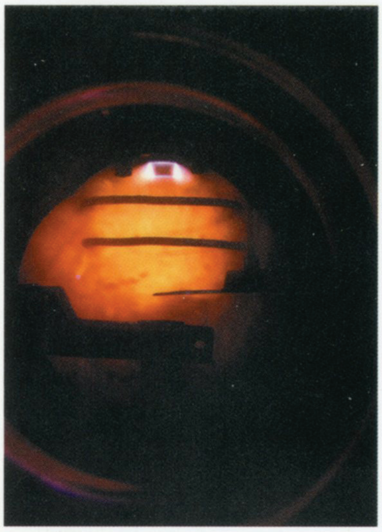
Cambridge material eyes

Winter 1999 Issue 8

Atom by Atom



Thin film deposition with an additional plasma (the orange region) between the source (top) and the substrates.

"The excitement of thin film deposition is that we can construct new materials from scratch" says Dr Zoe Barber. "We can make complex materials in this way, but we need to have precise control on how the atoms are being deposited and what energy is going into the film as it grows. With a technique such as sputter deposition, the film may be bombarded with high energy species, and this has a profound influence on its resultant structure."

The laboratory in which Zoe's group works, a part of the Device Materials Group, bristles with stainless steel chambers, pipes and noisy vacuum pumps, with the odd plume of liquid nitrogen vapour. "We have to use ultra-high vacuum systems to control the atomic species present during film growth" she explains "During the process of sputter deposition a target of the material to be deposited is held at a high voltage in a low pressure gas to produce a discharge. Energetic particles attracted towards it knock atoms out, which are then deposited on the substrate underneath."

A new technique of thin film deposition by sputtering is being developed within the group. Adding a further plasma between the target and the substrate forces the ejected target atoms to travel through this plasma before reaching the substrate. In doing so, they stand a high probability of becoming ionised, and so can be directed by applying an appropriate electrical bias.

This technique turns out to have a major influence on the structure and properties of the thin films produced. A research student of Zoe's, Kuo Feng Chiu, developed and built the first equipment in the UK to study the technique. He has found that it is possible to develop texture, and to control smoothness, grain size, density and both electrical and mechanical properties of thin films in this way. Uniform coatings on the very small features required by the microelectronics industry are also now possible.

The exact composition of the intermediate plasma during deposition can be measured using optical emission spectroscopy. Dr Chris Christou, a plasma physicist, is determining how the behaviour of the plasma is affected by changes in parameters, and has already discovered how to reduce contamination significantly. He will also be looking at reactive deposition of thin films, achieved by adding a reactive gas, such as nitrogen, to the chamber during deposition to produce, for example, very thin hard nitride films. Hard coatings of carbon nitride have already been deposited using this technique. This work is being carried out partly under the umbrella of the Cambridge Collaborative Centre for Composites and Coatings, "C5". These projects are supported by grants from the EPSRC.

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Editorial

'Virtual Incubators'

A recent government leak in the Sunday Times heralded the announcement of a major partnership between Cambridge University and MIT which will create a Transatlantic Institute to foster high-technology entrepreneurial endeavour. The Institute will grow commercial enterprises within a University environment and aim to turn these into world-class businesses.

This latest initiative completes a 'sea change' in University thinking, much of it over the last decade. In the 70s and 80s, any academic starting a company was seen as maverick at best, and would meet with criticism that university resources were being leaked away for personal gain. On the other hand, it has remained highly respectable to build partnerships with the research departments of established companies, often the large surviving Multinationals, and indeed that is a policy that this Department still develops successfully through its embedded company scheme.

However, we must, once and for all, stem the 'brain drain' of the brightest and best students out of Materials Science into the large money handling institutions, where the lure is risk coupled to high rewards. In addition to bringing in industrial research contracts, we need academically-led start up companies to follow our own research ideas through into commerce. We will still be talking to the same industries, but as potential venture partners, and University support will come through an enterprise centre, or 'virtual incubator' as the Americans would have it.

