Cambridge
materialeyes

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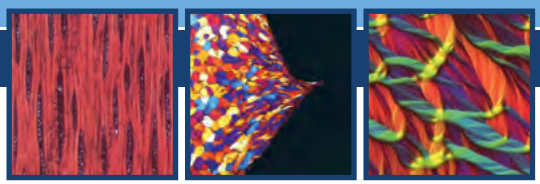

Triple Expansion

The Department is well-known for its research in electron microscopy and the range of electron microscopes housed within the Wolfson Electron Microscopy Suite (WEMS), the purpose-built suite of rooms that was a cornerstone of the new MSM building plans. Over the next few months, the Department's suite of microscopes will be augmented by three new, and rather different, electron microscopes.

The first, now installed and being used in earnest, is a Thermo Fisher (formerly FEI) Titan Krios. This instrument forms a key part of an agreement between the University and Thermo Fisher in which the Krios, on loan from the company, is housed within WEMS and is offered to five pharmaceutical companies to undertake cryo-electron microscopy. The Department has access to the instrument when not being used by the pharma companies. Such instruments offer unique capability and we're keen to explore how such an instrument can be used to solve difficult materials problems, requiring low dose and low temperatures and the ability to capture images at high frame rate. We plan to look at pharmaceutical crystals, polymers, hybrids and battery materials.

The second, funded by the EPSRC Strategic Equipment Panel, with Paul Midgley as PI, is a 'multi-dimensional' electron microscope. This instrument is designed to capitalise on the remarkable new technology and processing power now available. It builds upon STEM-based electron tomography, pioneered in the Department over the past 20 years or so, to allow simultaneous imaging and spectroscopy (real space and energy space), imaging and diffraction (real and reciprocal space), and all combined with 3D electron tomography. With such an instrument we are able to record easily Tb of data in just a single session, requiring

significant and efficient data processing, including machine learning, a key aspect of the ongoing research. We are planning to install this microscope in summer 2019.

The third instrument is a time-resolved scanning electron microscope dedicated to ultra-fast and ultra-sensitive cathodoluminescence studies. Again this was funded through an EPSRC Strategic Equipment grant, with Rachel Oliver as the PI, and is primarily designed to study the optical and electronic properties of semiconductor and plasmonic structures but can be applied to any interesting luminescent material; it will be a key part of Rachel's continuing work on developing novel GaN materials and devices. Not only will the instrument be able to map the luminescent features with high spatial resolution, and with picosecond time resolution, crucially the temperature can also be varied so as to be able to infer not only the time scales on which electrons relax to low energy sites emitting a photon, but also the time scales by which electrons reduce their energy by other, non-light-emitting routes. The instrument is due for delivery in 2019 and will be open to external users as well as those within Cambridge University.

Editorial

As the new Head, the first thing I must do is thank my predecessor Mark Blamire for his leadership over the past 5 years. During his tenure we have settled into our new building, the Department has gone from strength to strength, and we are well placed to weather whatever political storms lie around the corner. Thanks also to Zoe Barber and Serena Best, Mark's deputies during that time. Moreover Serena has willingly continued in her role, joined by James Elliott as my other deputy.

Thank-you also and farewell to Paul Bristowe, who retired at the end of the last academic year – Paul's contribution to both research and teaching will be greatly missed. We wish Paul a happy, healthy and long retirement. Another long-standing member of the Department who has left for cricket fields anew was Noel Rutter, long-standing senior Teaching Fellow. Together with the help of Jess Gwynne (who has succeeded him in that role), Noel had a major hand in transforming the teaching in the Department to leave our undergraduate numbers at record highs; we thank Noel for all his efforts over the years. Over the summer we warmly welcomed our new Goldsmiths' Professor, Manish Chhowalla and we look forward to working with him.

The faculty continue to win prizes, medals and fellowships (see page 4), and it's a particular delight to see early career academics in that list and also winning prestigious European research grants. Preparations for the next REF continue with activities starting to ramp up as the submission date of late 2020 looms into sight. 2020 also marks the 100th anniversary of the founding of the Goldsmiths' Laboratory and thus, in essence, of the Department, and such an auspicious date deserves to be marked and celebrated – more on this in issues to come!

