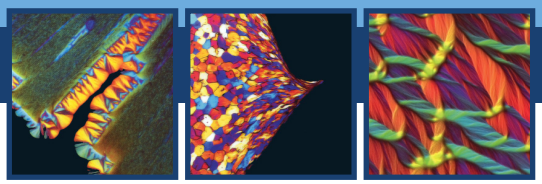
Cambridge
materialeyes

February 2011 Issue 20



Start-on-Site

Major projects follow sigmoidal curves. Formal events to mark the 'start-on-site' are judiciously arranged to occur a little way up that curve and so it is with our new building: an impressive hole has already been dug (located as on the map in Issue 19 of *Material Eyes*) and some concrete poured. Serious construction begins this spring. Meanwhile several low brick walls have been built close-by to inform the selection of bricks for the facing of the building.

On Friday 29 October 2010, in the Hauser Forum, a number of members of the Department joined the Vice-Chancellor, Sir Leszek Borysiewicz, donors and other distinguished guests as well as representatives of the organisations closely involved with the project to mark the 'Start-on Site'. At midday Chris Tredget, MD of the main contractor, Willmott Dixon, spoke of his pleasure that his company had been selected to construct another building at West Cambridge, appearing to relish the challenges imposed by the environmental requirements of advanced equipment, notably electron microscopes! Michael Bienias, Director of EMBS, outlined the processes followed by the University in reaching this stage of the project and taking it through to completion. He assured us that the project would be delivered on time and on budget. In looking forward to completion of the building, Lindsay Greer thanked all those who have been involved. He reiterated our gratitude to individuals and organisations that have contributed to funding the project, pointing out that so often in its history the Department, as a relative youngster, has had to make do with 'hand-me-down' buildings from longer established departments instead of having its own space specifically designed for its purposes.

In thanking the architects, NBBJ, Lindsay particularly expressed his appreciation of their skilled and tolerant interpretation of the Department's needs as they had evolved during planning. Finally, the weather being quite kind for late October, the party walked to the construction site (shown above).

Editorial

In terms of funding for higher education, we do live in interesting times. While we wait for the implications of proposed changes to become clearer, we have our own headline news: the knighthood for Colin Humphreys (p. 2); the £6.3M grant to Sir Colin and to colleagues at Bath Manchester and Strathclyde for *Lighting the Future*, aiming towards sensibly-priced, highly-efficient lighting from GaN LEDs; and the official start of work on our new building.

In teaching, this year sees the inauguration of our very own Materials Science course in Part IA NST; the MASt (Master of Advanced Studies) course that allows Bachelor's graduates from elsewhere to take our 4th-year course in parallel with our Part III students; and the Rolls-Royce/EPSRC Doctoral Training Centre on *High-Performance Structural Metallics*. And next year we will be involved in the University's new MPhil in *Nuclear Energy*. Our undergraduate teaching continues to attract very favourable comments in the National Student Survey, and student numbers are climbing fast (p. 2). This year, as last, our research-student intake includes the winners of the IoM^3 Royal Charter Prize (for the UK's top materials graduate) and AT Green Award (for the top graduate with excellence in ceramic materials).

It was a particular pleasure to welcome David Willetts to unveil our new Titan transmission electron microscope in September (p.2). We hope that the quality of the work on display and the clear prospects for financial benefit to the UK were timely in the approach to the Comprehensive Spending Review.

Professor Lindsay Greer, Head of Department

Golden Centenary

The Department is very grateful to all those individuals and organisations contributing to the new building project. We are particularly pleased that the Worshipful Company of Goldsmiths is numbered among them. Their large donation to fit out the ground floor teaching suite in the new building comes exactly 100 years after the Company's first, but by no means only, contribution to metallurgy and materials science in Cambridge. Subsequent donations have, among other things, supported the creation of the Goldsmiths' Laboratory and the provision of additional funding to enable the Readership in Metallurgy to become the Goldsmiths' Professorship. Other contributors to fitting out rooms in the new building will be acknowledged in later issues of *Material Eyes*.

