Cambridge
materialeyes

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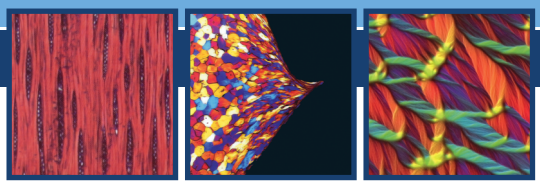
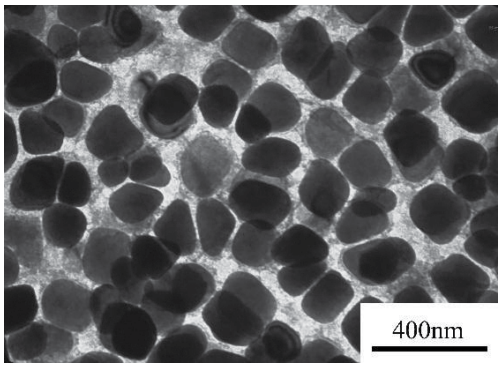


Superalloys:
super-hot and super-strong



The Rolls-Royce UTC (University Technology Centre) has maintained a close connection between the department and the company since it was set up 20 years ago. After many years in a hut, albeit beautifully refurbished, in the middle of the New Museums Site, the UTC is now housed within the Department's new building. Currently the research is carried out by six postdocs and over a dozen PhD students under the direction of Cathie Rae and Howard Stone. So far nickel-base superalloys for use as blades or discs in the hottest parts of aeroengine gas turbines - the turbine inlet temperature can exceed 1500°C - have formed the principal focus of their work with the aim of developing an even better understanding of the relationship between processing, microstructure, behaviour and performance. This electron micrograph shows a typical microstructure with a closely spaced array of small gamma prime precipitates.

In this nationally significant area it is important that the work of research groups around the country is coordinated and so the Cambridge group has been working in partnership with groups in Birmingham and Swansea since 2009. Last summer the Government announced a new five-year Strategic Partnership in "Structural Metallic Systems for Advanced Gas Turbine Applications" building on these universities as core partners plus additional input from groups in Manchester, Oxford, Sheffield and Imperial College. The Partnership is in the second half of a 10 year - £50m programme, jointly funded by EPSRC and Rolls-Royce with additional contributions from each of the core partner Universities. Howard Stone is the designated Principal Investigator overseeing the entire programme in the seven universities with overall coordination through close liaison with Rolls-Royce. In Cambridge the work will include not only the UTC but others in the Department and will focus mainly on the development of new materials including nickel alloys for discs, intermetallics for blades, steel for shafts and novel abrasive materials for blade tips.

In addition to the research, another national priority is to ensure a continuing supply of highly trained scientists and engineers in this area to move into industry on completion of their doctorates. Therefore EPSRC and Rolls-Royce will jointly fund an extension of the existing Doctoral Training Partnership (DTP) to support PhD students in the core university departments; Cathie Rae will lead for Cambridge in this DTP. Funding for the DTP is structured so that PhD students starting in the final intake in October 2015 will be supported for four years, thus coinciding with the currently scheduled completion date for the research Partnership.

Side-by-side with research and doctoral training will be efforts to raise public awareness of the importance of materials science to industrial progress. These will range from outreach activities in schools to regular briefing of the BBC's "Naked Scientists".

Editorial

Every six or so years, the government runs a research assessment exercise (REF) for all Departments in UK universities. The primary method of assessment is the rating of four papers submitted by academic staff from the assessment period into categories ranging from 4* "world-leading" down to 1* "recognised nationally". There are also new methods for measuring research impact mostly to do with commercial exploitation of research results which are graded in the same way. The results of the latest REF were published in December 2014 and the Department's overall average grade was 3.65 (UoA13 panel), with 69% of our submission judged worldleading. In numerical terms this not only makes us the top Materials Science department in the country, but in fact the top science department in any University. As is the way of these things, we have already started the census period for the next REF, but our two recent lectureship appointments, Jason Robinson and Sohini Kar-Narayan should provide the impetus to continue this success.

