

Oxygen bubbles heal wounds



In mid-May this year Amadeus Capital Partners announced an investment in Inotec AMD to support further trials and development of the Natrox ("natural oxygen") device, which has already gained regulatory approval in several countries including the EU and the USA. What underlies these important developments?

Some ulcers and surgical wounds prove to be persistently painful and very resistant to healing but it has long been known that many of these respond well to a steady supply of humid oxygen. In 2001 Derek Fray heard a presentation about wound healing using oxygen in which it became clear that the method then being used was far from satisfactory. He recognised a connection to hydrometallurgical research which he had carried out a decade earlier and, on returning to Cambridge, he set about investigating another way of generating a supply of moist oxygen. This led to the provision of financial support from the Department for one year during which Derek and postdoc Vega Kotzeva created and patented a device which achieved that aim. Central to the device is a membrane of Nafion (a proton conducting ionomer) across which a potential difference of about 1.0 V is applied by a battery. On the anode side water is electrolysed into protons, electrons and oxygen molecules; the protons pass through the membrane and the electrons go round the external circuit while the oxygen and some water vapour pass through a membrane that is permeable to gases but not liquids. On the cathode side the electrons are reunited with the protons to create hydrogen which passes through another membrane to an oxidation catalyst where it reacts with oxygen from ambient humid air, to form water which diffuses back to the anode side to maintain the water supply there. The generation of oxygen creates sufficient pressure to drive a steady supply through a small tube to a special pad designed (via the same hydrometallurgical research) to pass bubbles of humid oxygen to the wound surface and

to pass exudate from the wound in the other direction. In use the cell and battery are worn under the patient's clothing, thereby helping to maintain the humidity of the air being taken into the system, and a suitable dressing is placed on top of the pad.

Anticipating a successful outcome to the research, in 2005 Derek and Melvin Vinton set up a spin-out company Inotec AMD Ltd. Derek also had discussions with Cambridge Enterprise, the University's commercialisation arm where Margaret Wilkinson, in particular, helped with formalities such as patent applications, with licensing of the technology to Inotec AMD and with sources of seed funding. Clinical trials are an essential component of any medical development. These have been carried out in several hospitals in the U.K. and abroad, including Addenbrooke's Hospital in Cambridge, and have involved hundreds of patients, a very significant proportion of whom have experienced substantial benefit in terms of pain relief, accelerated/complete healing and ease of use, whether in hospital or at home.

After many stages of development what does the commercially available Natrox device look like? The picture shows the cell and battery holder on the left and the pad to cover the wound on the right; the hand indicates the scale. Two batteries are supplied (one green, one blue to aid identification) so that one can be charged while the other is in use.

www.inotecamd.com

Editorial

Having been in our new building for nearly three years, we felt it was time that we held a Departmental open day to showcase the building and the research that we do in it. This will be held on the afternoon of 23rd September and, as well as giving you the opportunity to see many of the laboratories and the work that goes on in them, it will be a chance to talk to a broad spectrum of Department members, from PhD students to retired academics. I hope many of you will be able to attend. To register, please see:

www.msm.cam.ac.uk/alumni/OpenDay

Although probably invisible during the Open Day, we are distinctly short of office space in the building and so we have commissioned the original architects to perform a design study for an extension which we will showcase in our tea room during the open day. Such an extension would certainly satisfy our medium term needs, but money needs to be raised for it to go ahead.

Professor Mark Blamire, Head of Department

Inside:

<i>Glass Acts</i>	2	<i>Where we are now</i>	3
<i>Knights of the Realm</i>	2	<i>En garde: nanorevelations</i>	4
<i>Postdoctoral Affairs</i>	2	<i>Congratulations</i>	4
<i>Modelling Doctorates</i>	3		

Glass Acts

A very wide range of research is in progress in the Department, including research into some strikingly different types of amorphous material. Three kinds are featured here, each made by a different method but always one that aims to avoid or eliminate crystallinity. These methods include rapid cooling of a liquid, sputter deposition and transformation induced on heating. The materials used include the metallic glass former $\text{La}_{55}\text{Ni}_{20}\text{Al}_{25}$, superconducting Mo–Si and zeolitic imidazolate frameworks (ZIFs), the last named a relatively new family of nanoporous, low density structures formed from metal ions connected by organic ligands.



There has been work over the years in the Device Materials Group on thin films of amorphous superconductors, such as Mo–Si, with transition temperatures of up to 8 K. More recently, Zoe Barber and colleagues in Cambridge and Glasgow [*AIP Advances* **5** (2015) 087106] have been looking into their application as photon detectors. This is because good quality, uniform superconducting properties may be achieved in the thinnest layers (e.g. < 5 nm), since nucleation and growth of a crystalline structure is not required. Research continues on the investigation of short range order in these films, and has shown that substrate cooling during thin-film deposition reduces ordering and promotes the highest superconducting transition temperatures.

