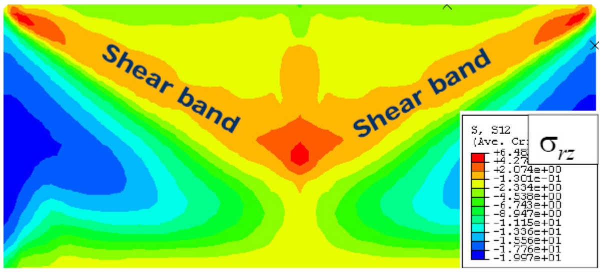
Cambridge material eyes

Summer 2006 Issue 15

Pfizer Institute: now into its second phase

The pharmaceutical industry is the most research-intensive in the UK. Traditionally most of this research energy has been focused on "discovery": the design and synthesis, pharmacology and toxicology of new active molecules. However, the crystallization of drugs and their fabrication into dosage forms (e.g. tablets or inhalation powders) are also critical. Materials Science plays a central role in all these aspects. Work originally carried out by Ruth Cameron in conjunction with Pfizer led to the emergence of the concept of Pharmaceutical Materials Science and subsequently to the establishment of the Pfizer Institute shared between the Departments of Materials Science and of Chemistry, with the Cambridge Crystallographic Data Centre playing a key minority role. Phase I of the Institute, with Bill Bonfield as the first director, enjoyed a successful first three years. Subsequently the funding has been extended into a second phase to run until 2008.



Prediction of internal stress in a pressed pharmaceutical tablet using finite-element modelling [Reprinted from *Powder Technology* **152,** Wu, Elliott et al., Modelling the mechanical behaviour of pharmaceutical powders during compaction, 107-117, Copyright (2005), with permission from Elsevier]

Current research in the Institute aims to achieve an understanding of the relationship between molecular structure and the resultant crystal structures and to study crystal dissolution. The importance of the control of crystal structure is emphasised by the characterisation of a new drug in terms of its crystal structure by regulatory bodies such as the FDA. The science of the making of tablets or the generation of forms for inhalation involves a computational thrust, led by James Elliott. Codes developed from those originally written for simulation at the molecular level are being used to study particle packing and adhesion, while finite-element software developed for powder metallurgy is being applied to predict premature-failure modes in tablets of various shapes (illustrated above). The Institute, now under the directorship of Alan Windle, is positioning itself to form key partnerships with Government agencies as it looks towards the end of the decade and beyond.

Editorial

Derek Fray's period as Head, 2001-05, has left the Department thriving. In teaching, various reviews of the Department's activities have noted the quality of our courses and the satisfaction voiced by our students. In the present year, our undergraduate numbers — long perceived as a relative weakness — are 20% higher in our major courses (Part IA and Part IB). In research, the total research expenditure in 2004-05 was £4.9m, compared to £3.3m in 2000-01. Research funding also shows a healthy diversity: 44% from EPSRC, 40% from industry, 12% from sources such as the EC and the Cambridge-MIT Institute, and 4% from charities. Indicators such as these demonstrate how much the Department owes to Derek. They also denote a hard act to follow. But as the new Head of Department I above all feel that it is a great privilege to be serving such a strong, able and well motivated Department.

Cambridge's strengths cannot hide gross underfunding in many areas. We may come second only to Harvard (see: http://ed.sjtu.edu.cn/rank/2005/ARWU2005TOP500list.htm) in the world-ranking of universities but our current investment in the applied sciences is being dwarfed by that in Cambridge, Massachusetts where (to quote just one example) a $100M, 13,000 m^2 building with three subterranean floors is just being completed to house interdisciplinary work in the physical sciences and engineering. One way to fight back is through fund-raising, and the University's approaching 800th anniversary in 2009 provides a focus for this. As detailed at www.foundation.cam.ac.uk/800-home.php the 800th Campaign is now underway, mobilizing philanthropic support from Cambridge alumni and friends worldwide to help underpin the University's future. The Campaign will focus on staff and students and on raising endowments that will strengthen Cambridge's ability to make the investments essential to future success. Our Department's participation in the Campaign will feature in future issues of *Material Eyes*, but we have made a start with the set of postcards enclosed with this issue, as noted on page 3.

