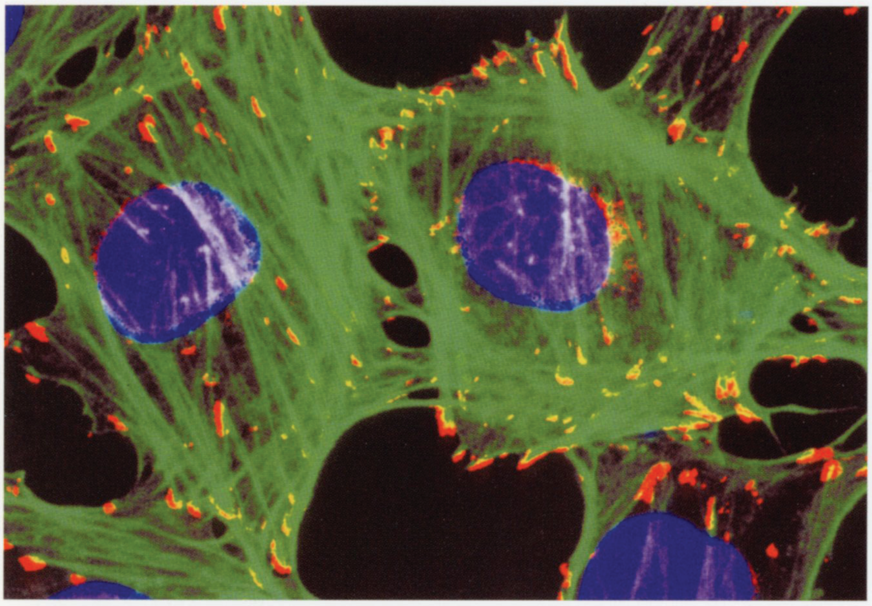
Cambridge material eyes

Summer 2000 Issue 9

Body building



Confocal microscope image of human osteoblast cells attaching to an HAPEX™ surface (purple-cell nucleus, green-cytoskeleton, orange-adhesion molecules) scale-nucleus diameter = 25 μm.

'Bone is alive, it has cells and we continually make new bone. However, unless we make materials which are also 'bio-active' in that they encourage bone to grow towards the implant surface, then implants using synthetic materials will have only limited life,' explains Professor Bonfield. Such materials are referred to as biomaterials and one of the key biomaterials is hydroxyapatite, a calcium phosphate ceramic which is a major constituent of bone and can now be produced synthetically in the laboratory. This type of material has already been used as a bone substitute for filling in skeletal defects as described in the accompanying article (Skeleton Key).

The next step in the development of this type of bone substitute was the development of a bioactive hydroxyapatite–polymer composite as an artificial bone that can be cut with a scalpel, thus allowing a surgeon to shape the bone to fit. This is of particular advantage for the fitting of middle ear prostheses, as the middle ear space is individual to each patient. The clinical success of such prostheses relies on the surgeon being able to fit precisely the middle ear space. By mechanically matching the properties of the real and artificial bone, it was shown that bone-making cells adhered to the implant surface to make new bone matrix. An IRC was set up in London in 1991, headed by Bonfield, which allowed the technology to be advanced from laboratory scale to a clinically licensed product (HAPEX™). Since its launch in 1995, 22 different types of middle ear prostheses have incorporated a HAPEX™ trimmable shaft.

These types of biomaterial are examples of tissue engineering which can also involve developing bone matrix outside the body. Following the success of developing bone substitute material for minor-load-bearing applications, Bonfield and his colleagues in Cambridge, plan to extend the research to the point where they can construct biomaterials compatible with every part of the human skeleton, with substantial benefit to all.

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A Bright Future

On July 20th the Department celebrated the opening of its latest partnership venture with Thomas Swan Scientific Equipment Ltd and the EPSRC. It will focus on the science and technology of GaN which is the most promising inorganic material for blue light LEDs and lasers. While reds and greens are possible with several materials it is the achievement of blue that opens up the possibility of low power consumption white light through the use of fluorescent coatings. The tabloid press made much of the 'everlasting light bulb' in their coverage of the event, but the true impact of multi-coloured LEDs will be much wider. The Department's role in the partnership is much more that of a developer than of an inventor. It will marshal its own considerable electron microscopic expertise, under Colin Humphreys, and interface it with the new on-site MOCVD processing facility provided by Thomas Swan. The structure and defect levels in GaN will thus be studied in materials made on commercial scale equipment, with the objective of designing and fabricating prototype devices.

The facility was opened by Dr John Taylor, the Director General of the Research Councils, in the presence of the Vice Chancellor. Dr Taylor underlined the increases in funding for UK science just announced in the Government's spending review. The amount of extra money is about £1bn, which represents an increase of 7% pa over three years. A significant part is earmarked for new buildings, and PhD stipends will increase to reach £9000 by October 2003. Of course there is much fine print, and 2003 is an election away, but the encouragement is most welcome. We are grateful to both John Taylor and to Sir Alec for their very successful representation of science in high places.

