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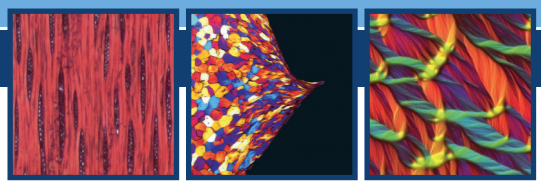
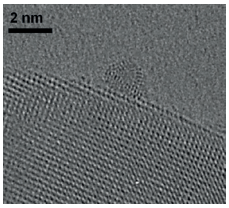


Photocatalysis for Purification

Nanostructured titanium dioxide, TiO_2, is a common photocatalyst. In pristine form, TiO_2 absorbs photons only in the UV region, a minor component of the solar spectrum (around 5%), limiting the efficiency of any photo-activated processes. Najeeb Ullah and Giorgio Divitini working with Vasant Kumar and Cate Ducati have developed a new TiO_2-based catalyst active in the visible range of the spectrum. Extending the absorption range, the new material is capable of degrading organic contaminants and bacteria from water and air with superior performance and reaction speeds, 10 to 100 times faster than catalysts based on conventional titanium dioxide. Importantly, the material can work in low-light conditions including cloudy weather and indoors (using ambient and/or artificial light).



Najeeb and Giorgio were runners-up in the 2012 Dow Sustainability Students Award for this work. A patent application was made in September 2012 through Cambridge Enterprise and a start-up company *Cambridge Solar Environmental Solutions* (CamSES Ltd) aims for commercialisation of this material.

The new photocatalyst has many potential applications for water purification and pollutant removal, for which most current processes favour filtration. Some examples include: textile dyes, where of the 0.7 million tons produced every year worldwide 10% are released as effluents; purification of drinking water without the need for a power source or replacement filters; and a low-cost, low-power solution for the purification of air inside buildings.

The new photocatalyst is a composite of a semiconductor material decorated with metal nanoparticles that can be prepared by simple chemical methods using aqueous solutions. The figure shows a high-resolution TEM image of the new catalyst in the form of a metallic nanoparticle on a titania substrate. The composites are very stable and may be used repeatedly without loss in photocatalytic activity. The rates are very high for all types of redox reactions, including generation of hydrogen from water. These materials, when used as a suspension without assistance from any other catalysts, showed high activity for producing hydrogen gas when methanol was the sacrificial agent. The team has thus achieved expertise in synthesizing new composite photocatalysts that are extremely active, and they will continue to search to improve the properties and expand the range of applications. They are also investigating a new disruptive technology for splitting water to produce hydrogen such that no sacrificial agents are used.

New Aixtron GaN growth facility

David Willetts, Minister for Universities and Science, opened the Department's new Aixtron GaN growth facility, temporarily housed in the Physics of Medicine Building, on 28 March. He was presented with a six-inch disc of LEDs surrounded by a ring of operating LEDs here being demonstrated to the Minister by Professor Sir Colin Humphreys, watched by Michael LeGoff (CEO of *Plessey*); see Issue 23 for details of the collaboration.

Editorial

By Grace of the Regent House, the *Professorship of Materials Science (1988)* was on 27July 2012 renamed the *Sir Alan Cottrell Professorship of Materials Science*, the work of the Professor to be supported by a new Fund established by our Cottrell Appeal. We thank our donors (www.msm.cam.ac.uk/alumni/cottrell/supporters.php) and HRH Prince Edward the Earl of Wessex and Sir Graeme Davies, respectively Patron and Chairman of the Appeal, for their contributions in arriving at this successful conclusion. To complete the 'full report' promised in my previous editorial, I need only add that the Department will soon start on the inspiring task of making the inaugural appointment to this prestigious chair.

I'm pleased to record that Julia King, VC of Aston University and a member of our Cottrell Appeal Committee, was named as a DBE in the Queen's Birthday Honours in June 2012. And Brian Cantor, VC of the University of York, was named a CBE in the New Year's Honours in 2013. Both are alumni of our Department, and it is a joy to see their outstanding leadership of their universities so recognised.

The focus on Africa (p. 2) brings to mind our Department's high international profile. A further sign of this is our agreement, just concluded, to assist the University of Nizwa in setting up Oman's first teaching and research in Materials Science & Metallurgy. We expect great things to come of this, as Oman is rich in metallurgical history and resources.

The move to our new building at West Cambridge will take place over July to September, and then I step down as Head of Department, confident that the support staff, academic staff and students will carry the Department on to yet greater achievements.

