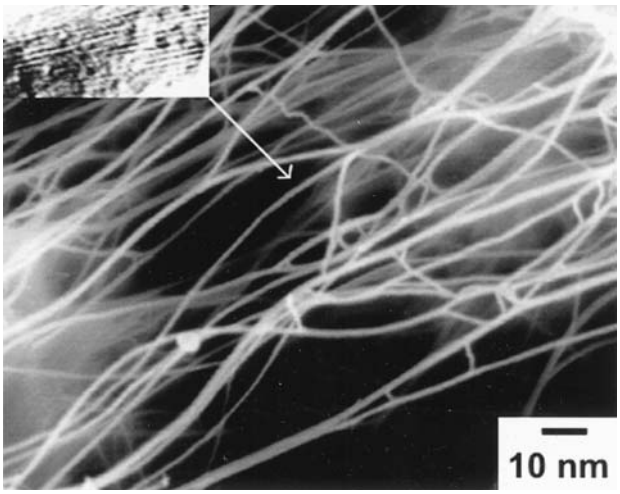
Cambridge material eyes

Winter 2003/4 Issue 13

Nanotubes by the tonne . . .



A laboratory scale process for synthesising carbon nanotubes has led to the development of one of the major processing plants in Europe – and it has all happened in the space of two years. The patents for the process are owned by Cambridge University and licensed to Thomas Swan and Co Ltd, a leading performance and fine chemicals manufacturing company, which is commissioning an industrial-scale carbon nanotube plant.

Professor Alan Windle explains:

"Nanotubes now have the potential to rival carbon fibres, as they can be made very simply through the pyrolysis of common hydrocarbon feedstocks. The process we have developed is to make single-walled nanotubes, which have traditionally been the biggest challenge to form, but are now required on a tonnage scale in order to be commercially useful.

"There are many different ways of making nanotubes: if one starts with graphene sheets as the precursors then these, given the right conditions, can re-form as nanotubes. The most promising method seems to be to grow them from Fe, Co or Ni particles, less than 10 nm in diameter. However as one sprays these nanoparticles into a gas, or deposits them on a substrate, they tend to agglomerate, and we have to stop this happening. The actual mechanism of growth is still a matter for conjecture – it is most likely that it involves the nucleation of graphene sheets at the surfaces of the metal nanoparticles.

"Single walled nano-tubes are actually very similar to polymer molecules: the diameter of a nanotube is only about twice that of a typical polymer molecule. They are however very much stiffer than most polymer molecules, so important clues to processing have come from very rigid polymers such as the Kevlar™ molecule, where the key to formability is the addition of a liquid phase to create a lyotropic crystalline phase.

"When synthesis is carried out using a polymer on silica, we can grow carpets consisting of multi-walled tubes some 20 nm in diameter but with a length/diameter ratios of up to 10^4! These 'carpets' have properties suited to high specific surface area electrodes. Working with Derek Fray and George Chen we have coated the nanotubes with polypyrrole, and Mark Hughes has demonstrated the potential of a thin 'wafer' type capacitor with a specific capacitance of greater than 2 farads/cm^2. Such a device would have applications to deal with peaks of power requirement which are a problem for batteries and fuel cells, and indeed to replace batteries in simple applications such as small toys."

EDITORIAL

May you live in interesting times …

One of the trials of University life is that it feels like a continual assessment of our activities by external organisations. It isn't quite as bad as that of course, and such exercises do provide the opportunity for us to present our achievements and take a strategic look forward.

The 2001 Research Assessment Exercise involved the evaluation of our research, primarily the quality of our publications and other factors such as student numbers and research income. As in the previous exercise the Department was delighted to be awarded a 5* - there were five 5* materials departments out of 30 which were the total number assessed. In a recent refinement of these results, a group of 6* departments was created to identify those who got 5* in the previous two assessments or who have improved significantly since the last exercise. We are now a 6* department which is good news in this time of educational inflation!

Such successes have a direct impact on the University's financial situation and although Cambridge has maintained its research standing, as reported in the press the University as a whole is running a substantial deficit and our internal financial systems are under review. This could lead to significant changes in how resources are deployed – another trial of university life these days. In addition, several of our senior staff retire over the next few years and it is imperative that we continue to nurture the next generation of outstanding young academics despite the University's difficulties. One approach is to build endowment funds to support academic posts so that we can maintain our place at the forefront of Materials Science.

