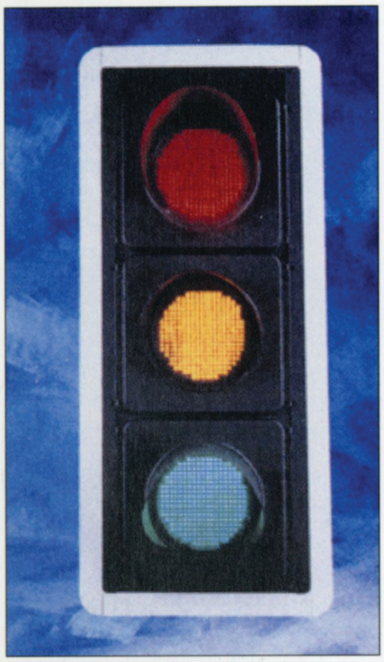
Cambridge material eyes

Autumn 1999 Issue 7

Bright Forecast



"**Gallium Nitride** is set to become the most important material since silicon for electronic applications", says Professor Colin Humphreys, "and our Department has been offered equipment which will allow us to grow such crystals ourselves." The offer of crystal growing equipment, worth in the region of £500,000 has come from a small local company, Thomas Swan, based at Harston. The equipment will be donated to the Department provided that the running and installation costs, which are of similar order of magnitude, can be found.

"This is a fantastic opportunity for us to catch up with a technology that we currently do not have in the UK", explains Professor Humphreys.

The significance of gallium nitride as a material for the future lies firstly in its light emitting properties. Light emitting diodes (LEDs) made of this material are currently being tested for use in traffic lights, where their brightness and longevity compared to normal bulbs will lead to immediate savings in power and maintenance bills. In addition, the possibility of converting blue LEDs to produce a white light using a suitable phosphor coating is also being developed which will enable low energy light bulbs to be developed lasting in the order of 100,000 hr. Gallium nitride will also almost certainly replace silicon as the material for high power amplifiers. Amongst other applications, such amplifiers, will enable satellite technology to be used for mobile phones, instead of relying on the use of transmitter masts.

"Our Department is regarded as an international centre for structural analysis of electronic materials, using techniques such as high resolution electron microscopy and electron energy loss spectroscopy to try and understand the electronic properties of device materials," explains Professor Humphreys." If we can grow our own materials it will be of great advantage. We will only get the equipment if we can raise sufficient funds to install and run it, however."

Further information from,
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Editorial

The decaying infrastructure of a number of Britain's leading Universities has at last been noticed by the Government, albeit with the prompting of the Welcome trust. Some £600 million has now been made available to Universities for "Infrastructural Renewal" in what is known as the Joint Infrastructure Fund (JIF). Of course the funds have to be bid for, with detailed submissions containing plans for the new buildings, and it appears that applications could exceed the funds available by a factor of ten or more.

Our bid for £32 million to provide a Multidisciplinary Materials Laboratory on the new West Cambridge Site (as featured in Issue 1 of Material Eyes) was submitted to EPSRC last week. In setting our sights for Materials research in Cambridge over the next quarter century, we have identified six research themes:

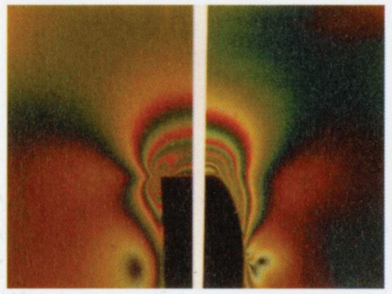
- **Characterisation**
- **Modelling**
- **Processing**
- **Device Materials**
- **Materials for Transport and Power**
- **Biomedical Materials**

The provision of modern accommodation in West Cambridge is important to the realisation of this vision If you are able to support the progress of our bid, through EPSRC and subsequent committees, in any way, then we would be exceedingly grateful.