Paul Midgley,
Head of Department

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Inside:

Goldsmiths: 700 & 100 years

Continuing a generous sequence stretching over a century, a further gift has been received from the Goldsmiths' Company Charity to mark both the 100th anniversary of the donation that funded the establishment of our Goldsmiths' Laboratory, which opened in 1920, and the imminent 700th anniversary of the Company's first royal charter. Given the Company's responsibilities in the field of precious metals they have an understandable concern about the shrinkage of UK expertise in the field in recent years. With the aim of reversing this trend the purpose of the gift is to fund three PhD studentships in the Department. It is planned that the first two students will start in 2019; one will be involved with an investigation of precious metal shape memory alloys, supervised by Nick Jones, and the other will focus on metallic glasses based on precious metals, supervised by Lindsay Greer.

In announcing the gift, Michael Prideaux, Prime Warden of the Goldsmiths' Company, said: "Items have been made of precious metals for millennia. Today, they are used across medical, electronic and aerospace applications as well as in jewellery and silversmithing. We are proud to be further developing a partnership that stretches back over 100 years between the Goldsmiths' Company and Cambridge's Department of Materials Science, a centre with an outstanding international reputation."

Notable Visitors

In recent months the Department has hosted two notable visitors. As part of his programme of visits to all parts of the University in order to introduce himself to staff and students the Vice-Chancellor toured the Department on 30 April. He was shown a wide range of our teaching and research facilities and we were delighted to see how interested he was in them. In particular the time that he took to talk to younger members of the Department who had prepared a display of posters in the Tea Room was greatly appreciated.

Then, on 16 May, we were visited by Sam Gyimah MP, then a joint Minister for Higher Education at the Department for Business, Energy and Industrial Strategy and the Department for Education with responsibilities focused on universities, science, research and innovation. His intensive tour took in many aspects of our research and included talks with graduate students, postdocs and members of staff from the UK and overseas.

Royce Institute opening

The Royce Institute in the Maxwell Centre (see Issue 32) was formally opened on 17 October. After an Address of Welcome by the Vice-Chancellor, Julia King, Baroness Brown of Cambridge (pictured with Sir Richard Friend) unveiled a commemorative plaque. The Chief Scientist of the Henry Royce Institute nationally, Professor Philip Withers, described the Institute's national plans. After Julia and Phil, both former members of staff in our Department), a series of talks outlined the Institute's work in Cambridge and the potential for interactions with industry. *Photographer: Graham CopeKoga*

Sad Farewells

Maddie McElroy spent 11 years with us before retiring in 2013 as Senior Electronics Technician, a role that underpins so much of the Department's work. Her many helpful contributions will long be remembered by those she assisted.

Dr Ron Broom joined the Department as an unpaid "visitor" when he retired from IBM in the early 1990s. He worked initially with the Electron Microscopy Group and then with Colin Humphreys. Among his various talents from which we benefited were his extraordinary skills as an instrument maker, for example creating novel electron microscope specimen stages in the workshop he built up in his garage at home. A fuller obituary is available on **www.msm.cam.ac.uk/news-and-events/news/obituary-dr-ron-broom**

All's well that ends well

The St John's College team captained by James Devine-Stoneman of our Department (see Issue 32) were successful in winning the 2018 BBC2 University Challenge competition. Many congratulations to all involved!

ABC Forum 2018

In opening the 2018 Armourers & Brasiers' Cambridge Forum, Bill Bonfield thanked the sponsors for their invaluable support and Lindsay Greer for once more assembling an interesting programme, additionally noteworthy because the first 3 speakers in the Gordon Seminars were women.

Noting the limitations in our understanding of the mechanical properties of materials with all but the simplest crystal structures, **Sandra Korte-Kerzel** (Aachen) described her exploration of strong and (fairly) ductile materials with relatively complex structures. The behaviour of γ- $Mg_{17}Al_{12}$ (found in most Mg-Al alloys) has been studied as a load bearing phase by techniques including deformation of 1 μm samples in an SEM and nano-indentation over a range of temperatures coupled with modelling. Grain boundaries present another challenge!