***Professor Lindsay Greer*, Head of Department**

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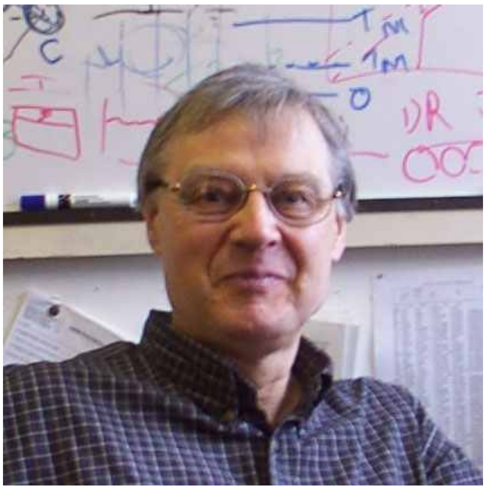
Professor Jan Evetts — in memoriam



Jan Evetts, Emeritus Professor of Device Materials in the Department died last August aged 66, only a year after retiring.

Jan joined the Department in 1962 working for the relatively new Superconductivity Research Group. His early research centred on the fundamental science and properties of superconducting materials at a time during which large-scale commercialisation of superconductors for high-field magnets was just beginning. This work culminated in 1972 in the publication with Archie Campbell of the major review article "Critical Currents in Superconductors" which became the definitive research monograph in the field. This article was reprinted in 2001 as part of the 50th volume of *Advances in Physics* as one of the most highly cited papers in the journal's history.

In 1988 the Government launched a new series of Interdisciplinary Research Centres (IRC's), and Cambridge was awarded the first of these to study superconductivity, particularly the high-temperature superconductivity which had recently been discovered in oxide materials. Despite considerable misgivings about the efficiency of such a large organisation, Jan agreed to be one of the co-directors of the IRC, a position which he retained until the end of the EPSRC funding in 1998. Jan led the conductor-development aspects of the IRC, work which led to the invention of a variety of new processes for creating highly textured flexible conductors which have been successfully transferred to industry.

Jan's parallel interest in magnetic materials and thin films led to the evolution of his group into the Device Materials Group which engaged in an ever-broadening range of functional materials research. In the 1980s he developed magnetic security tag technology which now has a market in excess of £300 million. He won an Academic Enterprise Award in 1985, on behalf of the group, for the development of superconducting device technology. By the time of his retirement, he had led the Device Materials Group for over thirty years; this group, which consisted of a handful of students and post-docs in the 1970s had by then grown to its present size of nearly fifty researchers and had, amongst its senior staff, Zoe Barber and Mark Blamire who both joined the Group as Ph.D. students in 1982. They have now been joined by Judith Driscoll and Neil Mathur as the permanent staff members of the Group.

During his time in the Department Jan was promoted, first to Reader and then in 1998 became the first *ad hominem* Professor in the Department's history. The 2005 European Applied Superconductivity Conference in Vienna was dedicated to him and the Applied Superconductivity Conference in Seattle and the UK Condensed Matter and Materials Physics Conference in Exeter will both have special sessions commemorating his career, illustrating his lasting achievements and the affection in which he was held by the scientific community.

His many research talks were memorable for their great enthusiasm as well as for the sheer amount of material which he was able to condense into a rapid and highly concentrated exposition. This rapid dissemination approach transferred itself also to undergraduate lectures, and those of us who supervised the students who had attended Jan's lectures often spent many hours patiently helping the less awake students catch up with the material which had rushed passed them. When comments were made about this style, Jan always claimed to have given a fifty lecture course on quantum mechanics to Metallurgy students in the 1960s, "and it was jolly good for them!"

Jan will continue to be greatly missed by all his former colleagues and students. He provided a role model for several generations of researchers who found that his open and friendly approach to students and senior scientists alike enabled them to understand his research and the reasons for doing it. He was always highly accessible and really enjoyed explaining complex science to whoever asked.

Rob Somekh and Jan Evetts with a film of metallic glass on a polymer sheet. This material is used for security tags.

Refrigeration becomes a hot topic

Almost one-sixth of the energy consumed in the U.K. is used for refrigeration, often using gases that have significant environmental effects when leakage occurs. Work by Derek Fray, Karl Sandeman, Neil Mathur and others in the Department is contributing to the development of a potentially more environmentally-friendly method of refrigeration. The method depends on the change of temperature produced when a strong magnetic field is applied to or removed from an appropriate material: "the magnetocaloric effect". For most materials the effect is very small, but recently materials have been developed showing significantly larger responses with the prospect of industrial application.