AHW

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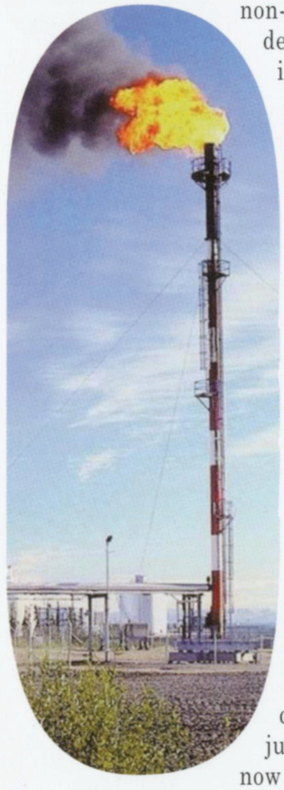
This newsletter is edited by Sue Jackson, produced by Navini Nynan and printed by ABS Print Services Ltd.

Sweet and Sour

The presence of diffusible hydrogen in steel can lead to a variety of problems in service, including the occurrence of the well-known phenomenon of hydrogen cracking, particularly in the vicinity of welded joints. Until recently there was no non-destructive technique available that would reliably detect the presence of diffusible hydrogen. The steel industry therefore developed techniques for minimising its presence, such as baking steel plates after processing or storing them in dry conditions prior to release, both costly processes.



Professor Derek Fray started working on the problem in 1990 together with a research student, Jan Stekly. "The technology for detecting the presence of hydrogen using sensors has been around for many years." explains Derek Fray. "What no-one realised was that by using such sensors to sample the air above a steel plate, the presence of diffusible hydrogen can be detected in a matter of seconds, giving a wonderfully simple non-destructive testing technique." Further research was carried out by Dr. Frank Dean and the sensor device was then developed at Ion Science, a company set up to develop sensor technology by Derek Fray and some colleagues in 1989. Dr. Frank Dean was employed on a LINK project concerned with hydrogen sensing in steel. Dr Frank Dean was employed on a LINK project concerned with hydrogen sensing in steel and, in conjunction with Derek Fray, invented this device. He is now manager of the division, at Ion Science Ltd devoted to the exploitation of this device. This local company employing some 20 people has now developed a monitor called Hydrosteel, which can detect the presence of diffusible hydrogen and measure the quantity present in a matter of minutes.

The 'Hydrosteel' sensing device is hand-held, weighing only 1.2 kg. A magnetised collector plate is attached to the steel plate or pipe and the diffusible hydrogen from a well-defined zone between the steel and the collector is swept into the sensitive analyser. Use of this device will not only save steel suppliers a lot of money, but will also offer considerable benefits to the oil industry.

Hydrogen cracking is a particular problem for the oil industry as oil from some reserves contains hydrogen sulphide, known as 'sour' oil. Hydrogen, a by-product of the corrosion process, can penetrate steel pipelines during service, causing hydrogen cracking, which can be difficult to detect and costly to repair. Use of the detector on pipelines can ensure that the inhibitors added to prevent this problem are working effectively.

For further information, please contact Professor Derek Fray
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Part III Graduates in Materials Science and Metallurgy

Elizabeth Wynne and Tom Quested receiving the Amourers and Braisiers' Medal and Institute of Materials Prizes respectively from Professor Alan Windle in June 2000.

Skeleton Key

One of the problems with operations such as hip replacements or even the mending of broken bones using surgical pins, is that the tissue surrounding a conventional implant made of ceramic or metal does not interact with it over time. Without a physical link between the implant and the bone, general wear mechanisms come into play over time and the implant becomes loose often making another operation necessary to repair the damage.

Dr Best and Josephine teaching Pt IA.

The development of a new range of 'Bioactive' materials is aimed to overcome such problems by more closely mimicking the tissues they are replacing. Dr Serena Best explains: " The mineral component of bone comprises a calcium phosphate compound similar in composition to hydroxyapatite. However, if you look carefully at bone mineral, you find that it is a reservoir for all sorts of ions from the body. If similar ions are added into the hydroxyapatite structure, they can make the material more biologically active, switching on the cells in surrounding tissue that are responsible for laying down new bone cells. The ions can also affect the solubility of the material they are in. By working with the chemistry of hydroxyapatite, we are aiming to fully understand and optimise the effects of adding the appropriate ions into the material to make a biological substitute for bone that will be accepted by the body and speed up the process of bone integration."