Combining 3 of Richard Smalley's top 10 challenges - energy, environment and water - **Camille Petit** (Imperial) focused on materials to purify water or, more widely, to capture other substances using less energy-demanding processes than currently. Nano-scale porosity is essential. Boron nitride with a skilfully tailored nanostructure successfully absorbs oil from contaminated water. Carbon dioxide can be captured in a morphologically optimised nanocomposite of a MOF and TiO_2 in which it can be photocatalytically reduced.

Generating electricity from sunlight has come a long way but the energies of all too many incoming photons are either too low or too high for effective direct use in solar cells. **Rachel Evans** (Cambridge) is developing materials for luminescent spectral converters to convert the energies and then guide the resulting (now useful) photons to the solar cell. Soft materials with a large Stokes shift such as ureasil show particular promise. Appropriate design will allow these devices to be attached to the walls of buildings where they can harvest diffuse light.
Starting from the search for a cheaper manufacturing method for GaN LEDs **Michael Le Goff** (CEO until July 2018, Plessey) led us through the life cycle (Infancy, Expansion, Maturity and Decline) of their involvement with the GaN-on-silicon process, which had involved the acquisition of Colin Humphreys' CamGaN spin-out. After initial success Plessey recognised that financing to scale-up production in the UK was not forthcoming so the decision was taken to focus on R&D in this country, to aim to licence the technology overseas and to seek other uses of LEDs such as MicroLeds.

Michael Ramage (Cambridge) outlined the challenges and showed some of the successes of using wood as a constructional material. Understanding of the engineering factors is growing; anisotropy of the material, methods of joining, protection from the weather and regular maintenance are all soluble problems and wood has a lower carbon footprint than steel or concrete. Achievements range from simple bridges of willow that takes root to a 14 storey-skyscraper. Use of natural fibres to make constructional composites shows promise too.

Prior to introducing the Master, Julian Beare, to present the 2018 Venture Prize, Bill Bonfield reported that eight viable companies have emerged from the ten awards made so far. In announcing this year's prize winner: **Kubal-Wraith** of Swansea, represented by Dr Szymon Kubal, the Master noted that Swansea is the first university to win a second award. Working with Tata Steel, Kubal-Wraith is developing a laser-based technique to provide continuous process monitoring of molten steel (or other metal) leading to a potential annual saving of £400M in the steel industry alone.

20th Kelly Lecture

In a meticulously illustrated lecture **Peter Bruce** (Oxford), who had been succinctly introduced by Lindsay Greer, focused on three topics: all solid state batteries; storing charge on oxygen ions; and electrical energy storage.

Enhancing the performance of the present generation of rechargeable Li batteries can be achieved by changing to Li electrodes and by replacing the inflammable (and so potentially hazardous) organic liquid electrolyte with a solid electrolyte to create an all solid state battery. A ceramic electrolyte on its own could have high ionic conductivity but would be brittle. A ceramic polymer composite would have enhanced mechanical properties and, with a microarchitecture including continuous conducting fully-dense ceramic channels, would also conduct well. He showed impressive examples of composites created via 3D printing and based on $Li_{1.4}Al_{0.4}Ge_{1.6}(PO_4)_3$ explaining the multi-step process.

Efforts to increase the charge storage in lithium-ion batteries include moving from graphite to silicon anodes and, at the cathodes, exploiting a recent development in electrochemistry - the recognition that in some materials electrons can be taken from oxygen. Hitherto at the cathode charge (electrons) has solely been stored on and removed from transition metals (e.g. on Co in $LiCoO_2$) as the battery operates but, in some materials, it has now been found possible to take electrons from oxygen ions, leaving hole states, e.g. in $Li_{1.2}[Ni^{2+}_{0.2}Mn^{4+}_{0.6}]O_2$. He presented an explanation of this phenomenon taking account of the detailed atomic arrangements and the associated bonding.

Increasing demands for ever higher electrical energy density, not least in the transport field, are driving research on other rechargeable battery systems. The Li-O_2 ("Li-air") system, which uses oxygen from the atmosphere, has the highest theoretical specific energy and progress is being made to solving the problems that stand in the way of its application, especially the poor charge/discharge repeatability. This requires understanding the mechanisms and the microstructural changes involved at the anode and the cathode, and identifying a satisfactory electrolyte. Progress is being made, for example through the use of organic mediators to prevent the formation of Li_2O_2 on the cathode surface.