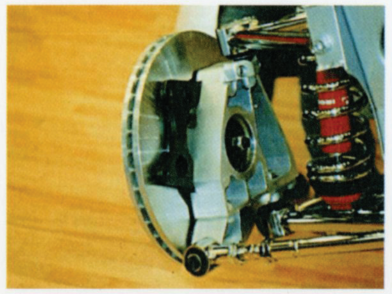
Contents

THE DERA-Cambridge Gordon Laboratory

June 10th is a significant day for the Department with the opening of the new partnership laboratory with DERA (Defence Evaluation and Research Agency). The laboratory will focus on research into composite materials and is to be named after Professor James Gordon who was famous both for his pioneering work in the development of composites and for his excellent books which have done so much to inspire materials scientists over two generations. James Gordon had close associations with DERA at Farnborough and also with Cambridge University, and it is thus especially appropriate that the partnership laboratory be named in his honour. The occasion will be marked by an inaugural lecture, and we are privileged that this will be given by Prof. Tony Kelly, CBE, FRS FEng, who, with James Gordon, is one of the founding fathers of the field of composite materials. Professor Kelly is a Distinguished Research Fellow in the Department and collaborates with much of the composite research.



The contours of shear stress shown in these photoelastic images indicate that while local stresses are sensitive to reinforcement shape, the overall load sharing characteristics are similar for a given aspect reinforcement ratio.



Al-based metal matrix composites are used for the brake discs on the Lotus Elise giving a weight saving of several kg.

Dr Bill Clyne will be the Director of the new laboratory and there is to be a new academic appointment at the Assistant Director of Research (ADR) level, together with research assistants and technical and infrastructural support. The laboratory will work in close association with composite research at DERA (Farnborough) including their manufacturing and prototyping facilities. In many respects the organisation will reflect the experience gained from the successful pioneering partnership with Rolls Royce with the UTC in aerospace-turbine materials which has now been in the Department for five years. The new laboratory represents a further component in the Department's embedded company policy, whereby it is establishing in-house exploitation highways for its own research.

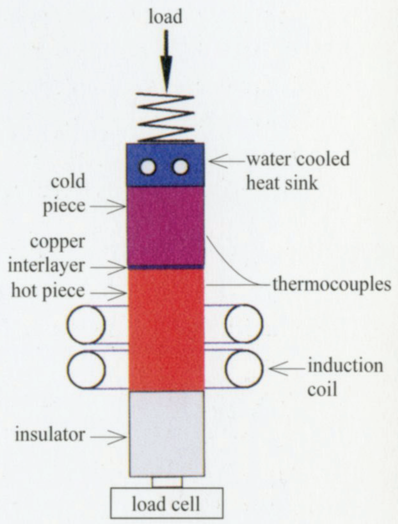
Research in the Gordon Laboratory will concentrate on the understanding and modelling of process-microstructure-property relationships with a view to producing novel classes of composite. It will also focus on the joining of composites, mechanisms of the compressive failure of composites and micro-perforation techniques. Another significant area will be research into the development of carbon nanotubes as described elsewhere in this edition of Material Eyes.

A key aspect of the Gordon laboratory is that it is planned to attract further embedded companies associated with composites and coatings which will interface with it as well as with other research in the area. In this way, not only will the work of Drs Bill Clegg, Ian Hutchings, David Knowles and Zoe Barber be integrated with the new laboratory, but the whole research effort will be managed as the Cambridge Collaborative Centre for Composites and Coatings (C^5). So watch this space !

Further details from Dr Bill Clyne, Director of the DERA-Cambridge Gordon Laboratory, Tel: 01223 334332, email: twc10@cus.cam.ac.uk

Diffusion Bonding Makes Waves

The joining of aluminium and aluminium base alloys to themselves and to other metals has long created problems because of the tenacious layer of surface oxide which is always present. The difficulties become more acute when melting of the components to be joined is not an option. Dr. Amir Shirzadi, working with Dr Rob Wallach, has recently developed a technique for diffusion bonding such materials, which has led to the filing of two patents, on behalf of the University, and has led to Amir being awarded the prestigious Henry Granjon prize from the International Institute of Welding.



Schematic diagram showing the equipment used for temperature gradient diffusion bonding

He explains: "Some advanced materials cannot be welded by conventional techniques because the high temperatures involved would destroy their properties. For such materials, diffusion bonding is an attractive solution because it is a solid state joining technique, which is normally carried out at a temperature much lower than the melting point of the material."