The change is now under our feet, and new opportunities abound. Perhaps we need to prepare ourselves for the day when 'Companies Started' is a normal heading on any academic CV, and Research Councils will actually favour applications where the collaborating company is the applicant's own.

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Polymer pills

Next time you swallow a tablet, have a thought for all the science that has gone into its creation. Not only have the contents of the tablet or capsule been painstakingly produced and tested, but so has the material that is used to encapsulate the particular drug you are taking, and which is responsible for releasing it at an appropriate rate. Georgina Milroy and Colleen Horan, Ph.D. students in Ruth Cameron's group, explain:

"Some tablets are made using a polymer matrix which supports the drug, whilst others may consist of a gelatin capsule which disintegrates to release beads inside, which may have a polymer coating. Such tablets are designed to deliver a drug in a controlled manner. In this way, a constant level of drug can be maintained in the body over the course of a day, for instance, without the user having to take too many tablets". Colleen's work focuses on this area, looking particularly at polymer combinations which modulate the release rate.

One of the key ways in which release rate is controlled is by tailoring the hydration properties of the device. Georgina uses techniques such as nuclear magnetic resonance and nuclear reaction analysis imaging to view water ingress and correlate it with microstructure and release properties.

By building up fundamental knowledge on the way these polymers behave, it will be possible to supplant the lengthy empirical trials currently used in drug development, with a more efficient design tool, thus helping to speed the process new drugs have to go through before being released for public consumption.

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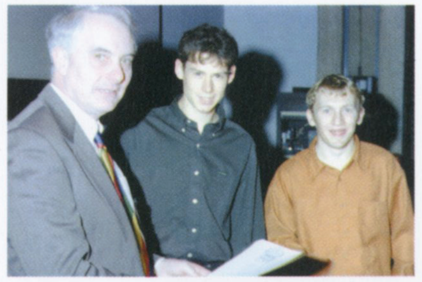
Kirsten Dickers was presented with the 1999 Goldsmiths' Prize and Medal for being the most successful candidate in the Part III. The awards were presented by Dr John Warner, Senior Vice President and Chief Administrative Officer of the Boeing Company.



James Chisholm and Noel Rutter, pictured here with Professor Alan Windle, were joint recipients of a Research Bursary for their first year research dissertations, awarded by The Amourers and Brasiers Company.

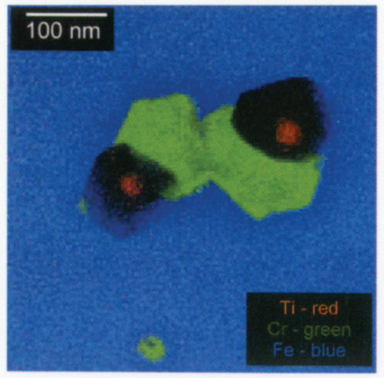
Think small

Described by Sir Alec Broers, Vice-Chancellor of the University, as "one of the most exciting instruments in the world" the Department has installed recently a new Philips CM300 FEG transmission electron microscope. Such was the excitement, that an official opening ceremony was held earlier this year. Dr Paul Midgley explains some of the reasons for all the excitement.

This microscope, which acts as a combined TEM and STEM, will allow us to advance our knowledge of the microstructure of modern materials using many different techniques. The instrument's field emission gun has an advantage over conventional guns in that it generates a very bright and coherent electron beam which makes it possible to perform electron holography – just as a laser allows optical holography compared to a tungsten light bulb. Amongst other benefits, electron holography yields information about the electrical and magnetic properties of the material which may be difficult to detect using any other technique. One of the aims of this type of research is to examine in-situ a working device, such as a transistor on an integrated circuit, and discover how its electronic and structural properties behave at the nanometre scale.