Metallic glasses have been of interest in the Department for many years now but finding a way to “rejuvenate” them by thermal cycling is a striking development. Recently Lindsay Greer led an international team with members from Japan, China and Italy as well as the UK [*Nature* **524** (2015) 200] looking at a number of metallic glasses, one in the form of melt-spun ribbon and three as bulk metallic glass rods. It is commonly assumed that glasses are structurally uniform at all length scales. However, on cycling these glasses many times over, a wide temperature range (e.g. from 0.1 to 0.6 as a fraction of the glass transition temperature)

they observe changes consistent with the presence of small-scale heterogeneities, probably less than 10 nm in size. These give rise to variations in thermal expansion from place to place, consequently creating stresses in the structure which reverse the relaxation processes that the glasses underwent on cooling from the liquid state during production, thus rejuvenating them. Lindsay’s ongoing work in this area has recently been rewarded with an EU Advanced ERC grant (“ExtendGlass”).

Whilst ZIFs are almost exclusively crystalline and decompose upon heating, their ability to form structures analogous to that of silica glass has been investigated by Tom Bennett and an international team. Focusing on one structure in the study, “ZIF-ZNI” [$\text{Zn}(\text{C}_3\text{H}_3\text{N}_2)_2$] is found to melt at temperature of circa 500 °C, yielding a liquid which can be quenched to yield a bulk glass of identical composition to the initial crystalline phase. Curiously, the glass displays ordering on length scales up to 0.6nm, i.e. twice that of silica glass. Much more detail is available in *Nature Communications* 6-8079 (2015).

So are these materials of interest scientifically or for their potential uses or both? Mo–Si shows promise for use in superconducting nanowire single- photon detectors for infrared photon counting with prospective applications from quantum communications to laser medicine. Very differently, rejuvenation of metallic glasses can improve their compressive plasticity and so potential usefulness, and the fact that rejuvenation can be produced by thermal cycling has significant implications for our understanding of the glassy state, especially at very short length-scales. Finally ZIFs may not have applications immediately in prospect but they also throw light on fundamentals of the glassy state and, to quote from the paper, the work “opens up possibilities for liquid casting and shaping [of] MOFs... an extremely exciting step forward in producing chemically functionizable hybrid glass materials.”