For joining aluminium alloys, insertion of a thin copper or zinc interlayer, allows a low melting point eutectic phase to be formed at a temperature about 100°C lower than the melting point. Even with this technique, the bond strengths produced are lower than that of the parent metal because of the planar bond interface which contains oxides and included particles. The new technique is based on imposing a temperature gradient across the surfaces to be joined to produce a non-planar (sinusoidal) interface which effectively increases the bonding area or metal to metal interface. This is an exciting development, as it is possible to change the shape of the interface from being planar to cellular, and up to fully dendritic, depending on the temperature gradient imposed.

Shear test results on aluminium-based composites and alloys show shear strengths up to parent metal values. It is anticipated that this technique can be used for joining dissimilar metal combinations, metal matrix composites and possibly nickel based materials.

Enquiries to Dr Rob Wallach Tel:01223-334330; email: erw1@cus.cam.ac.uk

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For any feedback regarding the content of this newsletter and any alterations to your address, please get in touch with Navini Nynan at the address below

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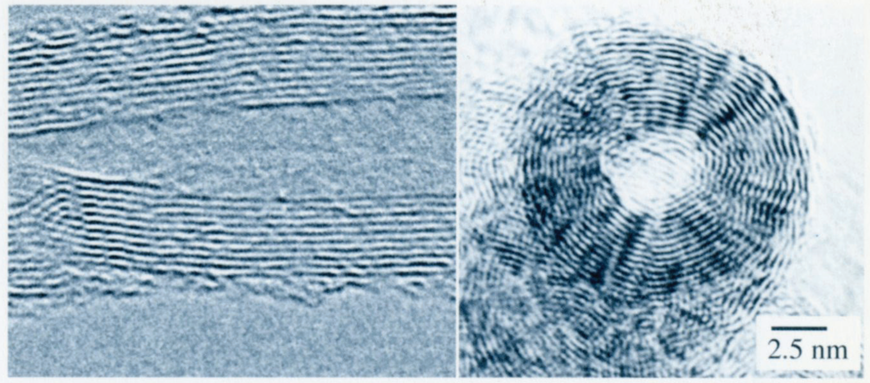
A Special Sort of Soot

The discovery of Buckminster fullerines or "Bucky balls" in 1985 gave new impetus to the study of carbon nanostructures. A variant of the first discovery, C60, is C70, in which the C60 'carbon football' gradually extends into a long thin single walled tube capped at each end by a hemisphere of the C60 molecule.

Normally, one sees multi-walled tubes, consisting typically of 5-10 concentric layers (see illustration). Whilst chemists and physicists are fired up about the properties of individual nanotubes, with typically one to two papers a day being published around the world, work in the Department has mainly focused on the processing of large numbers of these minute tubes which are scarcely thicker than polymer molecules, to incorporate them into polymer matrices as composites. Professor Alan Windle elaborates: "It has been found that appropriate surface treatment with concentrated acid makes it possible to disperse the nanotubes in water. As their concentration is increased by evaporating the water, the solution becomes increasingly viscous until it reaches a stage where it resembles a black jelly."



"If the water is then replaced by a solution containing polyvinyl alcohol, and evaporated, it is possible to create composites containing volume fractions of nanotubes up to 60%." Although the individual nano-tubes are estimated to have an axial elastic modulus in the region of one TPa, the reinforcing influence which nanotubes have on composites suggests that their full mechanical potential is not being realised, possibly because the matrix attachment is only to the outer graphene layer which then tends to slide over the inner layers.