UNIVERSITY OF CAMBRIDGE
Department of Materials Science and Metallurgy

Pembroke Street
Cambridge CB2 3QZ
01223 334300

www.msm.cam.ac.uk

Inside:

Titan Unveiled

On Friday 10 September David Willetts, the Minister for Universities and Science, devoted part of a visit to this University to unveil the latest addition to the Department's suite of transmission electron microscopes. The microscope, the most powerful of its type in the UK, is an FEI Titan 80-300 equipped with two key components: an aberration-corrected probe-forming lens and an electron monochromator. It is designed for high spatial resolution analysis at near-atomic level, allowing users to record energy-loss spectra from interfaces, quantum-well structures and a variety of nanoscale structures and devices. It was funded primarily through the HEFCE Science Research Investment Fund (SRIF) with additional contributions from several sources in the University. It is housed in the NanoScience Centre in a specially upgraded room. David Willetts talked with Professor Paul Midgley, who is in charge of the microscope, Dr Cate Ducati and others closely involved with the instrument, and was shown some of its potential capabilities.

Research projects that will be using the new microscope include:

- A study of ultra-fine-scale features of materials expected to be used in the next generation of lighting. These very efficient energy-saving lights reduce carbon emissions, possibly enabling the UK to close – or not build – as many as eight large power stations. Each light will provide lighting closely similar to sunlight and could last for 60 years.
- Aberration-corrected STEM will be used to investigate the atomic structure of materials at sub-Å resolution. In combination with the new technique of annular bright-field (ABF) imaging, it will be used to elucidate light-atom positions, including oxygen in functional oxides and lithium in novel battery materials. The high energy resolution available through the monochromator will be used in the study of surface plasmon resonances of silver and gold nanoparticles to better understand surface-enhanced Raman scattering and a variety of possible plasmonic devices.
- Another project will study photo-active materials, and develop tools to measure their response to photon irradiation *in situ* in the microscope. The Titan's excellent energy and spatial resolution will be used to map the photovoltaic behaviour of active solar cells, in particular to evaluate – on the atomic level – the effect of defects and surfaces on the performance of the device.

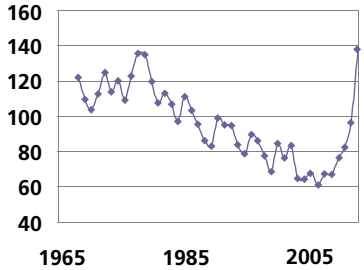
Expressing his gratitude for the visit, Prof. Sir Colin Humphreys said: "I am delighted that David Willetts has unveiled our new world-class electron microscope, which will be used in many collaborative projects with existing and emerging UK industries."

Nuclear Renaissance

Our department is among those contributing to Cambridge's one-year MPhil course on *Nuclear Energy*, which will admit its first students in October 2011. With its aim of educating the nuclear leaders of tomorrow, the course will cover: (i) the fundamental engineering, scientific and safety aspects of nuclear power, (ii) nuclear technology policy and business aspects, (iii) wider policy contexts of electricity generation in the 21st century.

The case for nuclear energy being made in many countries is based on, among other things, the requirement for energy security, and the need to limit carbon emissions. In the UK, there are plans for at least £30bn investment in new reactors over 15 years, possibly supplying 30% of our electricity by 2030. There is similar interest across the world, with large programmes in the US, China and India, and nuclear new-build under consideration in a further 20 countries. The new course is part of a University initiative on energy and is linked to the Cambridge Nuclear Energy Centre: **www.cnec.group.cam.ac.uk**

