Cambridge material eyes

Autumn 1997 Issue 4

Down with pollution

Smog over Mexico City, on a "clear" day, caused by exhaust fumes.

As public anxiety increases, concerning the volume of traffic on the roads and the levels of pollution caused, there is a ray of hope for the future. Work proposed by Dr Tim Burstein, who leads the Corrosion and Electro-chemical Processing group, is aimed at the development of fuel cells so that they can be used as non-polluting power sources for land transport. "People wish to retain their own transport systems, yet without poisoning the environment" he comments. "Restricting movement by legislation or by cost is the wrong way to go. The way forward is to generate cleaner forms of transport, and the method by which this can most readily be done currently is the fuel cell. It is extraordinary that we are still burning fuel to generate power, in the same way that people have done since the beginning of civilisation."

Fuel cells provide quite a different way of producing power. The fuel, which is a combustible reactive component, is oxidised anodically on a catalyst instead of combustively. By separating the oxidation and reduction reactions, the electrons produced during oxidation can be trapped and harnessed to generate electrical power directly. The theoretical efficiency of such a system is very much greater than that of a typical combustion engine because a fuel cell is not a heat engine. Some three times greater fuel efficiency should be possible, thereby reducing carbonaceous emissions by two thirds. A major advantage of using fuel cells, rather than combustion engines for power would be that carbon dioxide emissions would be greatly reduced. Other toxic emissions such as nitrogen oxides and sulphur oxides are eliminated. Solid particles or smokes such as found from petrol and particularly diesel engines are also eliminated.

For transport systems, methanol looks the most likely contender as a fuel, from the point of view of safety as well as ease of distribution and storage. The infrastructure for storage and distribution of the liquid fuel is effectively already in place. The basis of the reaction is to oxidise the carbon in the methanol. As the methanol is reacted it can be replenished from a storage tank in the same way that petrol is, at present, in cars. The trouble with conventional battery power for an electrical vehicle is the recharging time. For a vehicle powered by a methanol fuel cell stack, the recharging time will be the same as the refuelling time for a combustion powered vehicle.

Although the concept of fuel cells for power generation has been around for over 100 years, their application is limited by the lack of a suitable catalyst to keep the reaction running. This is the thrust of the work proposed by Dr Burstein. He aims to develop a cheap, recyclable catalyst which will provide a major step forward in the development of an effective fuel cell. One of the problems hampering the use of fuel cells at present is that the conventional noble metal catalysts such as platinum are 'poisoned' (i.e. become less efficient with time) by the products of the oxidation reaction. They are also expensive for widespread use in transport. Dr Burstein's team have discovered a synthetic catalyst based on carbides of nickel and tungsten which may prove effective for use in fuel cells: it contains no noble metal at all. Much work is required to explore the properties of such catalysts in an effort to pave the way towards a cleaner means of electrical power generation for the future.

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SeeK

Primary school children in Cambridge and the surrounding villages are getting treated to 'fun science' by a team of post graduates from the university, as a result of an initiative set up by Dr Rob Wallach, a lecturer within the Department. He first came across a scheme run in this way many years ago when he spent some time in Canada. It has long been a dream of his to treat British children to the same sort of stimulating science, and that dream has at last become reality through an initial small grant from COPUS (the Committee for the Public Understanding of Science) and lots of enthusiastic commitment from a large number of post graduate students.

Rob's scheme is known as 'SeeK' (Science and Engineering Experiments for Kids). Schools in the region are offered a selection of themed activities, closely tied to the national curriculum, which are designed to take either a morning or afternoon. Topics currently available include Forces, Electricity, Light and, of course, Materials. A team of students, typically six or seven, go along to each school that has booked a session and take over the class, introducing children in a fun and informative way about such topics as Newton's laws, simple circuits and solids, liquids and gases. This is done by the children working together in small groups to build rockets, burglar alarms, rain detectors. A popular grand finale is based on demonstrations with liquid nitrogen. This is always a great hit and introduces the children to something that is beyond the capacity of most schools to supply. Experiments are written up, with kit lists, with the hope that teachers can take some of the ideas to implement in their own teaching schemes. In this way, benefits should pass to teachers, who might themselves be hesitant about teaching science experimentally, as well as to the children.

The scheme has been received enthusiastically by local schools, and a recent workshop with teachers, held to talk over future plans, attracted a large and appreciative audience. Such is the success of the scheme and the demand for sessions that post-graduates are now being recruited from other Departments to make up the required work force and new methods of funding the scheme are being sought. Most schools have demonstrated a willingness to make financial contributions to keep the scheme operating, and it is hoped that eventually it will become self financing.

Details of how the scheme operates are available on the web site listed at the end of this article, and it is hoped that other universities will adopt the model so that the scheme can be run nation wide. [If you interested in starting such a scheme locally, do contact the organisers.] Not only do the teachers and children benefit, but so do the students who take part. They are usually exhausted after running a session, but come back infected with the same enthusiasm that they have generated in the children.