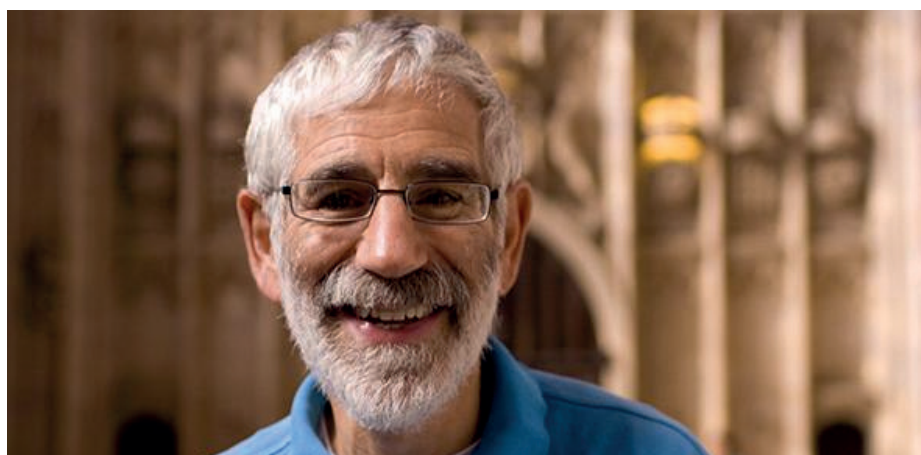
Knights of the Realm

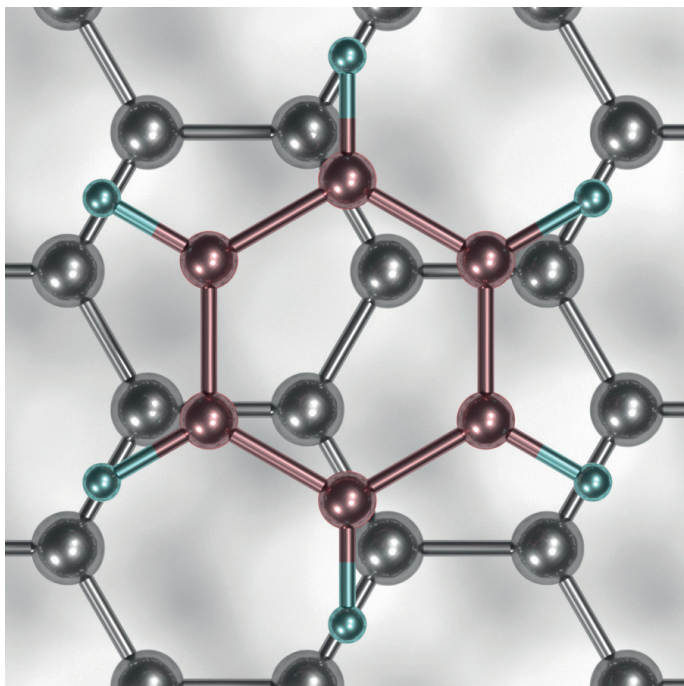
In Buckingham Palace on 27 October 2015 the investiture of Professor Sir Harry Bhadeshia “For services to Science and Technology” was performed by Prince William, Duke of Cambridge, whose enquiry about how to design steels generated a (necessarily brief) discussion. Here we see Harry with his older sister, Dina Abbott (in blue), younger sister, Sunita Hansraj (with hat) and daughter Maya Bhadeshia after the ceremony. Harry was delighted when his long-term collaborator Professor David Mackay was awarded a knighthood in the New Year Honours this year but then we were all deeply saddened by David’s death in April.



Postdoctoral Affairs

Rob Wallach retired from his Senior Lectureship in 2012 but keeps busy in many ways, not least in the newly created University post of Director of Postdoctoral Affairs, a recognition of the ever-increasing importance of postdocs in the work of the University. Postdocs now make up the largest staff grouping in the University.





Modelling Doctorates

In recent years the EPSRC has become ever more insistent on ensuring that training in research features prominently in the experience of graduate students. Thus EPSRC-funded PhD students in Materials Science are increasingly supported by inter-departmental "Centres for Doctoral Training" (CDTs), previously known as "Doctoral Training Centres" (DTCs), of which Cambridge is involved in several. One recent example, funded in 2014, is the CDT in Computational Methods for Materials Science which involves four University departments as well as a substantial number of industrial partners and is closely associated with the University's Lennard-Jones Centre for Scientific Computing linking materials modellers in several departments.

James Elliott of our Department is one of the two Deputy Directors who share responsibility for the day-to-day running of the Centre, which is funded initially for five annual intakes of students starting in 2014. Typically about 10 students are supported each year for four years. In their first year they are based in the new Maxwell Centre in West Cambridge where they take the materials modelling option within the broader MPhil in Scientific Computing and also undergo additional research training. Subject to satisfactory completion of the first year (formal examinations in January and the two assessed mini-projects), they continue for a further three years leading to a PhD on a project super-vised by a member of staff in one of the departments involved with the CDT. These fall into one of three streams: two are unsurprising, atomistic-scale modelling and continuum modelling, but the third - new this year - is based on using artificial intelligence in the design of materials.

One example of an atomistic project from our Department is currently being undertaken by Andrew Fowler, supervised by James Elliott. Andrew is investigating the frictional sliding of sheets of graphene. Starting with precisely superposed sheets in which the equivalent crystallographic directions (see picture) of the sheets are all parallel he evaluates the friction when one is slid over the other in different crystallographic directions using registry-dependent potentials, a modern development of Lennard-Jones potentials. This can be related to helium atom probe research of polyaromatic hydrocarbons diffusing on graphene currently being carried out in the Cavendish Laboratory.

See: www.csc.cam.ac.uk/academic/cdtcompmat/intro

Where we are now

Wondering about the right-angled corners in the Coton footpath close to the Department's new site has led to some interesting history. Before the Second World War the footpath followed a more direct route across fields owned by St John's College. Over the hedge to the north lay fields owned by Merton College, Oxford (yes, Oxford) and immediately to the west of that a field held by the Storey's Charity, land holdings which had been assigned in 1805 under the Enclosure Act for the Cambridge West Field. Early in the 1940s, seeking a site on which damaged aircraft could be repaired, the Government requisitioned the Storey's Charity field and a large rectangle from St John's. That rectangle included a length of the Coton footpath. The original route was stopped up and the footpath eventually reinstated just outside the rectangle; hence the right-angled bends.