Onward and Upward



From the mid-1980s, the number of undergraduates taking courses in the Department fell away, as it did in Materials Departments around the UK and North America. Happily in the last few years our numbers have been recovering steadily with increases in the first-year course feeding through into later years. This year sees the largest numbers embarking on Part IB, Part II and Part III for many years; the number in Part III is an all-time record. In terms of full-time equivalent numbers (FTEs) – shown graphically – the total is probably the highest ever. Caution is needed in comparing current figures with those from the distant past; Part III was introduced from October 1998 and now, for the first time ever, the Department has sole responsibility for the Part IA course so each first-year undergraduate is twice as valuable in FTE terms! Now is not the time to analyse the origin of these changes but simply to note the development with pleasure (and relief!) and to hope that healthy recruitment to Part IA and the good feedthrough to the higher years will continue.

Knight in LED Armour

The award of a knighthood to Colin Humphreys, for services to science, was announced in the Queen's Birthday Honours List 2010. This further honour for Colin (he already holds a CBE) recognises his immense contributions across a broad front, from directing our Rolls-Royce University Technology Partnership, and his work in popularising materials science, to his current world-leading work on solid-state lighting. With a distinguished record at Oxford and Liverpool, Colin joined our Department, and Selwyn College, in 1990, was elected Goldsmiths' Professor in 1992, and served as Head of Department 1991-95. He is currently a Director of Research, and this year is also the Master of the Worshipful Company of Armourers & Brasiers. Colin has promoted Materials Science in many ways, notably presiding (2002-03) over the IoM^3 and serving on or chairing countless review panels in the UK and across the world. He is a Fellow of many learned societies, and his list of honours and awards is long indeed.

Following on from the award of an MBE to David Duke in the New Year 2010, the Department now has a consistency of appearance in Honours Lists that is enviable, if difficult to maintain!

The Department is very grateful to The Lloyds Register Educational Trust for their generous donation to the University, which has provided scholarships covering full fees to two students – C Jackson and M Zarrouati – taking the MPhil in Micro- and Nanotechnology Enterprise in 2010-11.

ABC Forum 2010

The Forum was opened, on 15 June, by Rear Admiral Patrick Middleton on behalf of the Armourers and Brasiers' Company.

Walter Federle (Zoology, Cambridge), on *How insects walk on the ceiling: structure and function of natural adhesives,* impressively illustrated that, in recent years, animal attachment mechanisms have attracted attention because they are often superior to artificial adhesives.

In *Biominerals - columns, bricks, trees and bones*, Maggie Cusack (Glasgow) showed that invertebrates forming calcium-carbonate-based biominerals can control the crystal-growth process in order to determine the phase formed and the texture, thus controlling the properties of the resulting hard tissue.

More currently political, James Wilde (Carbon Trust) on *Opportunities created by a transition to a low-carbon economy* reminded us of the targets for reduction of carbon emissions and noted that the UK cannot hope to lead in all technologies. He focused on the advantages of offshore wind farms noting also the engineering challenges.

Henri Winand (Intelligent Energy, [IE]) introduced *Hybrid fuel cell taxis for London*. IE is pioneering the development of a full-performance, zero-emission black cab. A working vehicle using a hydrogen fuel-cell with lithium polymer batteries was unveiled recently. The aim is for all London taxis to be 'zero emission' by 2020.

Changing direction, Helen Atkinson (Leicester) on *Semi-solid processing of metallic alloys: the challenges*, presented memorable examples exploiting the thixotropic state for aluminium and magnesium alloys, and forecast the challenges in applying such techniques to the higher temperatures necessary for (e.g.) steels.

The Armourers and Brasiers' Venture Prize for 2010 was awarded to Mohan Edirisinghe and Eleanor Stride of UCL who have developed novel methods to encapsulate gases, liquids and solids from the nano- to the macro-scale. They can generate tiny bubbles that remain suspended in liquid for long periods; their company *ElectroCap* aims for biomedical and pharmaceutical exploitation of this technology.

