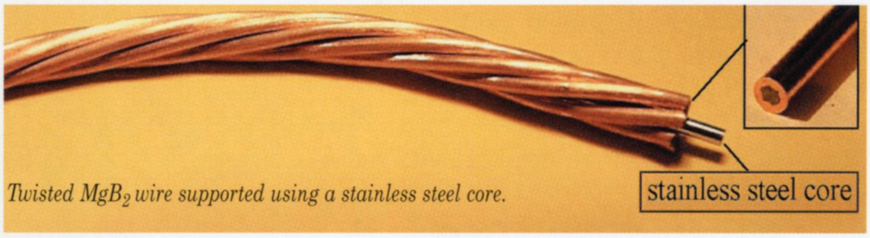
Cambridge material eyes

August 2001 *Issue 11*

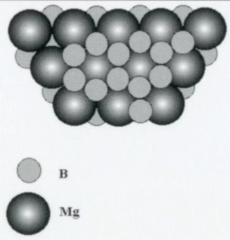
NEW SUPERCONDUCTOR STEALS THE SHOW



Twisted MgB_2 wire supported using a stainless steel core.

The discovery earlier this year that the readily available compound MgB_2 (see figure below), is superconducting has lead to a flurry of research activity. Dr Bartek Glowacki explains the cause of the excitement: "This material is very different from the other superconductors. With its discovery comes the realization that there may be many other similar, commonly occurring compounds that will also be found to exhibit superconducting properties. There are three critical parameters that characterise a superconducting material: the critical temperature, the critical current density and the upper critical field. For this material, it has been shown that the critical temperature is 39 K, which is easily achievable using liquid helium, the current density is in the region of 10^5 -10^6 A/cm^2 and an upper critical field value of around 36 tesla can be reached with appropriate processing.

All these figures indicate that MgB_2 will be very useful as a superconducting material. The real excitement lies in the fact that it can also be easily fabricated, unlike many of the existing superconducting materials. We are the first group in Europe to have manufactured superconducting MgB_2 wires. Over the years we have developed considerable expertise in manufacturing metal tapes coated with superconducting ceramic compounds. Such tapes were required because most of the current engineering applications for superconducting devices rely on the ability of the superconductor to conduct large electrical current over km length scales We already know how to produce superconducting tapes by the kilo. When this new superconducting material was discovered we could just go straight ahead and start to produce powder-in-tube wires, as we have all the equipment here, and we know what we are doing.



The atomic structure of magnesium diboride. Replacement of the magnesium atoms with copper could lead to the development of a new superconducting material.

We have been using our expertise in the area of wire and tape fabrication to explore how the new material behaves. We have been looking at two methods of fabrication of wires, one called the *ex-situ* process whereby ready-made powder of MgB_2 is packed inside metal tubes and deformed by drawing, swaging, twisting (see top photo) with or without final sintering, and an *in-situ* process whereby powder-in-tube, wire or coated conductors are made from fine constituent powders of the individual elements, in this case Mg and B. The *ex-situ* processing is very attractive from an economic point of view, as no sintering is required. The fabrication processes could make use of the technology currently used for flux-cored welding wires. Our initial work has shown that it might also be possible to raise the critical temperature for this type of superconductor to 50 K, by substituting the Mg with Cu. Ni and Fe seem to be suitable substrate materials for the production of coated tapes. We have applied for a patent on the use of these materials as substrates, as this could be very important for the production of low ac loss conductors for transformers. Application of superconductors to transmission cables still requires higher operating temperatures than currently possible, but who knows what the future will bring?"

