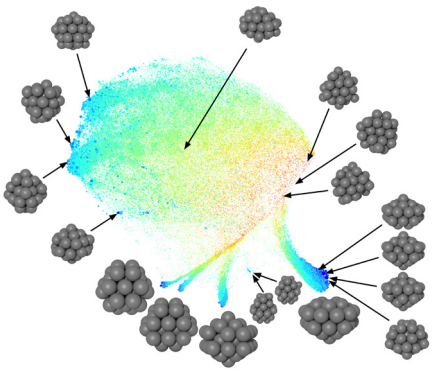
Cambridge
materialeyes

Winter 2021 Issue 37

Materials Theory

The Materials Theory Group (MTG) was founded by Chris Pickard when he joined the Department in 2015 as the inaugural *Sir Alan Cottrell Professor of Materials Science*, and has grown with the appointment of Bartomeu Monserrat as the *Gianna Angelopoulos Lecturer in Computational Materials Science* in 2020. Using modern supercomputers, research aims to solve the equations of quantum mechanics to discover new materials and phenomena, spanning areas including superconductivity, topological materials, optoelectronics and nuclear magnetic resonance, with a particular focus on the development of novel methods and algorithms. The team of postdocs, PhD and MPhil students is supported by state, industrial and philanthropic funding, with a recent highlight being a £1.5M *Future Leaders Fellowship* grant from UKRI. Research has been recognised with multiple awards, including three from the Institute of Physics: the 2015 *Rayleigh Medal* for Chris, the 2021 *Maxwell Medal* for Bartomeu, and the selection of a paper from the group as a 2020 *Top 10 Breakthrough*.



Output from a recently developed algorithm to visualize the complex structural information of materials. Credit: Ben Shires https://journals.aps.org/prx/abstract/10.1103/Phys-RevX.11.041026

The computational search for high-temperature superconductors, led by Chris, is core research. Inspired by the ideas of the late Neil Ashcroft, first-principles stochastic structure searching has been used to uncover potential superconducting hydrides. This hunt has been joined by researchers across the globe and, with the experimental confirmation of several of the key predictions and the claim in 2020 that room-temperature superconductivity had been achieved (albeit at extremely high pressures), the race is on to discover new high-temperature superconductors under more achievable conditions.

Another line of research is the study of topological materials, led by Bartomeu. These materials exhibit numerous exotic properties, such as dissipationless currents or non-Abelian states, which could find application in technologies ranging from low-power electronics to robust quantum computers. These properties only exist at very low temperatures, precluding applications, and recent work in the group has provided a microscopic explanation for the loss of topological properties with increasing temperature. This understanding can be used to design the first material that behaves conversely (with topological properties promoted by increasing temperature), paving the way for applications in practical devices.

The MTG participates in many outreach activities, with its own section in the Department's *YouTube* channel, and another: *Professor M does Science*, which teaches quantum mechanics to a worldwide audience. It is also an integral part of the *Lennard-Jones Centre*, bringing together researchers interested in Materials Theory from across the University.

1920 – 2020
We end the Department's centenary celebrations with a supplement to this issue of *Material Eyes*. Curated by Lindsay Greer, this highlights developments over more than a century, and also takes a look forward.

Editorial

Welcome to the Winter 2021 edition of *Material Eyes* with a bonus special Department Centenary Supplement.

This year it has been a privilege to celebrate 100 years of Materials Science in Cambridge despite the challenges of doing so in a time of COVID restrictions. The milestone has given us an opportunity to reflect on the huge contributions of the past, and to look ahead to the advances to be made in the future, while meeting together (mostly virtually!) with old and new Department members and friends. It was a particular pleasure that we were able to mark the anniversary in person in October in the extraordinary surroundings of the Goldsmiths' Hall in London.

Earlier this year we saw the retirement of Lorraine Dann, our Department Administrator for many years. Lorraine helped to steer us through huge changes during her time in office, and the Department owes her a great debt. The three of us, on behalf of the Department, would like to offer our heartfelt thanks for her support.

This Michaelmas Term we have had the pleasure of seeing in person teaching return more fully to the Department. Once again we would like to pay tribute to the skill of our academics and Professional Services Staff in making this happen safely and to our fantastic students who have risen to the challenges of the past year with grace and good humour.

Finally, our *Student Opportunity Fund*, launched in commemoration of our centenary, is enabling us to provide further ongoing support to our students – please do consider making a donation at the link below.

