senior Vice-President, Group Technology and Development, and from the University, headed by the Vice-Chancellor, Professor Sir Leszek Borysiewicz.

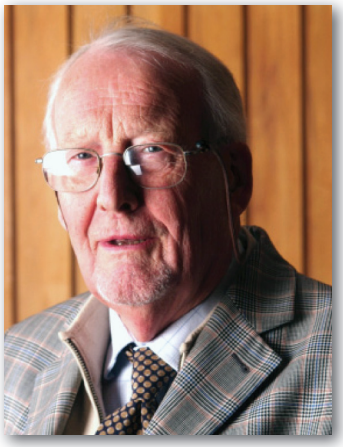
Delivering Digital Delights

Many research projects and undergraduate experiments have benefited from the in-house creation of tailor-made electronic devices. For almost 40 years one wizard, Keith Page has overseen that creation. Keith joined the Department in 1972 as an Assistant Technical Officer, steadily rising to Senior Technical Officer. From the outset his brief was to set up an electronics laboratory to design and maintain instrumentation for research and teaching. At that time medium-scale integrated circuits with just a few hundred transistors per chip were in their infancy and PCs were a decade away. How things have changed! Nevertheless, the job still involves a balance between repairs, 'design and build' and device-control software. That "there's something new to do and learn all the time" has been a major attraction of the post. Although always in charge, Keith has generally not been alone in 'Electronics'; currently he is ably assisted by Maddy MacElroy, who relieves him of much of the routine paperwork in addition to carrying out many electronic and mechanical tasks.

Keith recalls so many projects from the past that selecting examples risks being misleading. At one end of the spectrum of challenge and complexity lies a device familiar to everyone: the one that controls access to the photocopiers. At the other lie major items including a control system for an X-ray diffractometer, devised and implemented before such systems were routinely incorporated by manufacturers. Keith happily passes on his expertise. He has taught HNC courses part-time at the (then) Cambridge Polytechnic; now he gives lectures on electronics and electrical safety in the annual Induction Week for new graduate students. Asked for advice for prospective new users, he says "Know what you really need and be prepared to refine the specification by discussion."

We are all well aware of Keith's enthusiasm for sponsored cycle rides. During the past decade he has raised funds for several major medical charities tackling issues such as breast and other cancers, heart disease, strokes. Probably less well known are his many other activities: a keen bell-ringer (pictured: Keith with bike and some bell-ringing friends), an organist, an enthusiastic photographer and an active allotment holder! If you have ever thought you met Keith and he failed to acknowledge you, it's not amnesia on his part, it's just that you actually met his identical twin brother. Finally, we congratulate him on becoming a grandfather in March this year.

Congratulations



Sir Colin Humphreys
Fellow of the Royal Society

Michelle Moram
Lectureship, Imperial College

Jason Robinson
Royal Society University Research Fellowship

Anthony Kelly (right)
President's Medal, Royal Academy of Engineering

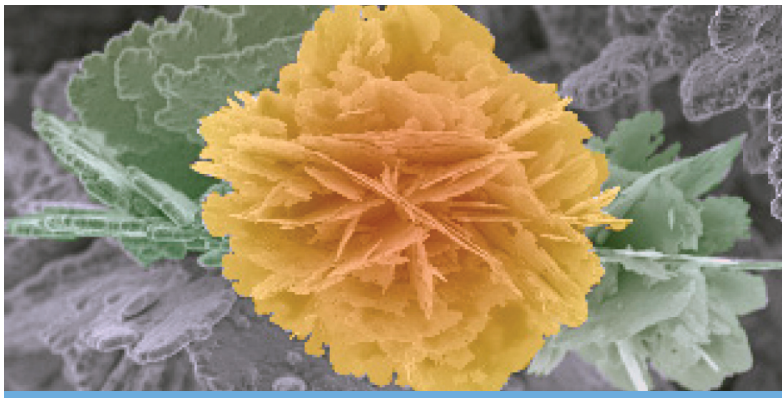
Anthony Cheetham
Platinum Medal & Prize, IOM^3

Serena Best
Chapman Medal & Prize and Kroll Medal & Prize, IOM^3

Kevin Knowles
Fellow, IOM^3

Krzysztof Koziol
Fellowship, Pembroke College

Diane Iza, David Munoz-Rojas, Talia Gershon, Claire Armstrong, Andrew Marin, Kevin Musselman, Judith Driscoll
2nd Place, Science as Art, MRS Conference, Apr 2011 "Cubist Microflower" (pictured below)



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