A spin-out company has been set up to develop 'green technology' for the refrigeration sector based on this effect in materials such as $CoMnSi_{1-x}Ge_x$. The company, Camfridge Limited, based in the St John's College Innovation Centre, is backed by local investors and the Carbon Trust. In the Department, Derek Fray and Karl Sandeman are continuing work to identify inexpensive d-metal alloys suitable for exploitation as a magnetic refrigerant to incorporate into Camfridge's active magnetic regenerator (AMR) component in pre-production prototypes and production devices. The team at Camfridge working under Neil Wilson is currently focusing on developing key components for the whole system and assembling these into a working prototype (for further information see http://www.camfridge.com/).

In an interesting contrast, Neil Mathur and Alex Mischenko with colleagues in Earth Sciences and from Cranfield University have been studying the analogous electrocaloric effect and have demonstrated that in thin films of the well known perovskite $Pb(Zr,Ti)O_3$ the effect is 100 times greater than any previously recorded. In thin films the necessary high field can be achieved using a modest potential difference. Thicker films will be investigated to produce appreciable cooling (for further information see AS Mischenko, Q Zhang, JF Scott, RW Whatmore and ND Mathur, *Science* **311**, 1270-71 (2006)).

The University's 800^{th} Anniversary

The postcards enclosed with this issue have been produced in association with the University's 800^{th} Campaign and carry the Campaign logo (left). We hope that you find the images attractive and that you can use the cards to raise the profile of the Department and of the Campaign. The images on the cards came from many research groups in the Department, but especial thanks go to Rafal Dunin-Borkowski and Ed Simpson for co-ordinating the effort. Additional sets of cards are available from the Department (contact remw2@msm.cam.ac.uk).

Revolution or "trickle down"?

Distant generations of Part II undergraduates dismantled manufactured articles to identify the materials used for each component, the processes of fabrication and the joining methods adopted, finally speculating on the reasons for the choice of materials and processes. Later a similar activity devised for Part IB based on a limited number of manufactured articles was so well received by some undergraduates that they devoted much more time to it than recommended! So it should be no surprise that during the recent review of the first year (Part IA) course the idea of introducing a similar project was put forward. The Part IA practicals had had the same weekly format of two sessions closely linked to the lectures for so long that few remembered it pre-dated the Crystalline State course created 40 years ago. Even those in the know could not say how long it had existed in the ancestral course, so the knee-jerk reaction was that the suggestion was nothing short of revolution. But then we thought: it worked in Part II, it works in Part IB, why should it not work in Part IA? So the other knee jerked; the only way to take an idea like this forward is to create a committee!

Detailed proposals duly emerged for a "Mini-project" to be launched in the middle of the Lent Term 2004, in which everyone would investigate an example of the same article and would work in very small groups (usually just two), reflecting the use of "teamwork" activities in later years, introduced in response to professional accreditation criteria and the wider need to provide for the acquisition of "transferable skills". A butane gas lighter was chosen as being cheap enough — over a hundred are "consumed" each year — yet having a sufficiently diverse and interesting range of components. Assisted by some helpful advice from the manufacturer, the painstaking work of separating all the components, understanding how they worked together and identifying the materials from which they were made was largely carried out by Frank Clarke, the chief Class Technician, and Derek Holmes, then a graduate student in Bill Clegg's group. We are greatly in their debt for the thoroughness of their investigations and the excellent data and illustrations produced. Detailed guidance was written for the undergraduates with additional information and briefing for the graduate students who were to act as demonstrators — and the butane was vented off before issuing lighters to the students!

Was the stated aim — "On completion of the practical sessions and the writing of your report you will have a fuller understanding of how some of the scientific principles and experimental techniques covered so far in the Materials & Mineral Sciences course underpin the selection and use of materials in engineering practice" — achieved? Responses to the on-line questionnaire revealed that the great majority reacted very positively, several adding thoughtful constructive comments. The conclusion was that the Mini-Project had proved a success and it has now become a regular feature.

Links with China

The first of a series outlining the Department's international links

With China now consuming 50% of the world's concrete and 25% of the world's steel, its economic growth is evident. The major initiative "UK-China Partners in Science" (http://www.uk.cn/science/), launched in January 2005 by Lord Sainsbury, Minister for Science and Innovation, aims to increase links and collaboration between the UK and China in science and technology. Meetings have covered topics as diverse as climate change, energy, biosciences, and information and communication technology. Materials science has featured also: the UK-China Advanced Materials Symposium was held on 5-7 December 2005 in Chongqing. Focusing on light metals, the event brought together a small group of participants, among whom were Lindsay Greer and James Curran from the Department.