Professor Lindsay Greer
Head of Department

UNIVERSITY OF CAMBRIDGE
Department of Materials Science and Metallurgy

Pembroke Street
Cambridge CB2 3QZ
01223 334300

msm.cam.ac.uk

Inside:

Into Africa

At a time when the University is actively increasing its formal links with Africa, for example through the inter-faculty *Cambridge in Africa* programme and the Judge Business School's *Cambridge Africa Business Network*, we recall that over the years Africa has played a major part in the careers of quite a number of our graduates. Here, with their agreement, we explore a small but varied sample.

Rosemary Burke graduated from the Part II Class in 1979 and then followed a successful career in a number of metallurgical and engineering companies, acquiring an MBA along the way and eventually becoming Director, Mergers & Acquisitions for the Corus Group. Then in 2006 she embarked on a new career in the charity sector in Africa, mainly in Ethiopia. She recently reported, "I'm here with Tearfund, which works to alleviate poverty using the existing local church networks. In this way our work reaches right down into the rural areas, to the parts 'other NGOs don't reach!' The majority of programmes involve the formation of self-help groups. These groups save (a new concept!), make loans to members, and work together to address whatever they consider the priority problem for their community to be. It's an inspiring and humbling programme." Her newsletters tell of the challenges and successes of the projects, including reports from individuals whose lives have been transformed by self-help schemes.

Winston Soboyejo was born in Palo Alto in California when his father was working for his PhD. Two years after that the family returned to Nigeria, then twelve years later Winston came to school in the UK, where he remained for higher education, a first degree from King's College, London and a PhD from Cambridge, supervised by John Knott and completed in 1988. Subsequently he moved to the USA, "attracted by the excitement of doing aerospace research" for McDonnell-Douglas. A mixed industrial and academic career followed, leading to his becoming Professor of Mechanical and Aerospace Engineering at Princeton University in 1999. Links with Africa were not forgotten. He became Director of the US/Africa Materials Institute and also realised "the need to develop an institution that can educate a critical mass of high-quality African scientists and engineers". To this end, he has been granted extended leave from Princeton (where he maintains a small research group) to work for the African University of Science and Technology (AUST) in Abuja, Nigeria, becoming President and Provost in January last year. His hope is for "AUST materials science and engineering to impact African Development and the global materials community over the next few years".

Following a first degree from the University of Manchester, **Segun Adewoye** joined the Department in 1973 to work for a PhD with Trevor Page. In 1976 he returned to Nigeria to teach metallurgy in the Department of Chemical Engineering in the then University of Ife, becoming Head of the Department of Metallurgical and Materials Engineering in 1984. After a short spell in industry he became Professor in 1989, developing an interest in nanoscience. As the pioneer Director of the Engineering Materials Development Institute from 1995 to 2003 he encouraged innovation in equipment and processing, and stimulated teaching and research in many Nigerian universities. From 2003 to 2012 he was Director-General of the National Agency for Science and Engineering Infrastructure (NASENI). During this period the Agency changed its rôle from conventional to advanced manufacturing technology (AMT) and established many AMT Centres in NASENI institutes and selected universities, as well as seeking ways to lower the cost of manufacturing. Noteworthy projects included the manufacture of a small hydro-turbine for installation in a river to generate electricity for a rural community. At the same time he maintained active involvement in university teaching and in research in nanoscience. He is currently a member of the Visiting Faculty at AUST and so he and Winston Soboyejo, who have collaborated for some twelve years to promote advanced manufacturing and nanotechnology, remain closely linked. Notably both were elected Fellows of the Nigerian Academy of Science (the equivalent of British FRS) in 2007. Beyond Nigeria, Segun has encouraged collaborations between materials scientists around Africa. Amongst many distinctions, he has served as President of the Africa Materials Research Society.

John Clarke remembers Segun Adewoye, who had been in the Department just one year when John arrived with a BSc in Metallurgy from Cardiff followed by 16 months experience in apartheid-dominated South Africa. With a background in low-temperature, "wet" metallurgy he embarked on a high-temperature PhD under Derek Fray, determined to finish in three years – he did. He then worked for RTZ and Johnson Matthey in the UK before Africa called again, for fifteen years of growing opportunities with Ashanti Goldfield in Ghana. His focus in Africa gradually moved from production to exploration and to progressively more senior executive rôles, with an emphasis on long-term strategic planning. He has several directorships: he is currently chairman of Great Quest Metals (based in Vancouver) and is a non-executive director of PMI Gold in Ghana and Mediterranean Resources in Turkey, all companies with mineral exploration and mining interests. Much travelling is involved but he finds the UK provides a good base. Currently, despite the political situation in Mali, Great Quest is planning to develop a major phosphate-mining operation in northern Mali. He comments that handling agrochemicals (the phosphates will be used in the production of fertilisers) is very different from producing metals; distribution is all important, one has to manage the downstream side. Recently he has taken on the temporary position (following seven years as a non-executive director) as CEO of Banro Corporation, a successful gold mining company in the DRC. Looking back, he comments that he has enjoyed his career and has appreciated the grounding that higher education gave him, not least in the need for rigour at critical stages of company development.