We hope you enjoy this issue.

Ruth Cameron, Jason Robinson and James Elliott

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We are proud to offer world-leading teaching and cutting-edge research training in Materials Science to undergraduate and postgraduate students. With your help, we can offer our hardworking students even more opportunities, through additional research and professional development support. Please consider supporting our Student Opportunity Fund today!

For more information or to give, visit: **www.philanthropy.cam.ac.uk/give-to-cambridge/materials-science-metallurgy-student-opportunity-fund**

ABC Forum 2021

On 23rd June, the 17th Armourers and Brasiers' Cambridge Forum was enjoyed on-line in real-time by nearly 400 participants across the world, with the opportunity (*https://www.youtube.com/playlist?list=PL-RQ5CcRMcW4cMdt1PrxCXOcacOiHdAjS*) to look back and take in even more detail from an excellent and entertaining programme. In his introduction, Emeritus Professor Bill Bonfield, Chair of the A&B Materials Science Committee, emphasised the unique and vital contribution that Materials Science makes to Society, and this theme was certainly reinforced during the event.

Prof. Lindsay Greer began with a tour through the 100 years since the foundation of the Department in Cambridge, and stepping back even further to the first laboratory, in 1860. Discussion of the incredible diversity of research which has developed from these early beginnings, and reference to some of the remarkable contributions and contributors, gave an inspiring start to the afternoon.

The following talks featured Department alumnae, beginning with Dr Alice Bunn, who told us about her fascination with space-technology and its value to humanity (see page 3). It's an exciting time, and there are some great opportunities, including prospects for zero-gravity research and manufacturing. Calling in from Cape Cod in the US, Dr Eilidh Bedford presented her *Adventures in Product Development*, with reference to work on membranes for filtration products. Following rapid development in the early days of the Covid pandemic these are now a key component of vaccine production, with further applications in medical and breathing filters, and air-filtration for transport. Materials Science was essential at all stages, from initial modelling, through to the first prototype, failure analysis, and scaling-up of manufacturing. Lastly, Prof. Frances Ross (at MIT) gave a fascinating overview of her work on in-situ, real-time electron microscopy for following Materials Science at the nanoscale. She showed captivating movies of crystal growth; the use of moiré fringes for following 2D-material stacking; and studies of island formation on surfaces.

The 2021 Kelly Lecture, *Sustainable Metals*, was given by Prof. Dierk Raabe of the Max Planck Institute, Düsseldorf. He delivered the message that Materials research has a huge impact on global sustainability, and that there is much to do! Besides the development and optimisation of materials for 'green technologies', there are many more demands, e.g. the deployment of coastal protection. The whole life-cycle, from materials extraction and production, through component fabrication, use, longevity, and disposal or recycling, must be considered and quantified.

Other events during the afternoon included *Brief Encounters*, in which 9 PhD students and postdocs each gave a 3-minute presentation on their research. This was a master-class in packing information into a very limited time! And, following the award of the 2021 *A&B Venture Prize* to Gianluca Memoli, of Metasonixx Ltd., we learnt about the development of a commercial route to acoustic metamaterials for sound manipulation, offering applications for directing sound, and for noise cancellation.

In addition to these talks and presentations, the on-line, virtual environment enabled a poster session, and individual networking capability. Whilst we missed real, face-to-face encounters, the opportunity to meet and chat on-screen with friends and colleagues in far-flung locations was a valuable compensation.

Joint Successes!

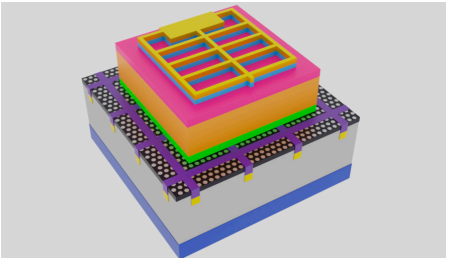
In a novel initiative Cambridge's School of Physical Sciences created nine new interdisciplinary lectureships, with the positions to be held jointly in two departments. Two of these were associated with Materials Science, and appointments were made in 2017. How has it worked out?