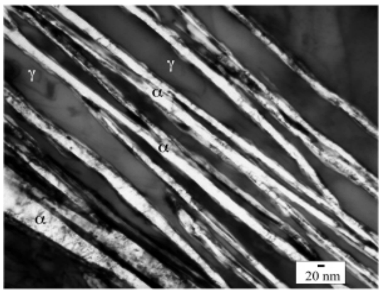
The Department has links with China at all levels from students to senior visiting Professors. A number of our PhD graduates have returned to China and now hold significant posts there (e.g. Prof. Rui Yang, Director of the R & D Center for Advanced Materials, Chinese Acad. of Sciences, Shenyang). In many areas there are collaborations of long standing, for example Prof. Colin Humphreys' work with the Univ. of Science and Technology of Beijing (Prof. Ko) and with the City University of Hong Kong (Prof. Lai). Prof. Derek Fray is currently collaborating with Northeastern Univ., Shenyang (Prof. Xu), and Prof. Lindsay Greer with the Inst. of Physics, Chinese Acad. of Sciences, Beijing (Prof. Wang), and Hebei University of Technology (Prof. Cui). Contacts such as these have also facilitated the building of links between UK companies and China.

In September 2006, Dr Vasant Kumar is co-ordinating our Department's participation in the China Distinguished Materials Forum established in the Univ. of Science & Technology, Beijing by China's Ministry of Science & Technology, Ministry of Education and the National Natural Science Foundation. The first delegation from the UK was from the Univ. of Oxford, coordinated by George Smith (former head, Materials Dept., Oxford) in April 2005. This year's Cambridge team (Colin Humphreys, Derek Fray, Bill Clyne and Vasant Kumar) will present talks, participate in discussions, visit labs and local industry, and firm up collaboration.

Large chunks of very strong steel

In December 2004 Harry Bhadeshia delivered the 52nd Hatfield Memorial Lecture in Sheffield on the subject of "*Large chunks of very strong steel*". His advocacy of steels is well known; this lecture is no exception. On the one hand we are cautioned about the challenges in scaling up from a small to a bulk-engineering dimension in the context of new materials. On the other, we are led to appreciate how a deep understanding of the underlying thermodynamics and kinetics of phase transformations can be employed to select simple compositions and prescribe heat treatments to produce new steels with significantly enhanced properties and substantial size in all three dimensions.

The introductory survey reminds us that atomic-scale defects are thermodynamically inevitable and so materials relying on structural perfection for excellence of their mechanical properties will fail when scaled up to engineering sizes. Rather, a high density of defects (e.g. dislocations and grain boundaries) should be sought. We are also reminded that a large elastic deformation in a material with a high Young's modulus generates a huge quantity of stored energy, easily exceeding the work to be done during fracture, a potentially catastrophic situation. Recalling Scifer (see http://www.msm.cam.ac.uk/phase-trans/abstracts/scifer.html) as a dramatic example, the use of deformation to strengthen metals by reducing grain size is discussed, and the limitations on the shapes that can be produced are noted. How are very small grains to be produced in bulk materials? Analysis of the factors involved points towards the need for large undercoolings to provide sufficient energy for the huge grain boundary area required. Also the kinetics must be sufficiently slow to avoid problems of recalescence that otherwise arise from the heat evolved during the transformation.



These and other considerations led to the selection of trial compositions around Fe–1.5Si–2Mn–1C and heat treatments involving as much as ten days (!) at just 200 °C. No rapid cooling is involved, so residual stresses are avoided even in large specimens. The resulting elegant bainitic micro-structure consists of very fine (~20–40 nm thick) ferritic plates, in which a large amount of the carbon remains trapped, in a matrix of stable, carbon-enriched austenite. That this scale is comparable with that of carbon nanotubes is not allowed to escape our notice. The ultimate tensile strength (~2.5 GPa), ductility (5–30%) and fracture toughness (30–40 MPa $m^{1/2}$) are impressive, as has been dramatically demonstrated in some ballistic tests for military armour. So what remains to be done? Delighted though he obviously is by the success achieved so far, Harry points out that the fatigue and corrosion behaviour remain to be investigated and that a lower carbon form would have attractions from the point of view of weldability, reminding us that every successful project raises yet more questions.