The research so far has shown that these materials do encourage cells to put down new bone, so the next step is to look at ways of using these materials successfully in a variety of different forms for defect filling and encouraging bones to mend themselves. At present the bone damage caused by wear has to be replaced either using bone extracted from the patient's pelvis or from a cadaver, so a synthetic replacement material will be hugely welcome.

The draw back of these bioactive ceramics, however, is their inferior strength and toughness. One way to overcome this potential limitation is to develop these materials as bioactive glass ceramics or as composites. With the potential of controlling composition and microstructure of these materials in this way, it is hoped to produce high toughness implants which can be easily shaped. The new bioactive materials are being tested in association with Addenbrookes Hospital.

For further information, please contact Dr Serena Best on
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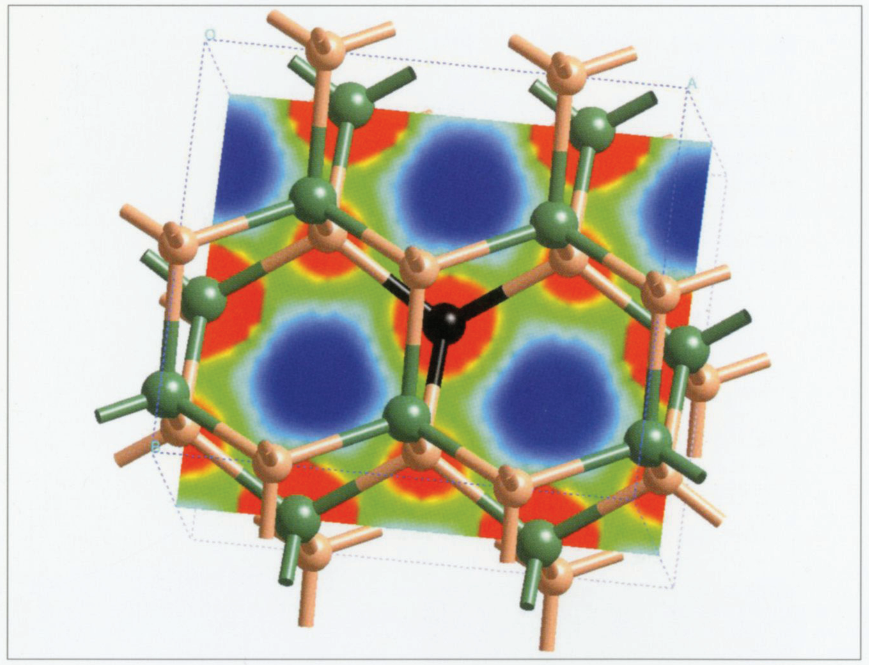
MPhil in Modelling of Materials

The first MPhil in Materials Modelling to be offered in this country has just been launched by the Department. "Computer modelling is now recognised in industry and academia as a *bona fide* research tool that can usefully complement experimental observation" explains Dr Paul Bristowe. "The materials scientist needs to be aware of the many computational techniques that are available and to be able to apply the most appropriate one for a given materials problem. The new course fills an educational gap in this area and will provide training on the requirements, possibilities and limitations of a wide range of computational models in materials science. Techniques covering the engineering scale right down to the atomic level will be dealt with. The course is interdisciplinary and will also involve other departments in Cambridge as well as participation from industry through seminars and research projects."

"Computer modelling can be either used to predict or explain the behaviour of materials. One recent project is the modelling of defects in gallium nitride (GaN), which is an optoelectronic material used for its ability to emit blue light (see Material Eyes, Autumn 1999). The optical properties of the material are influenced by crystal quality and the presence of defects. A recent experimental study has suggested that doping GaN with silicon will increase the density of stacking faults. By building a computational model we can understand at a fundamental level and predict how any substitutional impurity will influence the formation of stacking faults in this material. The work has practical implications in determining how GaN devices are made."



Calculated electron density distribution through a section of GaN containing a carbon impurity (black atom). High density is shown red, low density is shown blue.

The Department of Materials Science already has considerable expertise in materials modelling. Most research groups use some form of modelling. and most length scales and techniques are represented. They range from atomistic modelling of crystal defects (Paul Bristowe) to microstructural modelling of phase transformations (Harry Bhadeshia) to the macroscopic modelling of fabrication and joining processes (Rob Wallach). The new course is designed to attract students from all areas of the physical sciences and so will be broad-based allowing for students from different backgrounds. The topics and projects are closely linked to industrial interests, supporting companies including Corus, Rolls Royce, Unilever, Alcan, Siemens and Huntsman. The EPSRC are sponsoring 10 studentships.

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Out of the Fiery Furnace

Students from 1960 onwards will remember Dr Jim Charles, now retired but still active in the Department. "Out of the Fiery Furnace" (Institute of Materials Book No. 729, ISBN 1861251068) is an account of his professional career. It includes histories of the Metallurgy Departments both at the RSM and in Cambridge, his time in industry, academic research and archaeometallurgy.