This year we are able to welcome Dr Judith Driscoll as a lecturer in the Department from Imperial College, where she was a Reader in the Materials Department. She was a graduate student in Cambridge in the late eighties.

We have also been gratified that several of our post-doctoral researchers and junior academic staff have obtained positions in other Universities. (see congratulations on back page)

Finally, we must welcome Dr Alison Richard as our new Vice-Chancellor and express our enduring gratitude to her predecessor Sir Alec Broers for his unstinting service to the University.

Interesting times indeed and we look forward to the new academic year.

Contents

DoITPoMS

Finding the appropriate micrograph to use is often the most time-consuming element in the preparation of teaching materials for Materials Science. The Micrograph Library which has been set up under the 'DoITPoMS' project could be just the job to make life a bit easier for lecturers.

The 'Dissemination of Information Technology for the Promotion of Materials Science' consortium project is funded by HEFCE/FDTL to develop web-based resources aimed at supporting the teaching and learning of Materials Science. Two main resources have been produced to date: a Micrograph Library and a Library of Teaching and Learning Packages (or TLPs). The project is led by the University of Cambridge (Professor Bill Clyne and colleagues) in partnership with the following universities: Leeds, Manchester, London Metropolitan, Oxford Brookes and Sheffield.

Dave Hudson has been responsible for building the websites to support the resources. Dave explains the philosophy behind the project: "The resources we have produced are freely available for all students and teachers to use. The Micrograph Library is potentially a very valuable resource, providing a fully searchable collection of over 700 good-quality micrographs representing all the main categories of materials.

"Each micrograph has stored with it descriptive information, including keywords, system, composition, processing, microscopy technique, etc. All micrographs carry length bars. This information helps with the correct interpretation of micrographs and enables more powerful searching of the Library, which can also be browsed by systems, compositions and keywords.

"All binary alloys represented in the Library are linked to an interactive phase diagram. Keywords are linked to the corresponding entry in a new web-based version of the MATTER Glossary of Materials Science where this exists. We plan to maintain and supplement the Library, and welcome further contributions to it.

"In addition, we have produced a collection of self-contained teaching and learning packages (TLPs), each focusing on a common topic in undergraduate materials science teaching. These TLPs include video clips of experiments, questions and answers, and references for further study.

"The TLPs have largely been produced with the help of students from the Department working during summer vacations. The students seem to enjoy producing the TLPs themselves, and many of those involved have stayed on to work towards a PhD. The Armourers and Brasiers' Company provided additional funding for this work, for which the Department is most grateful. Indeed, one of the students, Derek Holmes, was awarded the Armourers and Brasiers' Alcan Prize for his project report in their national competition."

The 12 TLPs completed to date include: Atomic-Scale Structure of Materials, Beam Stiffness, Introduction to Dislocations, Fracture: the Effect of Flaws, Phase Diagrams and Solidification, and Diffraction Imaging.

Further information (and feedback forms) are available at the DoITPoMS project web sites:

www.msm.cam.ac.uk/doitpoms

The results of the project, now in its concluding phase, are being demonstrated to the wider community through workshops and demonstrations. The first of these workshops was recently held in Cambridge, and was a sell-out, with around 50 participants from all over the UK.

Made to measure

A research project that began by seeking to improve the thermal stability of optical devices has led to the development of a new type of structure that can be custom-made to produce a given thermal expansion coefficient. Dr Bill Clegg explains: "Initially we wanted to develop a material or structure that would compensate a Bragg grating for changes in temperature. These gratings can be used as filters in optical telecommunications and a change in temperature would cause the wavelength filtered to change. The idea is that the optic fibre would be fixed to the structure as shown in figure 1, which shows just one of the structures we developed, and the structure would apply a strain to the optic fibre that would compensate for the temperature changes.

"This one consists of a rod of one material, fixed to, say, a square frame of another material at its corners. When the temperature rises, the two materials used for the unit will expand by different amounts distorting the original frame. The distortion caused is dependent on the relative thermal expansions of the two component materials. By selecting an appropriate combination of materials or shape of frame, it is possible to make the original frame contract or expand by a given amount.

"We soon realised that a number of these units could be joined together to create an array, in either two or three dimensions. This approach allows the development of a wide range of structures with properties that can lie well outside those usually attainable in materials and which can be modified simply by changing the shape or the arrangement of the basic elements. We have made materials with thermal expansion coefficients as low as -500×10^{-6} K^{-1} has been made using Invar™ and aluminium as the two dissimilar materials in the initial starter unit. The structure's cheap and easy to make and it is not restricted to thermal expansion. You could use any property that would give a differential length change, piezoelectricity for instance and make actuators.