For more information, please contact Dr Bartek Glowacki T: 331738 email bag10@cam.ac.uk

EDITORIAL

This year we welcomed four MIT students to our Part III course; two came for the Michaelmas term and the other two for the Lent and Easter terms. The students were quickly integrated into the class and we enjoyed having them. The major differences that they found between our courses and those at MIT were the supervision system and the fact that very few of our courses had recommended texts and relied more on research papers and the lecture notes. The MIT courses which they had experienced are much more fundamental and have not changed much over the years (in fact the course I taught on thermodynamics at MIT in the late 1960s is still being given, virtually unchanged!). MIT courses are less applied and consist of 40 lecture blocks rather than Cambridge's 12 lecture slots. Next year, three MIT students will be coming for the Part II year and two of our students who would have taken our Part II course are going to MIT. We wish them all a stimulating and rewarding experience.

A very successful MPhil course on materials modelling has also been run this year for the first time. Students enjoyed the wide variety of topics taught by the Departments of Materials Science, Engineering and Physics. The course covered everything from ab-initio methods through thermodynamics and mesoscale and multiscale modelling to management, IPR and dissemination. The course was strongly supported by both manufacturing industry and government laboratories. Eight students enrolled this year and several more have already enrolled for next.

Professor Derek Fray
Head of Department

Contents

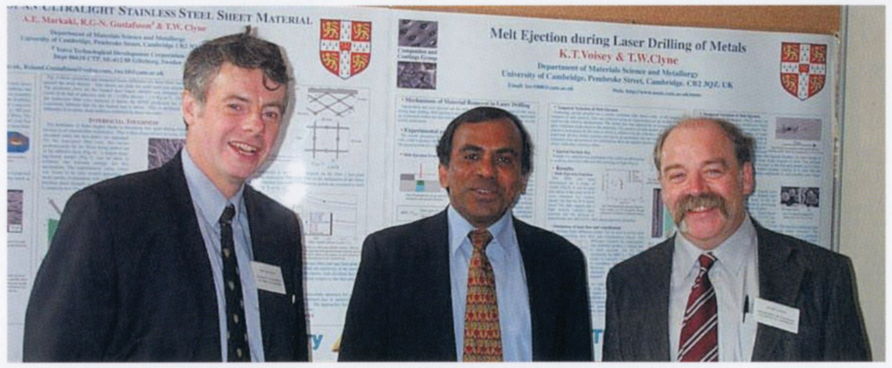
The Gordon Laboratory 2001

In 1999, a partnership between DERA (Defence Evaluation and Research Agency) and Cambridge University led to the founding of a new laboratory in the Department, dedicated to research in composite materials. Although DERA has now been re-structured, (to form the Defence Science and Technology Laboratory and a separate private company, Qinetiq), the activities of the laboratory will continue, under the leadership of Professor Bill Clyne and Dr Bill Clegg. Companies are offered the opportunity to become affiliates of the Gordon Laboratory and thus have access to core research.

Advances continue to be made in understanding the properties and behaviour of various composite materials and systems. For example, in the area of thermal conduction, composite systems can be used both where heat flow needs to be increased and also where a thermal barrier is required. The high thermal conductivity of vapour-grown carbon fibres is being used for the production of new types of high-conductivity glues, incorporating fine-scale carbon fibres, typically of the order of 0.1 - 0.5 μm diameter, into resin matrices. This work has potential applications in high-power integrated-circuit devices, where better heat dissipation will allow an increase in the power of the devices used.

Research effort is also being directed towards producing improved thermal barrier coatings, to allow increases in the operating temperatures of gas turbines. As the development of high-temperature alloys for applications such as the blades of jet engines nears the limits, thermal barrier coatings are seen as the way of increasing the possible operating temperatures - typically by increments of the order of 100°C. Other areas of current activity include the production of titanium foams for prosthetic implants, the development of highly flame-resistant low-cost composites and optimisation of the metallic fibre core structure of a novel sheet material with thin (200 μm) steel faceplates. All of these projects have strong industrial involvement.

For more information please contact Professor Bill Clyne (e-mail twc10@cam.ac.uk). Information about the Gordon Laboratory is available on the website at http://www.msm.cam.ac.uk/gordon/



From left to right: Professor Bill Clyne, Professor Subra Suresh and Dr Bill Clegg.