Department of Materials Science and Metallurgy

On a fast track – a profile of
Professor Bill Bonfield

Bill Bonfield competing in the 120 mile 1999 L'Etape du Tour de France

Professor Bill Bonfield, newly appointed Professor of Medical Materials is excited by the prospect of setting up a world class research centre at Cambridge.

He has come from Queen Mary and Westfield College, London, where he was both Professor of Materials and founding Director of the Interdisciplinary Research Centre (IRC) in Biomedical Materials. He started the IRC in 1991 with three people, and in the space of nine years it had grown to employing over 120. One of his major successes has been the development of an artificial bone that can be used for middle ear implants. This has been taken from a laboratory concept to the point where tens of thousands of patients have had prostheses made of this material successfully fitted. Professor Bonfield has left the IRC content that it will continue to flourish, feeding on the success of the first nine years.

Since arriving in Cambridge, he has been much encouraged by discussions with colleagues both in the Department and across the University as to the prospects for a major multi-disciplinary research activity in biomaterials, and he has already given colloquia in Engineering, the Cavendish Laboratory, the Melville Laboratory, and Materials Science. He will be working closely with Mr Neil Rushton, the Director of the Orthopaedic Research Unit at Addenbrooke's Hospital to facilitate the progression of novel biomaterials to clinical trial. He is also co-ordinating a new joint initiative with MIT on Biomaterials and Tissue Engineering. Dr Serena Best and two research students from Queen Mary have moved with Professor Bonfield to create the nucleus of the new research group, alongside Dr Ruth Cameron's existing activity, with eight further researchers due to start in October. Biomaterials will also be included in the undergraduate syllabus at all levels.

Professor Bonfield took his first degree in Metallurgy at Imperial College followed by a PhD on the deformation of germanium single crystals. He remembers demonstrating to both Alan Windle and Derek Fray at that time. He then went to the USA where he researched on materials for the space program. This led to his involvement with biological materials when he was investigating materials that would be suitable for replacing ivory for use in a precision instrument. His measurements of the mechanical properties of ivory and bone led to the publication of one of the most cited papers of the 60s. He returned to the UK as Reader in Materials Science at Queen Mary, initially working on microplasticity and extending this to bone biomechanics and the innovation of biomaterials for bone replacement.

Married with three children (4 PhDs between them) and five grandchildren, Bill Bonfield continues to live half way between London and Cambridge, giving himself plenty of time for reflection on the train. He is also a keen cyclist professing to own a number of flash bicycles and equally flash lycra shorts.

Please address any comments regarding this issue or alterations to your address to: Navini Nynan, Department of Materials Science and Metallurgy, University of Cambridge, Pembroke Street, Cambridge CB2 3QZ. Tel: 01223 334479 Fax 01223 334567. Email nn210@msm.cam.ac.uk

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Congratulations to

Dr Zoe Barber on her appointment to a Teaching Fellowship in Downing College and her upgrading to a University Lectureship in the Department.

Dr Serena Best on her election to a Teaching Fellowship at St John's College.

Professor Bill Bonfield on the 2000 Acta Metallurgica J Herbert Hollomon award.

Professor Robert Cahn on being elevated to the Rank of TMS Fellow, the highest award of The Minerals, Metals and Materials Society.

Dr George Chen on his award of a Schlumberger Interdisciplinary Research Fellowhip at Darwin College.

Professor Derek Fray on being awarded the 2000 Extraction and Processing Distinguished Lecture Award of the TMS.

Dr Lindsay Greer on receiving the 1999 Light Metals Cast Shop Award in recognition of the most notable Cast Shop research paper published in *Light Metals* 1999 and on his award of the Pilkington Teaching Prize.

Dr Linday Greer, Peter Schumacher, Paul Evans, Martin Evans, Martin Kearns, Peter Fisher and **Alan Green** on the award of the Cook Ablett Award of the Institute of Materials for their outstanding paper on nucleation mechanisms in aluminium alloys.

Dr Ian Hutchings on the NPL award for Materials Metrology of the Institute of Materials and the Donald Julius Groen Prize of the Tribology Group of the IMechE.

Raj Jakkaraju and **Chris Dobson** for winning 1 of only 4 poster prizes from a field of 456 for *"Microstructural evolution in copper films undergoing laser pulsing at high pressures"* at the Materials Research Society Fall Meeting in Boston.

Professor Tony Kelly on being awarded the 2000 Acta Metallurgica Gold Medal.

Neil Mathur on his appointment to a Senior Research Fellowhip in Churchill College.

Dr Paul Midgley on his appointment as Fellow of Peterhouse and his upgrading to a University Lectureship in the Department.