In short, this was an impressive contribution to the series of Hatfield Memorial Lectures. The full text is published in *Materials Science and Technology* **21**, 1293-1302 (2005); the illustrative slides and additional information can be found at http://www.msm.cam.ac.uk/phase-trans/2005/chunk.html.

Alumni News: Anne Glover, Co-Founder and Chief Executive of Amadeus Capital Partners Limited

Anne Glover is a prominent figure in the world of Venture Capital. She is Chief Executive of Amadeus Capital Partners Limited, which she co-founded with Hermann Hauser and Peter Wynn in 1997 and was elected chairman of the British Venture Capital Association (BVCA) for the year 2004-2005, an organisation which represents over 160 UK-based private equity and venture capital firms and of which she has been a leading member for some years.

Several influences steered her towards studying materials science as an undergraduate. With both parents being biochemists, Anne grew up in a scientifically-aware environment. Then, at a crucial time in choosing subjects to study in the sixth-form, her brother came up to Cambridge to read Engineering. Hearing about what he was studying and seeing some of his work proved attractive, but she wanted something more scientific. The timely discovery of J.E Gordon's famous book "The new science of strong materials" revealed the combination of science and applications involved in materials science and so she chose to aim for it. She came up to Clare in 1973, where she was taught by John Chilton and Michael Bown, and duly embarked on the Part II course in 1975. Amongst her exact contemporaries were Tony Rollett (also at Clare, and Head of Department in Carnegie Mellon University from 1995 to 2000), Lindsay Greer (our present Head of Department) and Alan Begg, one of her current colleagues on the DTI's Technology Strategy Board, where they are joined by Julia King from the immediately previous Part II year. Her recollections of what went on from time to time in the Part II lecture room before the lecturer arrived are not without interest. Sample memories from her time in the Department include sticking balls together in Part IA (some things never change!), learning to develop photographs and breaking things.

From Cambridge, Anne went to the USA, taking a Master's degree in Public and Private Management from Yale. She then worked with Cummins Engine for five years, gaining invaluable shop-floor experience, experience which she had been told she was too educated to acquire in the UK. Still in the US she spent five years with Bain & Co in Boston, enhancing and widening her experience to include business strategy. She returned to the UK to join Apax Partners & Co Ventures, moving from there to become Chief Operating Officer of Virtuality Group plc, an Apax investment. Thus she brought a wide range of experience as scientist, manager and investor to her rôle at Amadeus Capital Partners Limited and now additionally as one of a panel of experts advising the European Commission on the potential for the private equity industry.

Reflecting on how her career developed, she notes some of the advantages of a background in materials science and offers some instructive advice for students today. With a background combining the practical application of the basic sciences with some mathematical analysis in an engineering context, materials scientists are able to take a broad view, applying several disciplines to each problem they face. As they embark on their careers in their twenties they should recognise the importance of taking risks in the early stages, and should seek to gain experience of taking responsibility and, a particular challenge, of learning how to make things happen. While young, don't be afraid to try something that may fail. Scientists, after all, often learn a great deal from an experiment that doesn't work. In short they should test themselves against the world. These are attitudes that are much more widely built into careers advice in the US than here.

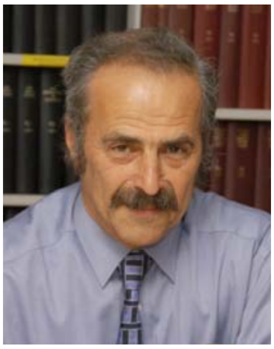
Turning to how the University has changed since the mid-70s, she enthuses about the development of spin-out companies, commenting that many are based on at least 10 years of research. She notes that there are now many entrepreneurial staff and students with the right drive and enthusiasm. On the other hand she wishes more high-growth companies would recruit actively on campus. In the course of this discussion she offers an informed analysis of the spectrum of times that typically elapse between bright idea and commercial realisation: a new material — as much as 25 years; a new engineering process — perhaps 15 years; a new computer — about 10 years; a new computer application — just 5 years.

The enjoyment and interest that Anne Glover finds in her varied work is very apparent, as is her affection for the subject that provided the launch pad for her career.