Thus we discover something of the Department's links with Africa and are reminded of the wide variety of careers that Materials Science and Metallurgy open up!

ABC Forum 2012

Professor Bill Bonfield (Past Master of the Armourers & Brasiers' Company) welcomed participants to the Company's 2012 Cambridge Forum, additionally supported by ten other organisations.

Julian Allwood (Cambridge) analysed the use of key materials, notably steel and aluminium, in three representative economies (California, Japan and UK), demonstrating that the target 20% reduction in carbon dioxide output associated with producing and using these materials would not be achievable without a significant reduction in the amount of new material manufactured. Ways forward include: better design reducing wastage; longer lasting components; and greater re-use of materials without re-melting.

Matt Rosseinsky (Liverpool) combined chemistry and crystallography to create more efficient materials for visible-light photocatalysis and light-harvesting, and better cathodes for solid-oxide fuel cells. He described a porphyrin-based metal-organic structure $CaCu_3Ti_4O_{12}$ where the key functionality derives from charge transfer between ions in distinct crystallographic sites and a promising but unstable complex perovskite ($Ba_{0.5}Sr_{0.5}Co_{0.8}Fe_{0.2}O_{3-\delta}$); research is in progress to identify a stable relative.

Andrew Bloodworth (British Geological Survey) assessed critical metal supply, "critical" reflecting high supply-risk and high economic importance. Insufficient of some elements exists in the "urban mine" to meet demand, and recovery from scrap is incomplete. The volume, value and variety of elements used are significant. Scarcity, geopolitics, the reluctance of major mining companies to exploit minor deposits, environmental considerations and a shortage of young recruits all play a part. Harvesting the sea bed and new techniques in old mines could contribute.

Noting HM Government's aims, Nigel Knee (EDF Energy) outlined his company's plans for two new UK nuclear power stations, each with two reactors. The many approvals required include funded decommissioning and environmental factors; and the company expects economic assurances. The plants, based on the European Pressurised Water Reactor, will have a 60-year lifetime, four-fold redundancy in the safety systems and robust resistance to earthquakes, aircraft and meltdown. Each reactor will drive one giant turbine, normally running at half speed to yield 1630 MWe.

George Smith (Oxford) explained how atom-probe tomography reveals the three-dimensional arrangement and chemical identities of millions of atoms. Illustrations included nano-rods in Al-Mg-Si alloys, and carbon atoms around a dislocation in a steel – a Cottrell atmosphere. He digressed briefly on the histories of field-ion research in Oxford and Cambridge and described the joys and frustrations of setting up a spin-out company and seeking further research funding.

Sir Timothy Ruggles-Brise, Master of the Company, then awarded the Armourers & Brasiers' Materials Science Venture Prize 2012 to Peter Edwards and Vladimir Kuznetsov (Oxford), and Jamie Ferguson (Isis Innovation) to help them establish manufacturing processes for their transparent conducting-oxide coatings based on oxides containing earth-abundant elements instead of indium. Peter Edwards outlined the science and their plans for development.

Automotive Materials Challenges

The 14th Kelly Lecture was given by Alan Taub, until recently VP for Global R&D at General Motors. In an excellently illustrated lecture on *Materials Challenges for a Sustainable Automotive Industry* he surveyed key aspects of the vehicle of the future, emphasizing the prospects and challenges for materials.

Commenting that vehicles have changed little in concept in 120+ years, he recalled that different decades have had different foci: Ralph Nader's *Unsafe at any speed* led to a concentration on safety in the sixties; the "oil shock" of the seventies highlighted fuel efficiency; now design has returned to centre stage. As the world population increases and vehicle ownership heads towards one vehicle per adult, we must reinvent the vehicle if we are to achieve sustainability. Attention must be given to: highly efficient use of a low-cost renewable energy source; emissions; safety; avoidance of congestion; and affordability.

For the first two, possibilities include replacing petrol by other liquids or, more probably, using electric propulsion with either a hydrogen fuel cell or a battery. Lithium-ion batteries appear to hold out the best prospects but battery packs remain heavy and of low capacity, limiting vehicle range. Fuel cells are lighter but challenges include storage for the hydrogen fuel and the membrane separating the anode and cathode regions (a very thin polymeric material is ideal if pinholes can be avoided).