"We can also modify the structure so that it can be used as an interlayer between dissimilar materials to relieve stresses that occur on heating or cooling.

"A group of us are now trying to develop these structures and we already have a number of possible application areas in which such a new material might be used. These include new fuel cell and sensor technology where thermal shock resistance is required, and electronic and high precision applications where thermal expansion can cause premature failure, and we are actively looking for others."

Collaboration and licensing relationships for the commercialisation of this exciting technology are now being sought. More information is available from the Technology Transfer Office.

Email:
malcolm.grimshaw@rsd.cam.ac.uk

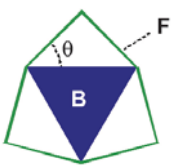


Figure 1 An example of a basic element used for making the structures described here. In this case the block, B, is triangular and the frame, F is hexagonal. The angle θ is critical.

Work on this project was carried out by Dr Bill Clegg, Dr Luc Vandeperre, Derek Holmes, Prof. Tony Kelly and Dr Vasant Kumar. Alison Howlett is studying how the individual elements deform as part of a PTP project in collaboration with Drs D. J. Pedder and J. Fernie at TWI.

Generous Support from the Armourers and Brasiers Provides a Forum for UK Materials Science

The Worshipful Company of Armourers and Brasiers has agreed to sponsor an annual event to be held at the Department of Materials Science and Metallurgy to raise the profile of materials science in the UK academic and industrial communities, while being international in scope. To be known as the Armourers and Brasiers Cambridge Forum, the event will follow the format of the very successful Open Days held in recent years by the Gordon Laboratory; these Open Days have attracted high-level involvement from industry, research councils and other influential bodies such as the European Commission. The day consists of poster displays showing the wide range of research in the Department, a short series of talks from leading researchers from around the UK, the Kelly Lecture, and a dinner in a Cambridge College.

The Kelly Lectures

The Kelly Lecture has rapidly become a well recognised international event. Each year a world-leading researcher is invited to speak on a major area of materials science. This year, the fifth Kelly lecture *'Bulk Nonequilibrium Alloys by Stabilization of Supercooled Liquid: Fabrication and Functional Properties'* was given by Akihisa Inoue, Director of the Institute for Materials Research (IMR), Tohoku University, Japan. The IMR has more citations to its research in the scientific literature than any other materials laboratory, and Inoue himself is among the most cited materials scientists world-wide. He is famous for developing novel metallic materials for structural and magnetic applications.

ABC Forum 2004

Next year's event will be on Wednesday 9th June. The Kelly lecturer will be Professor Herbert Gleiter, Director of the Institute of Nanotechnology, Research Centre Karlsruhe, Germany. Professor Gleiter is a world leader in the fast-growing field of nanomaterials.

Professor Lindsay Greer comments:

"The Armourers and Brasiers Company is very generous in its support of Materials Science in several UK universities. At Cambridge we have benefited from the provision of bursaries and prizes, and support for project work by our undergraduates in the UK and on the Continent. We are absolutely delighted that the Company has agreed to sponsor the Forum which will provide very useful opportunities for high-level networking to promote materials science in the UK, and for showing the quality of UK materials science on a world stage."

For details of next year's event please contact Prof. Greer, or visit the Department web site at http://www.msm.cam.ac.uk

Prof. Tony Kelly presenting Prof. Akihisa Inoue with a plaque commemorating his lecture on 12 June 2003

Sensor success

A sensor capable of detecting the presence of hydrogen in molten aluminium has been developed in the Department, and is now being commercialised by Environmental Monitoring and Control Ltd. and Foseco Ltd. The solid-electrolyte sensor based upon the proton conductor $CaZr_{0.9}In_{0.1}O_{3-\delta}$ containing a reference of zirconium and zirconium hydride has been developed by Carsten Schwandt and Derek Fray. This sensor is totally solid-state and responds instantaneously to hydrogen when immersed in molten aluminium.

Molten aluminium and its alloys can easily pick up hydrogen from humid air by the reaction of the aluminium with water vapour to give alumina and hydrogen that dissolves in the liquid metal. On solidification, the solubility of hydrogen in the metal decreases dramatically resulting in porosity. As many aluminium alloys are used in the aircraft industry, it is important that the number of defects is minimised. As the pick up is a continuous process, on-line analysis is required but conventional methods are not particularly convenient.