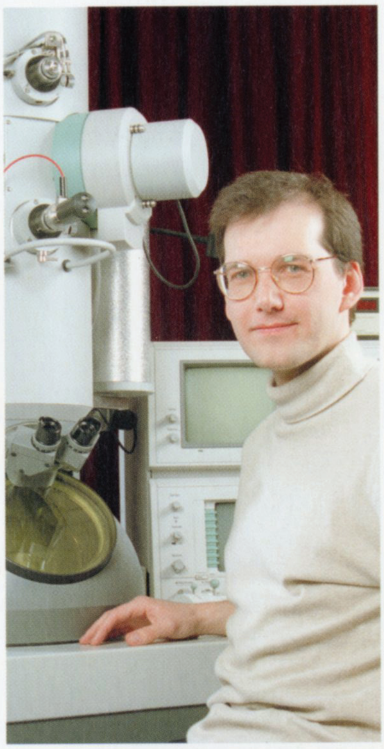
Apart from a potential strength improvement in polymers through the inclusion of carbon nanotubes, other property advantages can be obtained. For instance, the presence of nanotubes appears to retard the degradation of the polymer matrix in a composite material. The nanotubes are also very efficient in increasing electrical conductivity of the polymer so that a loading of only one part in a thousand can prevent the build up of static charge. Conventionally static build-up, which can cause a fire safety hazard, has been reduced by the addition of graphite powder, but this makes it difficult to obtain a good surface finish as well as reducing mechanical performance. One of the first commercial application of nanotube-filled polymers is in the automobile industry where electrostatic paint application technology demands a measure of conductivity yet a high gloss surface finish is of the essence.

This research is essentially an inter group activity including Professors Fray, Humphreys and Windle, and is now set to continue as a team activity, related to the new Cambridge-DERA Gordon Laboratory.

For further information, please contact Professor Alan Windle Tel: 01223 334321; email: ahw1@cus.cam.ac.uk

Under the Microscope
- a profile of Dr Paul Midgley

Paul Midgley joined the Department in 1997 as Assistant Director of Research (ADR) in Electron Microscopy. He graduated with a first degree in Physics from the University of Bristol in 1987, but admits to becoming totally hooked on electron microscopy after only six months of his PhD which led to his transfer from the super conductivity research group to the electron microscopy group, with a strong interest in materials. Following his PhD, Paul spent a further six years at Bristol during which time he was awarded two Research fellowships from the Royal Commission for the Exhibition of 1851 and the Royal Society, before his move to Cambridge.



Paul's research now concentrates on the development of new techniques for electron microscopy such as energy filtered TEM for mapping of elements to sub-nanometer resolution, as well as the use of electron holography for the study of a variety of electronic materials.

"The Department has one of the finest arrays of electron-optical equipment of any university in the world, including eight transmission microscopes, four scanning electron microscopes and a wide range of sample preparation equipment." comments Paul. "The microscopy in the department is going from strength to strength. It is all very well developing new techniques, but the excitement comes from seeing them used to solve real materials problems."

It is now possible to map chemical compositions at a nanometer level, routinely and accurately. This allows interfacial reactions to be studied, as well as material structures and compositions. This type of analysis was very rare, and difficult to do, even ten years ago, which illustrates the advances made in recent years in the field of electron microscopy.

Paul is a Senior Research Associate at Peterhouse, and supervises at Gonville and Caius. He also runs the Department's Part III and Graduate lecture courses on electron microscopy.

He confesses to be still trying to find out how things work at Cambridge, (although this can be a problem for Cambridge veterans too!) As for extra curricular activities, the hot air ballooning that used to feature as a pastime in Bristol has bitten the dust in the Fens, but Paul still finds an outlet for his sporting interests of badminton, tennis and cricket.

Dr Paul Midgley
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Congratulations to

- **Dr Paul Brown** on his appointment as Senior Lecturer at Nottingham University.
- **Dr Joanne Etheridge** on her Royal Society Research Fellowship.
- **Dr Lindsay Greer** and **Ms Alice Bunn** who have been awarded the 1998 Light Metals Award of The Minerals, Metal and Materials Society for a paper they co-authored with two others.
- **Prof. Colin Humphreys** on his award of an honorary Professorship of Experimental Physics at the Royal Institution.
- **Mrs Jenia Pekarskaya** for winning first prize for a poster in the high temperatures inter-metallic session at the Materials Research Society Annual Meeting in Boston.
- **Ms Wenhui Song** on winning a Skinner Prize for the best poster presentation in Faraday Discussion 112 on Physical Chemistry in the Mesoscopic Regime.
- **Drs Rob Wallach** and **Amir Shirzadi** on the Cook Ablett Award of the Institute of Materials for their outstanding paper on Diffusion Bonding.
- **Dr Terence Warner** who has been appointed as Associate Professor of Materials Chemistry at the University of Southern Denmark.

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