The microscope also features a Lorentz lens, an additional and powerful 'mini-lens', which allows the magnetic structure of thin films, such as those used in the recording industry, to be examined without interference from external magnetic fields generated by a conventional lens. The resolution of this lens allows us to examine, for example, the structure and width of magnetic domain walls to an accuracy unrivalled by any other instrument.

Many modern materials depend critically on the properties of interfaces and grain boundaries, so we need to resolve their structure and



Composite RGB image showing the distribution of Fe, Cr and Ti in a cluster of preciptates found in a 316 stainless steel. The dark regions in the image are Mo-rich. The image was acquired on the new Philips CM300 FEGTEM using energy-filtered transmission electron microscopy (EFTEM). Image courtesy of Paul Thomas

chemistry with high resolution. The small probe size (2Å) available in this instrument means that, in principle, we can perform microanalysis at very high spatial resolution, obtaining chemical information from individual atom columns using energy-loss and X-ray spectroscopy. One material for which this will be extremely useful is GaN, being used now for light emitting diodes and lasers because of its high brightness and blue emission. The material is full of defects (e.g. dislocations) which in other semiconductors would kill the light emission. It is important that we understand why this is not the case in GaN.

The small probe size also allows us to perform electron crystallography with high resolution. Techniques such as 'electron precession' enable diffraction patterns to be obtained from preciptates and interfacial phases, which can then be used to determine their atomic structure. The volume fraction of such phases is often too small to perform conventional X-ray diffraction.

This microscope is a national facility and we welcome interested parties to contact us regarding its use. The instrument is not an end in itself - it is important to put it to proper use.

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A glossy finish

There is a direct correlation between the value of a car and the appearance of the paint work. Robert Trezona, who is just completing his PhD work on the problems of characterising such coatings explains "If the paint fails within the warranty period for a new car, then this can lead to major costs. Currently such claims made in the States run to a figure that exceeds one fifth of the GDP of India." No wonder that car manufacturers are working to develop paint that will last, whatever the conditions.

To improve the performance of a coating, we need a reliable method of measuring its performance. It was for this reason that Ford originally approached Dr Ian Hutchings. His research group had already developed novel wear tests for ceramic coatings, and the question was: could these methods be extended to polymer coatings?

Car paint actually consists of up to five layers (as shown)-a transparent thermoset resin on the outside to give a glossy surface finish, the base coat to provide colour, primer to smooth out defects, an anti-chip layer (only where required) and an electrophoretically deposited bond coat next to the steel body. Of all these layers, the top one is the most important in protecting from chemical attack, small scale damage and ultraviolet degradation.

Two of the processes that have been established as causing damage to paint are three-body abrasion, caused by grit trapped between two sliding surfaces, and erosion, caused by particle impact. Robert's work on erosion has helped to develop a test rig which is now used as an industry standard. A single test can be used to provide information on the erosion resistance of each layer. Since these tests have been introduced, paints have improved dramatically.

The testing of abrasion resistance proved more difficult, but a method originally designed to test very hard TiN coatings was eventually adapted so that it also worked on the much softer polymer coatings. This technique is currently being evaluated for incorporation as an ASTM standard.

"We have used our rigs to conduct a full factorial experiment looking at the effects of curing conditions and environmental factors, and have found that we can now predict rates of paint degradation, depending on the conditions to which it is subjected" explains Robert. "Australia is definitely a bad place to keep a car!"

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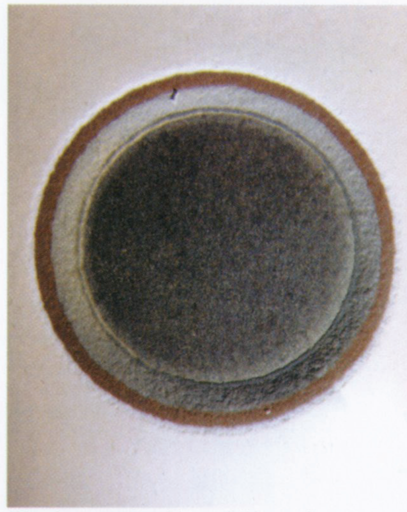

Circular scar in this multi-layered paint produced by erosion with sand particles. From this scar the durability of all four layers can be determined.