This initiative is also intended to strengthen further the University and Department's links with the local community. The scheme is currently being co-ordinated by Dr Joy Warde and Chris Daykin.

For further information, please contact Dr Rob Wallach T: 01223 334330 or Dr Joy Warde 334338, e-mail: erwl@cam.ac.uk

Web site address: http://rob7.msm.cam.ac.uk/SeeK/
(Note the use of upper and lower case letters in the address.)

Editorial - Teaching Matters

Excellence in teaching is one of the Department's two major objectives. A University is unique in that it commits itself both to generating new knowledge and to passing on established knowledge to the new generation. We lose sight of either one of these objectives at our peril.

As I write this, the day is moving towards pure theatre. The HEFCE (Higher Education Funding Council England) assessors have been with us for the whole of the week so far, and they are now locked away making their final decision on our excellence or otherwise in teaching. In 30 minutes or so I will be taking a small group of senior colleagues to hear them report their verdict on us in the presence of the Vice Chancellor in the dramatic setting of the Syndicate Room of the Old Schools.

We estimate that the TQA Assessment has cost us one man-year of additional effort. It is not the quality of our student output which is being measured nor, even, the quality of our teaching per se, (both of which might conceivably be seen to give a few of us 'older' Universities an unfair advantage) but the "Quality of the Learning Experience" - whatever that is.

Back now from the Old Schools, we know that our TQA score is 23/24! We are quite delighted at this accolade which complements the Department's top 5* rating in the Research Assessment Exercise last year. The TQA score puts us first (equal) amongst the other Cambridge Departments assessed so far, and reassures us as we continue to pursue excellence in both teaching and research.

AHW

If you have any alterations to your address, or comments on this issue, please send them to:

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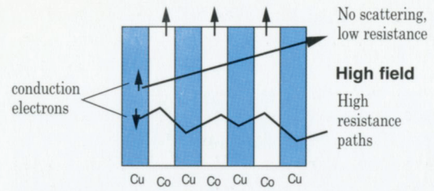
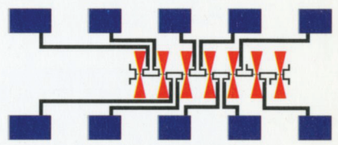
Spin Doctors

Magnetoresistive sensors that can detect changes in magnetic fields of the order of one tenth the strength of the earth's magnetic field are now a reality as a result of research undertaken by a team headed by Dr Jan Evetts. This opens the way to a new generation of simple, robust magnetic devices and sensors for application in many areas, such as read-heads for disc drives and control circuitry for electrical machinery. Such sensors can also be used to measure changes in rotation of small magnetic fields, very accurately, giving the possibility of precise three dimensional direction finding. A possible application, for instance, would be to track a fire-fighter's movements within a smoke filled building giving his precise location. " It is the robust nature of this type of sensor, as well as its simplicity, making it relatively cheap to produce, that is the exciting feature." explains Dr Evetts. " They can be used for all sorts of applications where a contactless measurement of position and orientation is required, as for instance in cars, where a large number of sensors are employed. Such sensors obviously have great advantages over their counterparts which involve the use of moving parts."

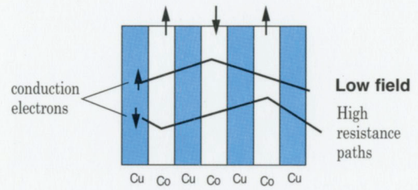
A magnetoresistive response is a change in electrical resistance caused by a change in magnetic field. Conventional magnetoresistive elements are based on nickel film or wire, and the changes in resistance observed are rather small, of the order of 1-2%. A breakthrough in magnetic sensor technology occurred about seven years ago when it was discovered that metal multi-layers, typically using copper and cobalt, could induce much larger changes in resistance for a given change in magnetic field. This signalled the discovery of the so-called giant magnetoresistive (GMR) devices which has lead to the production of "on-chip" GMR devices with a field sensitivity 200 times greater than that achieved by more conventional GMR devices.



Schematic of conduction electrons passing through a multi-layer in high and low magnetic fields.



Seven "on-chip" GMR devices with contact pads



Detail of one device element

The mechanism

Cobalt is ferromagnetic at room temperatures and the electrons in its band structure can be considered as having two populations, one with spin up and one with spin down. The differences in these populations produces a magnetic moment in a particular direction. Conduction electrons aligned with the magnetic moment cannot find sites to be scattered into, and thus if there is no scattering, there is a low resistance path through the cobalt layer. If, however, a conduction electron is aligned in the opposite direction to the magnetic moment, then it can easily be scattered into available electron states in the cobalt layer, giving a high resistance path.