The sensor technology developed in the Department was transferred to a spin-out company Environmental Monitoring and Control Ltd. (EMC). The sensor was incorporated into a robust lance and the software developed to create a user-friendly measuring instrument. The response from those using the sensors in extensive trials being undertaken by Foseco Ltd. has been very positive. EMC is currently sponsoring a student in the Department, Mathew Hills, supervised by Vasant Kumar to investigate further the properties of the electrolyte and the sensor.

For further information, please contact Professor Derek Fray djf25@msm.cam.ac.uk

Miracle Man . . .
– a profile of Professor Colin Humphreys

Professor Colin Humphreys has a way with words and an abundance of energy which he uses to promote his passions. These have ranged from microdots and memory metals to gallium nitride and, most recently, the miracles of the Old Testament. He seems always to be making the headlines.

Colin Humphreys graduated from Imperial College before coming to Cambridge to complete his PhD at the Cavendish Laboratory, in 'Aspects of multiple beam electron diffraction and X-ray diffraction topography'. He then moved to Oxford and worked both in theoretical and practical aspects of electron microscopy before accepting a Chair and becoming Head of Department in Liverpool.

He moved back to Cambridge in 1990, to a newly created Chair, taking over from Derek Hull as Head of Department in 1991. He brought two high resolution electron microscopes with him from Liverpool and initially concentrated on electron microscopy of semi-conductors. He then became Director of the new Rolls Royce UTC, which led to an involvement with aerospace materials. ("I think it is good to change your research direction from time to time", he says.)

His involvement with gallium nitride started in 1999 when Thomas Swan, a local company, offered the Department a GaN growth system. "It was a steep learning curve, but we now have an excellent facility producing the new material and an EPSRC research grant of around £1.2M to develop applications." A recent full page article in the Guardian shows how successful he has been in promoting the new material which has applications ranging from long-lasting light bulbs to detecting cancer cells.

As well as all this, Colin has found the time to write a popular book called 'The Miracles of Exodus' in which he explains the science behind the Old Testament stories and in the process, re-plots the likely route taken by the Israelites, fleeing from Egypt. "I wrote it over about two years", he says, "writing every night between 9pm and midnight."

Currently President of the Institute of Materials, Minerals and Mining, he is keen to promote Materials Science in schools, and is backing the launch of a new A-level in Materials Science which will encourage young people to be aware of the subject; and that can only be a good thing.

Professor Humphreys, a Fellow of Selwyn College, is married with two daughters.

The Miracles of Exodus is published by Continuum at £16.99.

For any comments about this newsletter or alterations to your address, please contact Carol Ann Monteith by e-mail cm259@msm.cam.ac.uk

Congratulations to:

Professor Colin Humphreys on being awarded a CBE, in the New Year's Honours List, the Robert Franklin Mehl Gold Medal and on being the 2003 Institute of Metals Lecturer.

Professor Bill Bonfield on his election to The Royal Society and being the first to be awarded the Chapman Medal from The Institute of Materials, Minerals and Mining.

Professor Tony Kelly on receiving an Honorary Degree of Doctor of Science from the University of Reading.

Professor Derek Fray on being elected a Fellow of Royal Society of Chemistry and on the award of the Gold Medal 2003 from The Institute of Materials, Minerals and Mining.

Prof Harry Bhadeshia for being awarded the Brooker Medal 2002 by TWI and the Sawamura Award from the Iron and Steel Institute of Japan (awarded jointly with Dr Nobuhiro Fujita).

Professor Sir John Meurig Thomas on being awarded the Linus Pauling Gold Medal by Stanford University and the Giulio Natta Centenary Medal, in recognition of his contributions to catalysis, by the Italian Chemistry Society.

Professor Robert Cahn on being awarded the 2002 MRS David Turnbull Lectureship.

Dr Paul Bristowe on his promotion to a Readership in Computational Materials Science.

Dr George Chen on being appointed to a Readership in the School of Chemical, Environmental and Mining Engineering, The University of Nottingham.

Dr Milo Shaffer on being appointed to a Lectureship in the Department of Chemistry, Imperial College.

Dr Francis Tailoka on being appointed to an Associate Professorship at the University of Pretoria.

This newsletter is written by Dr Sue Jackson, produced by Carol Ann Monteith and printed by L & R Print Ltd.