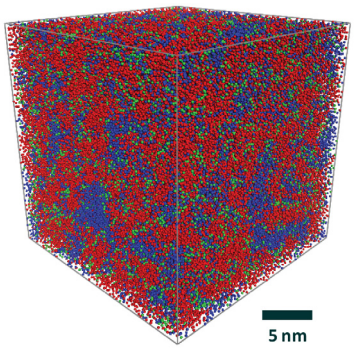
The culmination of the afternoon was the 12th Kelly Lecture by Ke Lu (Director of the Institute of Metal Research, Chinese Academy of Sciences, Shenyang) who was informative and inspiring on *Nano-twinned materials*, the dramatic and potentially important kernel being his discovery that nano-twinning in metals can lead to increased strength whilst maintaining ductility. This behaviour involves the differences between twin boundaries (necessarily coherent) and general, incoherent boundaries. He also described methods for making nanotwinned materials.

Tony Kelly himself proposed the vote of thanks in his characteristic erudite and entertaining style.

Sustainable Energy

EPSRC's website explains: "The *Supergen* initiative is the primary delivery mechanism for sustainable-energy research". In the Department, under this initiative, Bartek Glowacki targets the *Delivery of Sustainable Hydrogen*, while James Elliott is in the *Fuel Cell Consortium*.....

In fuel cells, two essential components are the medium that lies between the electrodes and the catalyst that facilitates dissociation of the fuel at lower temperatures. Proton-exchange membrane fuel cells are an industrially important class, based on dissociation and ionisation of hydrogen, transporting the resulting protons from anode to cathode through a membrane. One of the most common membranes is based on the Nafion® family of branched copolymers of PTFE with sulphonic acid side-chains. Nafion® is attractive, but it is expensive and, needing adsorbed water for proton transport, is limited to temperatures < 120°C. Developed by DuPont over 40 years ago, Nafion® has a structural morphology still not characterised from the molecular to the macroscopic scale, but it does involve phase separation on a 3-5 nm scale (see figure, where blue shows the water channels). One part of James' project explores how the structure changes with water content, important in influencing the dissociation of hydrogen to proton and electron. Understanding should enable creation of low-cost, high-performance membranes. James' group gathers data from small-angle X-ray scattering and atomic-force microscopy, and uses maximum-entropy methods to reconcile these with thermodynamic and hybrid density-functional-theory calculations. This is a challenge with complex stereochemical configurations, but the agreement so far is encouraging. Next, investigation of the membrane-catalyst-carbon interface will aim to improve the contact between the catalyst and the membrane or the conductive scaffold, and to reduce the required amount of very expensive catalyst by as much as a factor of 100!



Metals-Minerals-Materials

While its origins in Cambridge research were much earlier, our subject first appeared in the Natural Sciences Tripos in 1943 as the Pt I half-subject *Metallurgy*, with focus on steel production and on aluminium alloys for aircraft. In 1965, combined with the half-subject *Mineralogy & Crystallography* given by the Department of Mineralogy & Petrology, this formed the full Pt IA subject *Crystalline State*, focusing on crystal structure and properties. This very successful course is remembered by many for its usefulness in later years in a wide range of solid-state sciences. Over the years, the course remained shared 50:50 with the Department of Earth Sciences (into which Mineralogy and Petrology had been absorbed). Its name evolved (to *Crystalline Materials* and then to *Materials and Mineral Sciences*), as did its content. But it proved difficult to accommodate mineral sciences, given the burgeoning nature of materials science, now encompassing not just alloys, but also polymers, ceramics, composites, electronic materials and biomaterials. Our new Pt IA course *Materials Science*, now run by our Department alone, started this academic year, and we look forward to yet more evolution in the teaching of our subject in the arena of first-year Natural Sciences, where we have the wonderful opportunity to attract talented chemists, physicists, and others, into our discipline.