Dr Emilie Ringe came from a similar joint position at Rice University in the US: a Materials Scientist linked with the Chemistry Department. The position at Cambridge (combining Materials Science with Earth Sciences) appealed greatly, offering the opportunity to amplify her networking and, on arrival, it became clear that Earth Sciences offered horizon-broadening problems and challenges to which she could contribute. Dr Louise Hirst came from a US National lab., and was seeking greater independence and the opportunity to become involved with teaching. She says that she couldn't have found a better job description (combining Materials Science with Physics) to fit with her aspirations, and has been able to build an interdisciplinary team to address translational research challenges and target higher impact.

Louise and Emilie agree that they hold a privileged position, with access to students, grant opportunities, colleagues and facilities in two departments. Having these links leads to wider collaborations for others: "you're a conduit! People seek you out because you have broader knowledge". What about the concern that there's twice the work-load, with pressure from two departments to teach, take on administration and acquire research funding? The answer is in being self-aware and knowing what's possible, whilst having the confidence to turn things down. But staff meetings and e-mail loads are indeed doubled!

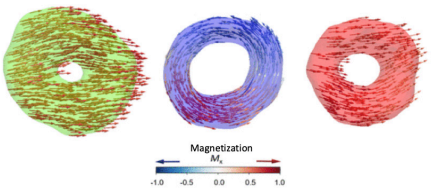
Emilie has two labs – one in each department, as there is a natural divide. In contrast, Louise's current experimental work is based in Physics, and she and her group base their office-work in Materials Science. In both cases the space between the respective departments is seen as a bonus, allowing a brief break during transit, as well as benefitting from the occasional switch in surroundings. In terms of international recognition and career progression, huge advantages surely come from interdisciplinarity, but there is always a concern of being seen as neither one thing nor the other. New ground must be broken here (not only does Emilie work between Departments, but also between University Faculties!).

In recent work requiring a range of skills drawn from both Physics and Materials Science, Louise's group has developed ultra-thin (< 100 nm) GaAs photovoltaics with integrated nanophotonic gratings for space power applications (*DOI: 10.1002/pip.3463*). This started by uncovering the physical mechanisms driving optimal grating design and continued, through novel fabrication methods of these designs, on to assessing space-worthiness by exposing devices to damaging particle radiation.



80 nm thick GaAs photovoltaic device (2.5 mm × 2.5 mm) on an integrated nanophotonic structure.

Emilie has applied her expertise to new fields and samples: for example, in the understanding of magnetism in doughnut-shaped magnetite nanoparticles. Together with a student she jointly advises with Professors Richard Harrison (Earth Sciences) and Paul Midgley (Materials), she has characterized the exact three-dimensional shape of synthetic iron oxide structures, and explored how small changes and defects in their shapes affect their magnetic behaviour: *https://pubs.acs.org/doi/abs/10.1021/acs.nanolett.0c02795*



Predictions of remanent state for 3 different iron oxide particle shapes, with average outer diameter (L to R): 80, 72 and 61 nm.

From Materials Engineering to Space, and back again

Brief remarks and chance meetings often have unexpected, far-reaching effects on our lives, and this was certainly the case for Alice Bunn in her discovery of Materials Science. Alice didn't receive careers advice to point her in this direction, but a school teacher recommended the book: *The New Science of Strong Materials: Or Why You Don't Fall Through the Floor* by J.E. Gordon, which piqued her interest. She made contact with a professor at Birmingham University to find out more and was given a tour of the Metallurgy & Materials Department, which then led to her choosing a Materials Science & Engineering degree course at Leeds University.

The 2nd year of this took her on an ERASMUS exchange to Tampere, Finland, which offered a broader and more flexible approach than the UK system and allowed her to "dabble in many different topics". Also of note, in 1993 Finland was ahead of the curve on internet communication and use of e-mail. Back in Leeds for her final year and without clear plans for what she'd do post-degree, Alice assisted her project supervisor in organising a conference. There was another chance meeting: one of the presentations caught her attention, she chatted with the speaker and then met his supervisor (Lindsay Greer), and the outcome was that, in 1995, she began a PhD on grain refinement in aluminium alloys at Cambridge.

Alice thoroughly enjoyed Cambridge student life (including Presidency of Darwin College Student Association and involvement on Ball Committees), and also discovered that she had a flare for science outreach. She was part of a group in the Department who won funding to support activities related to the Public Understanding of Science. They toured Cambridgeshire primary schools (in Alice's gran's car!) with science talks and demonstrations, bringing fun and education to all involved.