Finally Peter gave a very brief account of the newly established Faraday Institution and its focus on electrochemical energy storage.

In proposing the vote of thanks, Clare Grey complimented Peter Bruce on his elegant talk which illustrated how fundamental materials discoveries are the key to making progress towards the ultimate Li rechargeable battery.

Shaping the Sun – Rachel Evans

Using sunlight to generate electricity is a rapidly developing, sustainable technology, but conventional solar panels make little or no use of many of the incident photons because their energy is unsuitable. Tackling this problem is the aim of Rachel Evans, who joined the Department from Trinity College Dublin (TCD) in January 2017, the latest move in a multi-step journey from the Welsh Valleys via Chemistry (MChem, PhD) at Swansea University and posts in several European countries including Portugal, France and Switzerland. Along the way, she has received the RSC/SCI UK Young Researchers' Medal and the Dillwyn Medal for STEMM (Learned Soc. of Wales). Very recently she has been elected a Fellow of the IOM3 and the RSC.

After nearly two years, Rachel is well absorbed into all three aspects of university life - teaching, research, and administration. In the Department apart from research, she is teaching Part II and III courses on Electrochemical Materials and Soft Matter respectively and naturally is involved in the associated supervising. Unsurprisingly committee work has come her way; she is Secretary of the Equality & Diversity Committee and serves on the Research Committee. With Sohini Kar-Narayan she organised the recent 4th CAMatNet Symposium. To all this she has recently added a Teaching Fellowship in Jesus College in succession to Noel Rutter. Externally she is much involved with the RSC, not least as chair of the Photophysics and Photochemistry Group, and she is CSO and Co-Founder of TCD spin-out Senoptica Technologies who are commercialising an optical sensor platform invented in her lab that will verify the integrity of food packaging across the distribution chain, thus helping reduce waste.

Looking more closely at her research: one way around the problem mentioned above is the creation of materials that can absorb a "wrong" energy photon (or two such photons) and emit another with a usable energy. Then come the interdisciplinary challenges of identifying and fabricating the optimum geometry for an efficient combination of such a material with a conventional solar cell, ideally leading to solar cells that can be mounted on walls in a built environment to harvest diffuse light as well as direct sunlight. Her group consists of 5 PhD students including one who came with her from TCD; all being well, a postdoc will be joining shortly. Very recently we were delighted to learn that her research is to be supported by an ERC Consolidator Grant.

Plainly, Rachel's life is very full but when the occasional opportunity to escape comes along, she enjoys water-borne activities such as surfing, stand-up paddle boarding and exploring by boat, as pictured on Inle Lake, Myanmar.

Congratulations

Manish Chhowlla, elected to the Goldsmiths Chair
Rachel Oliver and **Vasant Kumar**, Personal Chairs
Sohini Kar-Narayan, Reader
Judith Driscoll, Fellowship of the Royal Academy of Engineering and the Kroll Medal, IOM3
Serena Best, Fellowship of AIMBE
Ruth Cameron, the Griffith Medal and Prize, IOM3,
Howard Stone and the Rolls-Royce Materials Strategic Partnership, Gold Medal, IOM3
Lindsay Greer, John Hunt Medal, IOM3
Rachel Oliver, Rank Prize Lectureship 2018
Cate Ducati, RMS Medal for Innovation in Applied Microscopy for Engineering and Physical Sciences
Emily Ringe, ERC Starting Grant
Rachel Evans, ERC Consolidator Grant; Fellowships of IOM3, RSC & Jesus College
Robert Hoye, RAEng. Research Fellowship and Engineers Trust Young Engineer of the Year award
Guillaume Nataf, Royal Commission for the Exhibition of 1851 Research Fellowship
Tom Bennett, ISIS Science Impact Award
Owen Saxton, Lord Rayleigh Medal and Prize, IOP
Fabien Massabuau, Armourers and Brasiers' PDRA Prize

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