Each year, the Gordon Laboratory hosts an Open Day. In June this year the guest lecturer was Professor Subra Suresh, Head of the Department of Materials Science and Engineering at MIT, who spoke about recent research into the effects of length scale, spanning the nanometre to macroscopic dimensions, on the mechanical properties of small-volume composite structures of interest in a variety of miniature technologies. Those attending the Open Day had the opportunity to hear about the various areas of industrial collaboration within the Department, from bio-medical materials to titanium extraction.

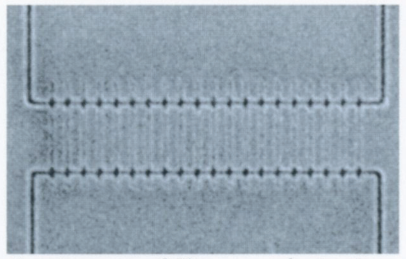
Highly focused research

The development of a focused ion-beam system for nano-fabrication within the Department has opened the doors to a host of novel research programmes for many members of the Department. Dr Mark Blamire, Reader in Device Materials, explains:

"We are using a focused beam of gallium ions which have sufficient energy and momentum to remove material from a surface, which means we can use the beam for creating nano-structures to our specification. Although focused ion beams are routinely used in the semiconductor industry for characterising integrated circuits, we are now able to use this type of beam for nano-scale fabrication. We have the only instrument in Cambridge for doing this type of research.

One of our research areas is in making nano-scale superconducting devices by taking a superconducting material and creating non-superconducting regions in it on a 50 nm length scale (a nanometre is about one ten thousandth of the diameter of a human hair). This is exploratory science: we are not working on things that will be applied tomorrow.

For instance, one of our current projects is to produce anisotropy in magnetic materials. By writing very finely spaced lines we can create a natural 'grain' or texture in the magnetic materials, which induces a natural anisotropy, giving an easy and a hard axis. This type of patterning gives much greater control



A series array of 10 superconducting junctions fabricated using the Department's focused ion beam system. The vertical slit which defines each junction is 50μm across. Photo courtesy of Robert Hadfield

than existing techniques, allowing us to produce complex magnetic effects."

Plans for a new Interdisciplinary Research Centre (IRC) for the study of nanotechnology have recently been approved, which will be formed as a result of collaboration between several different Departments within the University. A new laboratory to house the IRC will be built on the University's West Cambridge site, next to the existing IRC for Superconductivity. The Device Materials Group's fabrication equipment will be moved to that building when it is completed, which will provide a much cleaner and lower noise environment than the Annexe in which it is currently based, whilst also opening up greater opportunities for collaborative research.

For further information, please contact Dr Mark Blamire,
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For any comments about this newsletter or alterations to your address, please contact Carol Ann Monteith by email cm259@msm.cam.ac.uk

Encouraging Entrepreneurs

Professor Alan Windle celebrated the end of his five-year stint in the hot seat as Head of Department by taking on a new challenge. At the beginning of the year he was appointed Executive Director of CMI, the newly formed company owned jointly by Cambridge University and the Massachusetts Institute of Technology (MIT). This new post is officially a 60% commitment, allowing Alan the opportunity to continue teaching and running his research group. Unofficially, of course, this dual role leads to 150% commitment. He explains what his CMI job entails:

"CMI is an experiment in creating a link between two world-class universities which are distinctly different in some key respects. Funding integrated research programmes only accounts for a relatively small part of our overall aim. A major role is to establish a national network with other UK universities to enhance the process of technology transfer through universities to commerce. We also aim to make state-of-the-art teaching and professional practice programmes available in Cambridge and to establish an undergraduate exchange programme with MIT (something in which the Materials Department is already involved). There has been tremendous commitment towards making the undergraduate exchange scheme work both from Departments and Colleges and the demand for places on the scheme already outnumbers the places available by three to one.