Cross section through an automotive paint finish showing the transparent clearcoat, a white basecoat, the primer and electrocoat on a steel panel.

Department of Materials Science and Metallurgy

A lasting bond
- a profile of Dr Rob Wallach

Rob owes it all to his wife! "When I was first at Cambridge as an undergraduate in the early sixties, reading Natural Sciences at Fitzwilliam, I didn't like it – too formal and not the right time for me," he recalls. As a result he promptly disappeared to Canada on graduating, and spent the next four years doing industrial research at Alcan (and sailing). They soon sent him back and funded him to do a PhD at Darwin. This was the crucial stage of Rob's life, when he met his wife to be, Robin. Cambridge suddenly became a more attractive place, and the Wallach family have been here ever since.

Rob was initially awarded an EPSRC fellowship following his PhD, and made history by becoming one of the first male Research fellows at Girton in 1975. Shortly after, he was appointed an assistant lecturer in the Department and started his research group on the joining of materials. He continued his interest in research with an industrial relevance and the work of his group has embraced modelling of joining processes, the behaviour of joints and the development of new processes, resulting in several patents. Rob was also instrumental in setting up the PTP industrial partnerships scheme (see Material Eyes issue 5) which has resulted in seven PhD studentships throughout the university each year since 1996. Several of these have been attached to Rob's group.

Rob is firmly committed to teaching, not only to lecturing and supervising but also to promoting an interest in science and engineering at primary schools, through the SeeK scheme which he founded (see Material Eyes, issue 4).

He is now involved with many different university committees, as well as lecturing on staff development courses. "The university is changing, as it needs to, and it is important that the people doing the teaching and research have an input to this."

As though this weren't all enough, Rob also became financial tutor at Kings in 1980 when he was awarded a full teaching fellowship, and eventually took over as Senior Tutor in 1996. He is determined that the students in his care should have a better experience than he had as an undergraduate!

Rob is also an enthusiastic player at a local tennis club and in his spare time makes musical instruments for his two talented daughters (a cello already made, and a violin on the way).

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Comments regarding the contents of this newsletter and any alterations to your address, should be addressed to Katariina Göschl at the address below or call on
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Congratulations to

Professor Bill Bonfind, Director of the IRC in Biomedical Materials at. QMWC, London, on his election to the new chair of Medical Materials in our Department.

Dr Paul Bristowe on his election to a teaching fellowship at Clare College.

Professor Robert Cahn on his award of the 2000 Fellow Award of the (American) Minerals, Metals & Materials Society. This award is limited to 100 members and is presented for outstanding contributions to metallurgy or materials science and technology.

Dr Christian Dandre on his appointment as Lecturer in the Department of Materials Engineering at the University of Wales, Swansea.

Professor Colin Humphreys on his award of the Kelvin Medal and Prize of the Institute of Physics for his contributions to the public understanding of physics.

Sir David John, Chairman of our External Funding Board, on his KCMG.

Dr Vicki Keast on her election to a Royal Society Dorothy Hodgkin Research Fellowship.

Dr Tom Matthams on his appointment as Assistant Director of Research assigned to the new DERA-Cambridge Gordon Laboratory for Composite Research.

Dr Neil Mathur on his award of a Royal Society University Research Fellowship.

Dr Simon Newcomb on his appointment to the Research Chair in Electron Microscopy in the Materials and Surface Science Institute, The University of Limerick.

Sir John Meurig Thomas Distinguished Research Fellow of this Department on the award of the 1999 Honorary Fellowship of the Royal Academy of Engineering 'for his enormous contribution to the popularisation of science (and by association, engineering).

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