Light Blue Materials

The history of the Department by Jim Charles and Lindsay Greer advertised in the previous issue of *Material Eyes* has proved to be of considerable interest to alumni and present members. The book (ISBN 1 904350 35 6), normally priced at £36.00/$70.00, is still available to readers of *Material Eyes* at the special offer price of £27.00/$52.50. You can order on-line at http://www.maney.co.uk/books/lightblue or Tel: 01223 334349.

Katikati, clematis, catalysis and corrosion — profile of Professor G.T. Burstein



Tim Burstein arrived in Cambridge in the early 70s, with a PhD from the University of Auckland and experience as a post-doc at Imperial College, to work in Sam Hoar's laboratory. This move saw the continuation of his specialising in the corrosion of materials and the start of a career which has taken him all over the world, bringing him international awards and recognition.

He teaches corrosion and materials chemistry in Parts IB, II and III. He initiated the Surfaces and Interfaces course in Part II, as well as Management Studies for Parts II and III; his own Management Studies lectures to Part II are ever popular with the students. His love of teaching was rewarded with one of the University's Pilkington Prizes in 2004.

Tim's research covers diverse subjects including metal corrosion, surface processing through electrochemical routes, and fuel cells. Metal corrosion remains the bain of the engineer's lot, with many problems still unsolved. The research into corrosion provides an anchor for a highly multidisciplinary subject covering all industry, which the research students find satisfying. Corrosion is also a "green" subject where lifetime extension plays a crucial role in saving energy and raw materials. Corrosion science is a most elegant subject, despite (or perhaps because of) the fact that failed components may be dirty. Tim believes that large-scale application of fuel cells for vehicles is most likely to succeed if the conventional platinum electrocatalysts are replaced by base materials. He combines his deep understanding of the nature of passivity towards corrosion with research into designing electrocatalytic activity on passive surfaces: this combination is a challenging problem in surface science, the solution for which has a bright future. His extensive work on corrosion science and engineering is this year being recognised by his award of the UR Evans Sword from the Institute of Corrosion.

Professor Burstein is married, with three adult children needing transport to and from distant universities. He derives great enjoyment from travel overseas, particularly to his native New Zealand, where the beaches and virgin forests (with their plethora of botanic interest) provide hiking, climbing and supreme relaxation. He spent his childhood in Katikati, a then-remote village, and still occasionally visits there, with Mt Ngatamahinerua always beckoning to be climbed. Music, maths, language and linguistics, literature, philosophy, and the sciences, play major rôles in his wide-ranging leisure interests, side-by-side with frequent visits to art exhibitions, and walking, particularly in Wales. His unabated passion for clematis and for sophora fuels a wider interest in local and distant wildlife.

Congratulations to:

Prof. Harry Bhadeshia: IOM^3 Bessemer Medal for 2006

Prof. Lindsay Greer: appointed Advisory Professor at Chongqing University, PR China from December 2005; IOM^3 Hume Rothery Prize for 2006

Andrew Rayment: promoted to Senior Technical Officer

Dr Noel Rutter: Teaching Fellow from June 2006

Dr Amir Shirzadi: Appointed Executive Editor for the new journal by IOM^3: *Energy Materials*

Dr Howard Stone: ADR in Rolls-Royce UTC from April 2006

Dr Bartek Glowacki with **Dr Bill Nuttall** (Judge Business School and Dept. of Engineering) and **Dr Richard Clarke** (UKAEA Culham)**:** received one of the East of England Energy Group's 3rd Annual Innovation Awards for their work on fusion energy

Dr Sammy Tin: (now at Illinois Institute of Technology) IOM^3 Cook Ablett Award (with co-authors) for 2006

Sir John Meurig Thomas: Silver medal for services to science, celebrating the 750th anniversary of the University of Siena.

And well done to **Amaia Cipitria**, **Jamie Muir Wood** and **Chris Shortall** for the three poster prizes (out of a total of 10) at Euromat 2005 in Prague. Also, to **Nicole van der Laak** for the best student oral presentation in April at the Microscopy of Semiconducting Materials Conf. and **Dominik Eder:** best paper at nanoSMat2005.

Dr Amir Shirzadi (above right) receives his Armourers & Brasiers' Research Fellowship from Prof. Lindsay Greer. The Fellowship, of value £2,500, is a prize for the best postdoctoral work in the Department. Amir's research focuses on developing and modelling new methods in diffusion bonding/brazing processes, and surface and joint interface modification in metallic materials.

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