The Vice-Chancellor, Professor Sir Alec Broers and the Chairman of CMI, Lord Trotman of Osmotherley, listen to Professor Alan Windle, Executive Director, at the official opening.

As it happens, the experience of working with Derek Fray last summer to establish the intellectual property rights for the remarkably valuable titanium extraction process, so that the University and the inventors would receive due recompense, was instrumental in my move to CMI. The difficulties we encountered then convinced me of the necessity of working towards improving the University's ability to set up effective technology transfer processes. MIT has been very good at this in the past, and there are lessons to be learnt. Equally, MIT will benefit from the excellent reputation that Cambridge has in the field of research. CMI is driven by the belief that exposure to different ways of doing things will in the long run be of benefit to both parties, and I am enjoying the challenge to help to achieve this."

For further information about CMI, please telephone 01223 327207
Details are available at www.cmi.cam.ac.uk

Department of Materials Science and Metallurgy

Dem bones, dem bones . . .
– a profile of Dr Serena Best

Dr Serena Best took up her post as lecturer in the Department in May 2000, having spent the previous nine years researching at Queen Mary and Westfield College (as it was then known) at the University of London. Her first degree was in Materials Science and Engineering at Surrey University. Her research interests in the field of biomedical materials, stem from those days: her third-year dissertation was on materials for use in connection with the eye. "At one stage I considered training as a medical doctor, but decided that working in a field that supported medical technology was just as important in terms of saving peoples lives - and perhaps in the end more interesting and challenging."

Her research career began in 1986 working for a PhD with Professor Bill Bonfield's 'Bone Group' in London. Since then Serena's work has been mainly in the area of characterising bioactive materials such as hydroxyapatite, which bond with bone, as reported in a previous issue of Material Eyes. Serena is married and lives in Royston with her husband and four year old son. One of their interests is in renovating old houses, and they are now on their third, although this is the first that they have attempted with a young child in tow.

A Fellow of St John's, Serena also finds time to be actively involved in the Institute of Materials and the Royal Microscopical Society. She is particularly keen to help promote the awareness of Materials Science in young people and one way of doing this is to go into schools and talk on the subject. "I am concerned that there are not enough people coming into the subject at University level, often because they don't know what it has to offer."

She should prove a good advertisement for the subject.

Dr Serena Best T: 01223 334307 email smb51@cam.ac.uk

Student Prizes

It has become a tradition for the undergraduate prizes to be awarded in the tea room each year. This year Professor Derek Fray congratulated the winners.

Derek Holmes receives the Armourers and Brasiers' Prize

Thomas Jackson receives the CEGB Prize

Tim Smeeton receives the Goldsmiths' Prize and Medal

Clifford McAleese receives the Armourers and Brasiers' Prize and Medal

Congratulations to:

Nickil Sharma on being awarded a prize at the Microscopy of Semiconductor Materials Conference in Oxford.

Tony Ofori on being selected by the International Precious Metals Institute (IPMI) to receive their Annual Student Award.

Professor Colin Humphreys on being awarded the Honorary Degree of Doctor of Science by the University of Leicester and on being invited to give the Royal Academy of Engineering Sterling Lectures in Singapore and Malaysia.

Professor Robert Cahn on being awarded the Acta Materialia Gold Medal for the year 2002.

Matthew Weyland on being awarded a Research Fellowship by The Royal Commission for the Exhibition of *1851*.

Professor Colin Humphreys on being awarded the European Materials Gold Medal 2001 by the Federation of European Materials Societies.

Dr Tim Burstein on being elected to an Honorary Professorship by the University of Pretoria.

Professor Tony Kelly on being awarded the Honorary Degree of Doctor of Engineering by the University of Hanyang, Korea.

Professor Harry Bhadeshia on being awarded the Réaumur 2001 award by Société Française de Métallurgie et Matériaux.

This newsletter is edited by Sue Jackson, produced by Carol Ann Monteith and printed by ABS Print Services Ltd.