The cracks are beginning to show

Bill Clegg was promoted to a Professorship of Materials Science in October but what steps led to this achievement? Following a BSc from Manchester, a DPhil from Oxford, a spell at the University of California at Davis and a Fellowship in the Oxford Department of Materials, Bill joined ICI in 1984 to start research in ceramics. He came here in 1992 and was elected a Fellow of Selwyn in 1994. How did Cambridge differ from his previous posts? Bill recalls that teaching was the great unknown when he started; independent observers know that he rose admirably to that challenge. He was "in at the start" of the Gordon Lab (opened in 1999) and also enjoys collaborations with others in the Department, around Cambridge, and indeed around the rest of the world. For example, we recall a project many years ago with Volvo on tough, layered ceramics (think abalone shells) resistant to thermal shock; the first project in which Bill's long-term technician, Robert Stearn was involved. Subsequently Bill was awarded the Verulam Prize of the Institute of Materials in 1998 for his work on layered ceramics. Now, following early work by Sandra Korte, there is an emphasis on the deformation and fracture of rather small volumes (micropillars) using a nano-indenter, with a flat punch. The size of a micropillar is so small that the stored elastic strain energy under load is insufficient to drive a crack through the material. And because cracks do not propagate it is possible to make dislocations move without applying such extremely high pressures that the dislocation core structure changes. This work is now being used in the Rolls-Royce/EPSRC Strategic Partnership, a major new initiative in the Department of which Bill forms a part. Other projects include a collaboration with the BP Institute, aiming to understand how stresses build up in a colloidal film as it dries, sometimes leading to distortion or cracking of the film. Bill's collaborations are structured so that members each offer skills and facilities that the others cannot because "the collaborations that work well are those involving genuine exchange traffic between members and I have always been very lucky with a great group". For more details see: **www.msm.cam.ac.uk/wjc/**

Bill lives - and gardens - in Coton and usually makes the daily journey to the Department and back on foot, a distance of about 2½ miles each way.

Congratulations

Colin Humphreys: Knighthood, Queen's Birthday Honours 2010
Bill Clegg: personal Professorship from October 2010
Zoe Barber and **Cathie Rae**: personal Readerships, from October 2010
Tony Cheetham: Honorary Degree, University of St Andrews
Sir John Meurig Thomas: Honorary Professorship, Dalian Institute of Chemical Physics, Chinese Academy of Science
Michelle Moram: Royal Society University Research Fellowship
Kevin Musselman: Junior Research Fellowship, Girton College
Rob Wallach: University of Cambridge Pilkington Teaching Prize
Oliver Croft: AT Green Award, IoM^3
Talia Gershon: Materials Literature Review Prize, IoM^3, and for captaining the blues CU Ladies Rugby Union team to a 25-0 win in the varsity match
Rowan Leary: Royal Charter Prize, IoM^3
Erika Oberg: 1st Poster Prize, Int. Conf. on Interfaces & Interphases in Multicomponent Materials (IIMM) 2010

Editorial team: John Leake, Lindsay Greer and Rachel Hobson
Comments to: **rjh24@cam.ac.uk**

The Department now has networking groups on *Linkedin* and *Facebook* sites. *Linkedin* is open to all who took a degree in Materials and/or Metallurgy and our *Facebook* group is open to any past members of the Department. Please request memberships via *Linkedin* or *Facebook*. As well as posting the occasional news story, we hope these fora will allow you to network with your former fellow students and colleagues.

Do you want to receive your copy of *Materials Eyes* electronically? If so, please email **rjh24@cam.ac.uk**. We will take you off the hard-copy circulation list and add you to an electronic list.

Diary Note!!

The next Armourers and Brasiers' Cambridge Forum will be held on Tuesday 14 June 2011 and will include the 13th Kelly Lecture to be given by Albert Fert (Univ. Paris-Sud), Nobel Laureate in Physics 2007, on the subject *Spintronics : electrons, spins, computers and telephones*. **www.msm.cam.ac.uk/forum/**