A vehicle in motion uses roughly one third of the fuel moving air around and another third indirectly heating the tyres and other components. Nevertheless weight reduction is desirable. Ways to achieve this, some implemented, some in development, include replacing steel by Al or Mg alloys and replacing mild steel by high-strength steel. Topics for investigation include the cost of forming and joining, and the possibility of greater use of superplastic forming. Al alloys might then be cheaper to use than steel. Appropriately for a Kelly Lecture, he noted that a polymer-composite vehicle would be the lightest achievable. Thermoplastic olefins are promising, but a better understanding of their properties is needed. Long-fibre composites are attractive but the cost of long carbon fibres is a deterrent. Tooling costs and moulding times remain issues. One problem now solved was identifying a UV stabiliser for the colour. Promising early results have been obtained for a composite made by injecting a thermoplastic into a fibre set-up to create a material with properties approximating a thermoset.

Corrosion is likely to recur because the industry is moving towards making only one physical prototype after a great deal of computer-aided design, so there may not be time for corrosion problems to be revealed. In short, a lot of work on materials will be needed!

Tony Kelly congratulated Alan Taub on his extensive grasp of science and for relating that science to many different technologies. He said, with the opposite of disrespect, that he had been reminded of the remark attributed to Enrico Fermi after hearing a lecture on a particularly abstruse topic "Before I came here I was confused about this subject. Having listened to your lecture I am still confused – but at a much higher level!". Alan Taub had placed materials at the centre of societal needs for the 21st century.

Sharper still, yet sharper – David Nicol

Electron microscopes have long filled a major rôle in the Department. For over 25 years David Nicol has been responsible for maintaining their full effectiveness. He began working for the University as a photographic technician in the (then) Metal Physics Group in the Cavendish before becoming involved with their electron microscopes. When he joined our Department in 1985, Mike Stobbs was in charge of electron microscopy, and as much as possible of the maintenance was done in-house, necessitating fault-finding down to component level; only in desperation were external engineers summoned. Now, with the ever-increasing dependence on software to which "we don't have the key", full-service contracts are the norm and close liaison with the manufacturers' engineers is essential. Nevertheless much has to be done internally, and David is assisted by Simon Griggs with the SEMs and the "bread and butter" TEMs in the Arup Building basement, and by Graham Sharp with the HREMs in the Old Cavendish, "an excellent building for lack of vibration or electrical interference". They also take in their stride the extensive range of sample-preparation facilities.

When he joined the Department, David was not involved with training but now he does most of the "hands-on" training for the TEMs, Helios dual-beam SEM/FIB and for some of the SEMs. With the advent of user-friendly software control, the number of new users has increased dramatically to around 100 each year. The advances in software have reduced the need for users to develop a deeper understanding of the techniques involved, which he finds "a little disappointing". Over the years he recalls working with some notable experts in electron microscopy and some excellent students, many now in senior positions around the world.

Inevitably the move to West Cambridge is giving David much to think about. Pouring of the massive concrete slab specified by Paul Midgley, Director of the EM Facility, was pictured in the February 2012 issue of *Material Eyes*. It is likely that the EM Group will be among the last to move so that, before the microscopes are installed, the new area can be checked for electrical and mechanical interference when the equipment in other groups is already running.

When he escapes from the demands of keeping everything running in the EM area, David has a two-mile journey home to wife Linda, pictured with David in Egypt, daughters Sarah and Emma, and cats Norman and Monkey – an inevitable source of vet's bills. He is also a long-time, if sometimes disappointed, supporter of Tottenham Hotspur.

Congratulations

Serena Best, Fellowship, Royal Academy of Engineering
Tony Cheetham, Treasurer, The Royal Society
Bartek Głowacki, Bernal Professor of Energy, University of Limerick (held part-time, with his Cambridge position)
Alan Windle, ScD (Cantab)
Emilie Ringe, Newton International Fellowship, The Royal Society
Sohini Kar Narayan, Fellowship, Clare Hall
Rachel Oliver, Department Teaching Prize
Jessica Gwynne, Department prize for Contribution to Teaching
Daniel Jewell, Best Paper Prize, ITA Titanium 2012
Tom Bennett, PANalytical Award, Best paper Award
Emma Pewsey, Access to Understanding Award, Europe PubMed Central organisation
Mehdi Golozar, Best Oral Presentation, 20th Jubilee Conference, Portoroz, Slovenia
Stephen Croxall and Abdulaziz Moshaweh, 1st Prize, Dept PhD Poster Prizes

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

The Dept has networking groups on LinkedIn and Facebook.
If you would prefer to receive your copy of *Material Eyes* electronically please email rjh24@cam.ac.uk

From the start of the new academic year in October 2013, our postal address will be
27 Charles Babbage Rd, Cambridge CB3 0FS