The multi-layer in a GMR device is designed with a carefully chosen copper thickness (typically 1.9 nm) to achieve anti-parallel magnetic coupling between successive cobalt layers in zero applied field. This means that alternate cobalt layers have opposite magnetic moments under zero magnetic field (see accompanying figure). Thus a conduction electron entering the multi-layer in zero field must be scattered in alternate cobalt layers, regardless of its spin direction, thus producing a high resistance. Under the influence of a high magnetic field, however, the anti-ferromagnetic coupling is overcome (see figure) and the magnetic moments of the Co layers become aligned, so that conduction electrons with the appropriate spin direction i.e. parallel to the magnetic moment find a low resistance channel for their movement throughout the multilayer thus giving a low resistance state at high magnetic fields. This is known as a "spin valve" effect, and it is this phenomenon which produces the greatly enhanced change of resistivity with applied magnetic field observed in GMR devices.

A further enhancement was made by Evetts' team, by introducing a soft adjacent layer (SAL) structure in association with the devices. This SAL layer concentrates the magnetic field across the gap producing a further amplification effect which is as large as 200 fold in prototype devices..

The final result of the research programme was to develop the actual devices, and that has now been achieved. "On-chip" GMR devices have been produced which are suitable for a range of sensor applications.

For further information please contact Dr Jan Evetts T: 01223 334364 e-mail: jee2@cus.cam.ac.uk

Environmentally Friendly

- a profile of Dr Ruth Cameron

A rare moment of leisure for Dr. Ruth Cameron, spent on a cycling and walking holiday in Scotland.

Dr. Ruth Cameron was appointed lecturer in the Department of Materials Science in 1993, specialising in polymers and biomaterials. (The latter term encompasses such materials as polymers used in medicine and biodegradeable materials.) Dr Cameron came up to Cambridge in 1985, and graduated from Newnham college with a degree in Natural Sciences, with a Part II in Physics and Theoretical Physics. She stayed on at the Cavendish to take her PhD which was "basically looking at the structure of starch to understand, for example, how bread goes stale". It was during this time that Ruth became interested in the interface between pharmacy and materials science and hence to the niche position that she has now developed in the study of biomaterials. Her work which she initially continued at the Cavendish as a Post-Doctoral Research Associate, exploited a new technique of using high intensity X-rays to look at microstructure. By combining small and wide angle X-ray scattering, detailed information on the way polymers degrade and interact can be obtained in a few seconds, allowing changes in structure to be monitored as they occur in real time.

Ruth's research makes use of many techniques and as well as X-ray work, she was also responsible for the installation and use of an environmental scanning electron microscope -the first to be purchased in the UK. This type of microscope enables wet or coated samples to be examined.

Currently, Ruth heads an eleven strong research team, with projects ranging from controlled drug release from polymer matrices, as described in the last issue of Material Eyes, to the production, ageing and composting of biodegradable starch co-polymers which could have eventual application in nappies and detergents.

"My job has taken over my life." admits Ruth Cameron "I'm happy though , because it has many aspects and I believe this area of research to be worthwhile.". Most of Ruth's team are industrially funded. This means that, as well as teaching and pursuing her research interests, she spends a considerable portion of her time raising industrial funding, not to mention applying for beam time on the synchrotron sources. Outside of the Department, Ruth is also actively involved in College life both at Lucy Cavendish College, where she was appointed a fellow in 1993 and at Trinity College where she is a College Lecturer. She holds the appointments of Director of Studies and Admissions Officer in Science for both colleges. "It is good to have a mix, between two colleges, in this way.", she comments.

Ruth is also actively involved in the promotion of science and has taken part in various initiatives, including a national lecture tour around schools, organised by the Institute of Physics. When all of this does allow time, Ruth enjoys her other interests which include music, reading, painting and when the opportunity allows, skiing.

Congratulations to

- Dr Harry Bhadeshia on the 1997 Royal Society Armourers and Brasiers'Company Award.
- Prof Robert Cahn on his election as a fellow of ASM International, USA and as a Foreign Fellow of the National Science Acadeny of India
- Dr Ruth Cameron on her promotion to a full University lectureship.
- Prof Sir Alan Cottrell on the Von Hippel Award, the highest honour awarded by the Materials Research society, USA.
- Dr Ian Hutchings on his appointment as Deputy Head of Department in succession to Dr John Leake who completes his term at the end of the year.
- Prof Sir Alan Cottrell on the Von Hippel Award, the highest honour awarded by the Materials Research society, USA.
- Dr Dewi Lewis on being awarded the Royal Society of Chemistry's Meldola Medal.
- Prof Alan Windle on his election as a Fellow of the Royal Society.

On the web

A project which aims to put software developed for modelling of materials (in the context of Materials Science and Metallurgy) on the web, is now operational.

The Materials Algorithms Project (MAP) serves as a centre for the "validation" and distribution of algorithms of use in the modelling of materials. Research software can be accessed from:

http://www.msm.cam.ac.uk/map/map main.html

This site contains the software library and full information. The project is a joint effort between the University of Cambridge and the National Physics Laboratory, sponsored by the EPSRC.

Visit us on the Web

http://www.msm.cam.ac.uk

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