Whilst enjoying PhD research (and, in passing, receiving the TMS *Smithells Memorial Prize*, and the TMS *Light Metals Award*, and coordinating an experiment which was flown in space), Alice realised that the absolute focus required and the long, isolated hours in a darkened room with an electron microscope weren't beckoning her to a future in academic research. Instead, her outreach experience led to an application to the London Science Museum, and she beat off stiff competition to land a 2-year fast-track placement, taking on exhibition development, presentational and curatorial roles. She particularly enjoyed the public-facing side of this, and the interdisciplinary collaboration, including links to medicine, energy and space. With the approach to millennium celebrations and events it was a particularly exciting time to be in the field of public engagement in science.

Work in the Science Museum's Space Gallery gave Alice an interest in the extremely valuable opportunities offered by space-based technology for understanding what's happening here on the earth: for example, the application of satellite data in climate monitoring. Her next move was to the Natural Environment Research Council as Coordinator of Earth Observation Science, later becoming Head of Earth Observation & Future Missions.

She took maternity breaks (she now has four children) and, although perhaps not appreciating their importance at the time, subsequently realised that the 'keeping in touch' weeks had been incredibly valuable in maintaining a network of connections. With a young family she returned to work part-time in the Government's Department of Business Innovation & Skills, focusing on environmental monitoring from space and enjoying links with commerce and industry.

Following a stint with the Department for Environment, Food & Rural Affairs as UK Location Programme Manager, Alice then joined the UK Space Agency. Here she brokered the international agreement that ensures space-faring countries freely share their satellite imagery with any country to help with disaster relief. Chairing international consortia, and bringing together countries across the globe (the US, China, Japan, Taiwan, India, Europe, South Africa, and more) proved incredibly rewarding. This required dealing with Government ministers and representatives, and building trust, whilst being aware of national and industrial sensitivities, and it ultimately led to cooperation between (sometimes unlikely) partners to support and assist those affected by natural disasters. Space technology saving many lives!

On appointment to the role of International Director, Alice coordinated security, regulation, communications and international engagement at the UK Space Agency; she advised governments and delivered keynote lectures at international meetings, such as the World Economic Forum, Global Space Congress and TEDx London. She led the UK delegation to the European Space Agency and was vice-chair of the Council overseeing UK interests in programmes ranging from telecommunications, environmental monitoring through to commercial lunar missions.

Back down to earth, Alice enjoys open water swimming – loving the freedom it gives, and the places it can take her. Her son was recently encouraged to join her, and they completed the Thames marathon (see picture), swimming in support of a charity promoting water safety, *SwimTayka*, for which Alice is trustee.

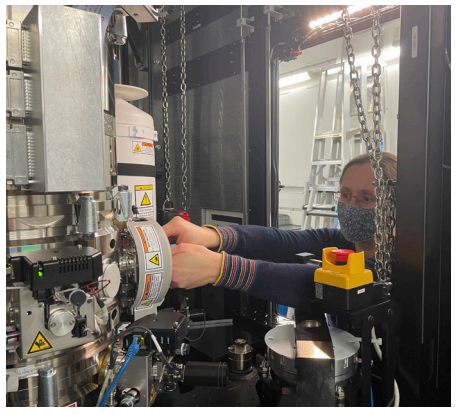
Her current full-time post as Chief Executive of the Institution for Mechanical Engineers is principally earth-bound. But, keen to maintain her links with space,

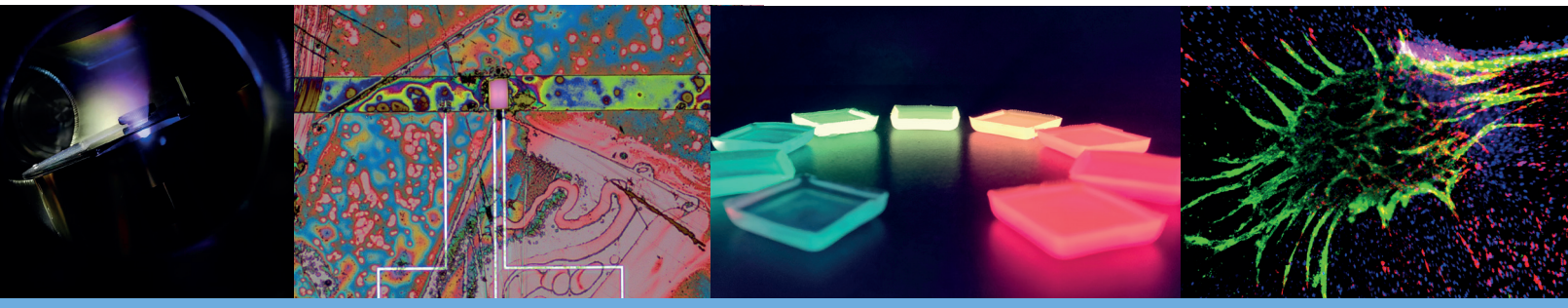
she remains on the Board of Directors of the US Space Foundation and on the World Economic Forum council on space technology. She remains passionate about outreach, particularly in schools. All her experiences related to space must surely encourage many children to consider a career in science, and her success in shaping vital international co-operation in the space sector is an inspiration for us all.