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Inside:

David John Duke MBE

(5 Feb 1948 – 29 Mar 2014)

In 1964 David Duke joined the Department of Metallurgy led by Alan Cottrell, and over the next 49 years David became an important and much loved thread of continuity through changes in Department name, buildings, staff and student cohorts. First working in different research groups, David will be best known to many of our alumni from his time as Assistant in the Process Laboratory, and in 1993 he was appointed Principal Technician (responsible for all aspects of departmental infrastructure, and head of the technical and assistant staff), a post he occupied until his retirement in 2013. Throughout his career, David was renowned for his resourcefulness, can-do spirit and indomitable good humour - all often needed, given the strains of research activity that increased some sixteen fold over his time in the Department, constrained by inadequate infrastructure in the old building. David's contribution to the Department's research success was recognised with a richly deserved MBE 'for services to science' in the 2010 New Year's Honours. His organisation of social events, including barbecues, Christmas extravaganzas, quizzes, his participation in DMSM sports teams, and his band 'Dave and the Saddos', all contributed immensely to Department life and spirit. David was also active in his village of Teversham, serving on the Parish Council 1987 to 2003, starting and then running the Junior Youth Club, and serving as a Governor of the Primary School. David is survived by his wife Marian, daughter Sandra and son Andrew.

The Dave Duke Memorial Appeal

It is planned to install a bench on the patio outside the new common room in memory of David Duke, recognising his central place in department life. With the money raised we hope to commission a bench made from stone and wood and have it suitably engraved.

Those interested in making a financial contribution to this project can donate online via the University web site: **www.philanthropy.cam.ac.uk/give-to-cambridge/david-duke-memorial**

Or, if donation by cheque is preferred, please contact Rachel Hobson for further information (rjh24@cam.ac.uk, 01223 334328).

Professor Anthony Kelly ScD FRS FREng CBE DL

(25 Jan 1929 – 4 Jun 2014)

An obituary of Tony Kelly will appear in the next Issue of *Material Eyes*.

In the News

Two of our younger members of staff have featured 'on air' recently. In mid-October, Sohini Kar-Narayan, Royal Society Dorothy Hodgkin Fellow and University Lecturer, took part in a panel discussion on the "Future of Energy" broadcast in the BBC Radio 5 Live Science series. Her contributions focused on her research on generating electrical power using piezoelectric and pyroelectric materials to harvest the energy available from ambient mechanical vibrations and temperature variations.

In June Krzysztof Koziol, Royal Society University Research Fellow, spoke in a programme on 'Power Transmission' in the BBC Radio 4 Frontiers series. He outlined the possibilities of developing highly effective electrical conductors based on carbon nanotubes either completely replacing copper or in combination with copper to form an ultrawire (see *Material Eyes* Issue 23). **www.bbc.co.uk/programmes/b046l80q**

Carbon Day

Last November the Macromolecular Materials Laboratory (MML) contributed to 'Carbon Day', a public outreach event organised by the Institute of Making at UCL. On the MML stand, attendees could assemble ball and stick molecular models of the different allotropes of carbon, play "assemble the pea-pod", and learn about the latest applications of carbon nanomaterials. In the model-assembly area, researchers from the MML assisted the participants in building models of carbon nanotubes, buckyballs (fullerenes), graphene, and diamond while explaining the differences and peculiarities of each material. The 'assemble the pea-pod' game allowed attendees to manipulate a live molecular dynamics simulation in real time with the objective of filling a nanotube with fullerenes, constructing a so-called nano pea-pod. Items only for display included a super strong and nearly invisible carbon nanotube fibre used both to support the weight of an LED lamp and to conduct the electricity to power it up and a graphene-based flexible luminous display (courtesy of the Cambridge Graphene Centre). The event ran for four hours and was a great opportunity for spreading knowledge and interest in carbon-based nanomaterials. MML participants were delighted with the interest and enthusiasm that people showed for our displays and hands-on activities.

High impact research

University submissions for the Research Excellence Framework (see page 1) included listings of research judged to have had particularly high impact. Two of the four projects submitted from our Department were in the ten or so highlighted by the University following the announcement of the results of the Framework exercise, see **www.cam.ac.uk/research/impact**. They were: 'Super Bainite' - high performance steel for armour (Harry Bhadeshia and colleagues) - and 'Lighting the Future' - manufacturing LEDs on large diameter silicon substrates (Colin Humphreys and colleagues). The same two projects feature in issue 14 of the EPSRC's journal *Pioneer*.