So what happened on the site? Buildings, small and large, were erected across the site, including two large hangars on the St John's part and they were used by the Short Brothers company for repairing Stirling Bombers, which that company manufactured. Officially it was known as the SEBRO site but after the war it was simply known as the Short's Factory site. The damaged aircraft were partially dismantled and brought to the site on "Queen Mary" transporters from Bourn airfield, just along Madingley Road, or from further afield. If repairable, they were repaired and taken to Bourn for reassembly; if not, they were cannibalised. Much more information ranging through the nature of the work and the recruitment of staff to the colour of the custard in the canteen can be found in "Short Stirling" by Pino Lombardi (Fonthill Media 2015). The aerial photograph [see below] shows the site in 1944 with Madingley Road near the top and the Coton footpath near the bottom.



After the war the owners of the site and the University (and some local organisations), not keen to have a factory retained on the western approach to the city, were anxious to have the site restored but that proved a complicated business. A very far-sighted step was the purchase by the University of the factory site and, significantly, the Merton College land by 1944. In the discussions leading up to the purchases the Treasurer of the University, H.M. Taylor wrote to the Senior Bursar of St John's in October 1947 in the following terms "If the University were to acquire this site it is probable that some of the buildings could be used for temporary laboratory purposes and that in due course more seemly buildings would be erected for "large scale" research work which cannot properly be housed in the town". And so it came to pass! The Department used part of one of the hangars for experimental work in the early 1950s and now has a "more seemly" building. The last of the substantial buildings (those in the lower part of the picture) survived until 1972. Part of their site now houses the new University Sports Centre while the Department's new building is located on former Merton land just above and to the right of the lake shown in blue on the university's current map of the area. We are grateful to staff of the Cambridgeshire Collection and Historic England for invaluable advice.



En garde: nanorevelations

Cate arrived in Cambridge in 1999 with a school background in the Classics and a first degree in Physics from the Università Statale in Milan. An undergraduate project in the year a Nobel Prize was awarded for the creation of fullerene focused her interest on the nanoscale. This in turn led to her coming to Cambridge to work for a PhD under John Robertson in the Engineering Department where she studied nanostructured carbon for field emission and electrochemistry applications. Recognising the need to “see” what they were making resulted in a fascination with electron microscopy and especially its application to materials with potential energy-oriented uses. She then joined the Electron Microscopy Group in our Department, initially as a postdoc. The combination of her skills with the advanced equipment in the EM Group have led to Cate having many collaborators from many places: other groups in the Department or in laboratories around Cambridge or further afield. Recent examples of such investigations include perovskite crystals for tunable white light emission, hybrid glasses (see page 2) and gas sensor arrays. Her distinction in research has been recognised, *inter alia*, by a Royal Society University Research Fellowship and a Research Fellowship at Churchill. After seven years in Churchill she moved to Trinity in 2015 as a Teaching Fellow and Director of Studies in Materials Science. In parallel with these appointments she was appointed a University Lecturer in 2009 and was promoted to Reader in Nanomaterials in 2013.

Teaching and its administration also play a significant role. Currently this includes lecture courses in Part II and at graduate level as well as acting as a Course Director of the MPhil in Micro- and Nanotechnology Enterprise. Cate has long been involved with the IOP's Electron Microscopy and Analysis Group (EMAG), which she currently chairs. To top that off she is involved in the start-up company, Cambridge Solar Environmental Solutions (see *Material Eyes* Issue 24).

At school and as an undergraduate Cate Ducati was a keen and skilful fencer and she has recently taken up fencing again although, as the following account will make clear, she finds the time available is all too limited, not least because her two sons rightfully require attention too.



Congratulations

Judith Driscoll, Inaugural Royal Academy of Engineering Armourers and Brasiers Company prize

Noel Rutter, 2016 Pilkington Teaching Prize

Serena Best and **Ruth Cameron**, EPSRC Joint Established Chair Fellowship

Enrique Galindo-Nava, Royal Academy of

Engineering Research Fellowship

Paul Midgley, Honorary Fellowship of the Royal Microscopical Society

Ed Pickering, Lectureship, School of Materials, Manchester University

Niladri Banerjee, Lectureship in Physics, Loughborough University

Xavier Moya, the Spanish Royal Society of Physics Young Researcher in Experimental Physics Prize

Angelo Di Bernardo, Research Fellowship, St John's College

Katerina Christofidou and **Wilberth Solano Alvarez**, 2016 CSAR Student Awards

Editorial team: John Leake, Mark Blamire and Rachel Hobson **Comments to:** rjh24@cam.ac.uk

The Department has networking groups on [LinkedIn](#), [Facebook](#) and [Twitter \(CU_Mat\)](#).

If you would prefer to receive your copy of *Material Eyes* electronically please email rjh24@cam.ac.uk