ABC Forum 2014

2014 saw a change of venue for the Forum. The whole of the building that houses the Babbage Lecture Theatre is currently undergoing major refurbishment so the Forum was based in the Pippard Lecture Theatre in the Cavendish Laboratory. Although some distance from the centre of Cambridge, this location had the advantage of easy access to our Department's new building. In welcoming all participants to the Gordon Seminars, Professor Bill Bonfield noted the geographical spread represented, thanked the sponsors warmly for their invaluable help, which makes free attendance possible, and welcomed the new Clerk of the Armourers & Brasiers' Company, Peter Bateman.

Stuart Clarke (BP Institute, Cambridge) discussed a range of solid/liquid interfaces studied by neutron reflection, sometimes augmented by atomic force microscopy, and in some cases including the effects of temperature and shear. For example, up to 60% of oil in a well remains stuck to the rock when the well is closed; a better under-standing of the oil/rock interface could lead to improved oil recovery. Among other applications, the surfaces of medical implants have been examined successfully.

John Saffell (Alphasense) introduced chemical sensors, focusing on examples of industry-university collaboration. Measurements of air quality require a sensitivity approaching 1 in 10; this can be achieved using a stable, selective catalyst; careful high-resolution electron microscopy is required during their development. Over 40 detectors monitor gaseous concentrations around Heathrow. In cities other detectors monitor particulates. Detectors may soon be linked via the cloud.

Turning to steels, **Francisca Caballero** (CENIM-CSIC, Madrid) explained the use of nanoscale methods to develop nanocrystalline steels. The transform-ation to bainite occurs at a relatively low temperature and is slow but industrial production should ideally take less than 10 hours. Additions of Mo, Cr or Co have been found to help. Amongst other features, thorough microstructural studies revealed carbon trapped by nanoscale twins and three forms of retained austenite.

Following tea and an opportunity to study posters displaying current research in the Department, **Bill Lee** (Imperial College) addressed the materials demands of new nuclear power stations, including fast breeder reactors, and the continuing exploration of fusion power. The UK's priority themes include fuels, reactors, recycling, modelling and more. Different classes of materials must be investigated, including refractory alloys and accident tolerant fuels, along with joining and non-destructive evaluation. University teaching (undergraduate and postgraduate) must be included.

Véronique Michaud (EPFL, Lausanne) reviewed the development of smart composite materials, noting the need to lower processing costs and enhance functionality. Developments include the production of materials that provide tailored damping, e.g. to reduce noise from rotor blades, and others capable of detecting and repairing cracks forming in their matrix. Ensuring the integrity of the interface between the active element and the host material is challenging.

Following the seminars, Bill Bonfield, chair of the judging panel, summarised the history of the Armourers & Brasiers' Venture Prize, noting that four of the six winning companies so far are flourishing. Five applicants were short-listed this year. The winner, announced by Jonathan Haw, Master of the Company, was Sirakoss Ltd, a bio-materials company spun out from the University of Aberdeen. Professor **Iain Gibson**, the Principal Investigator (pictured below), described their work towards the creation of novel bone grafts from synthetic materials with the potential to replace diseased or damaged bone in humans, now granted as a US patent.

Made-to-measure surfaces

After an informative tribute to Tony Kelly to mark his death barely two weeks before the Forum, Lindsay Greer introduced this year's Kelly Lecturer, Professor **Nicholas Spencer** from ETH Zurich.

For the first time the subject was not 3-d materials but their 2-d surfaces and the aim was to tailor surfaces to achieve a combination of ideal bulk properties with ideal surface properties including, for example, wettability, wear resistance or corrosion resistance. The surfaces described included self-assembled monolayers (SAMs) and surfaces with chemical and/or morphological gradients oriented along one or two dimensions.

Some SAMs consist of polymer molecules attached to a metal surface to form a 'polymer brush', which can retain a lot of solvent or other molecules close to the surface. The interaction of two surfaces covered with such brushes has been used to examine the phenomena of continuous and discontinuous shear thickening, the latter a cause of problems when, for example, pumping cement slurries.

By patterning SAMs on surfaces the effects of chemistry and topography can be separated. For example an ultraflat surface has been created consisting of small, sharply separated, alternating regions of gold and titanium. Amongst other things, such surfaces provide a test of techniques such as X-ray Photoelectron Spectroscopy (XPS).

Particularly impressive were the studies of gradients on surfaces; these included chemical gradients (sometimes involving two components with antiparallel gradients) or roughness gradients or both simultaneously, applied orthogonally. Surfaces with a roughness gradient created by sintering negatively charged silica nanoparticles onto positively charged poly(ethylene-imine)-coated silica surfaces with a steadily varying particle density were used to study the response of osteoblasts; they showed considerable systematic variation from the particle free region to the most densely covered region. Finally he showed a short movie elegantly demonstrating the motion of a droplet on a surface with a wettability gradient before presenting an impressive summary slide.

Traditionally Tony Kelly himself would have proposed the vote of thanks. In his place Alan Windle congratulated Nic Spencer on the skill demonstrated by his research and on the beauty of the resulting images. Prompted by a picture of Nic Spencer's research group on the Aletsch glacier he recalled that the same glacier featured in a paper on the friction of snow and ice by Frank Bowden in 1953, in which the series of weights used apparently coincided with the then weights of members of his family.

The Armourers and Brasiers Cambridge Forum 2015 will be held on Tuesday 16 June. For details, please see:
www.msm.cam.ac.uk/forum

Glasses and Grains: arrowing in on nucleation

The Part II Class of 1975-76, the first under the combined title of "Metallurgy and Materials Science", formed a memorable group. Their names can be found in *Light Blue Materials* and include one of the authors of that volume, Lindsay Greer, an accomplished archer who gained his half-blue captaining the University Bowmen. Lindsay was at Trinity Hall where Mike Stobbs was his Director of Studies. A PhD with John Leake on transformations of metallic glasses led to election to a Research Fellowship at Churchill but the attractions of David Turnbull's group at Harvard proved irresistible. Lindsay spent four very successful years there, becoming an Assistant Professor, before returning to a post in our Department in February 1984 and, soon afterwards, taking up a teaching Fellowship at Sidney Sussex.

In almost four decades since he started work on metallic glasses the field has developed dramatically from very thin melt-spun ribbons to bulk metallic glasses, leading in turn to a significant expansion of actual and prospective applications (perhaps your next smart phone will have a metallic-glass case). Of course the glassy state is not truly stable but how may its state change, at what rate and how may its stability be maximised? After studying structural relaxation, Lindsay focused on understanding the nucleation of crystalline phases. Wider studies of nucleation culminated in the publication, with Ken Kelton, of a monograph on the subject in 2010. Investigations of nucleation and other phenomena in metallic glasses, notably mechanical properties, have led to many international collaborations. Recognition of his work has resulted in his becoming a member of a number of advisory boards overseas and receiving several awards, including the Bruce Chalmers Award from the TMS in 2012 and an honorary doctorate from AGH University of Science and Technology in Cracow in 2014 (Lindsay is pictured left with the Rector of AGH).

Lindsay sees teaching as "the most important bit of what we do" and has always made substantial contributions at all levels. Many other aspects of life in the Department, the University more widely and in his College help to keep Lindsay's diary full. In recent years, his two most demanding roles (both now completed) have been Vice-Master of his College and Head of Department. That period saw several successes, notably the endowment of new professorships, and chart-topping entries for RAE2008 and REF2014, but, above all, his time was dominated by overseeing the planning, construction and occupation stages of the new building, bringing many challenges along the way. It is to Lindsay that the building owes one unusual and pleasing feature, the carefully designed and skilfully laid patterns in the external brickwork, which represent a hugely magnified microstructure and which show up so well in the almost horizontal illumination from the west late on a fine autumn afternoon. But truth will out: as a schoolboy in Ballymena in Northern Ireland his second preference for possible career was architecture!

Congratulations

Sohini Kar-Narayan, Lectureship from January 2015
Jason Robinson, Lectureship from January 2015
Vasant Kumar, Readership from the 1st October 2014 and Kroll Medal, IOM3
Tony Cheetham, Member of the American Academy of Arts and Sciences
Lindsay Greer, Honorary Doctorate, AGH University of Science and Technology, Cracow
Bill Clyne, Helmholtz International Fellow Award
John Meurig Thomas, The Blaise Pascal Medal for Materials Sciences, European Academy of Sciences; Ahmed Zewail Prize in Molecular Sciences 2015, Elsevier
Alex Eggeman, University Research Fellowship, Royal Society

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

The Department has networking groups on *LinkedIn* and *Facebook*.
If you would prefer to receive your copy of *Material Eyes* electronically please email rjh24@cam.ac.uk