A Sensitive View

Electron microscopy has evolved rapidly in recent years: hardware developments include improved electron optics, monochromation, camera sensitivity and spectrometer efficiency, and software is able to process vast 'multi-dimensional' data sets in a robust and speedy fashion. The result is that much, much more information is now attainable.

Professors Paul Midgley and Cate Ducati are pleased to report that many of these developments are exploited by the *Thermo Fisher Spectra* Scanning Transmission Electron Microscope, recently installed in the *Wolfson Electron Microscopy Suite*. Funded through an EPSRC *Strategic Equipment Grant*, this has the ability to analyse materials at the atomic- and nano-scales in two- and three-dimensions. The Spectra can operate from 40 kV to 300 kV: low voltage being used for the study of samples with low atomic number and/or of low dimension, in which knock-on damage may be predominant; high voltage for organic and hybrid samples, in which radiolysis can be hugely detrimental. This new instrument is designed to enable multi-dimensional investigation of highly beam-sensitive materials using the latest generation of direct electron detectors, with remarkably sensitive and linear responses.





Hope for us all!

James Hope, who is a Mechanical Engineer by training, came to the Department following an apprenticeship in the Physics Department. He felt welcomed and encouraged from the start, and was keen to contribute to some of the important research going on in Materials Science.

With personal experience of the hardship and stresses associated with balancing a full-time job with domestic caring responsibilities, James is very aware that there are ups and downs in everyone's life and work. There may be times when we feel uninspired and disengaged, but a remedy can come in the form of a simple reminder of the rewards of the job. For example, he describes the feeling of pride and satisfaction on realising the contribution he'd made to the development of an artificial heart valve in the Centre for Medical Materials.

James is now well-known within the Department and beyond as one of our team of well-being advocates who, for example, can offer guidance and advice on aspects of mental or physical health, or concerns about dignity at work. Beginning by simply wanting to help others and to let them know that he was there, he is aware that one of the most important aspects of this role is visibility. And he's keen to ensure that there is consistent support and advice for all who ask. Whilst the pandemic has undoubtedly given the awareness of well-being issues a kick-start, James would like to see the team develop further and reach out to all, in order to support the whole community even better.

With the help of the well-being team and others, a Gardening Club has sprung up in the Department, and it goes from strength to strength. Not only does this impact upon those who grow and tend the plants, but it also gives much pleasure to those who can appreciate the outcome! The tearoom is more welcoming than ever, and users are encouraged to get away from phones and laptops in order to boost their mood and be able to return to work truly refreshed.

Away from work, James loves open water swimming (e.g. at Milton Country Park, or in the Great Ouse), gaining great joy from an early start and a cold dip on a Saturday morning. He is also a proponent of the art of Krav Maga as a means of self-defence (see photograph), using a combination of techniques sourced from Boxing, Wrestling, Judo, Aikido, and Karate. He coaches children, and gets huge satisfaction from seeing their enjoyment of the sport, and the confidence it can inspire.

Will the Department continue to reap the rewards offered by this local well-being champion? Let's Hope so!

YouTube channel

Cambridge Materials, *https://www.youtube.com/channel/UC25s6oKGOMEwftxvhpa67Ew* launched in April 2021, providing a platform to share Departmental events. It currently features the Centenary Anniversary Celebrations and the Armourers and Brasiers' Cambridge Forum, which can be followed by a global audience. The channel also includes videos about activities of the Department's members, from outreach videos for a wide audience to the more specialised Goldsmiths' Seminar Series, and these have already been seen by thousands of viewers. Watch this space to learn about exciting new content!

New Lectureships

Tom Bennett Following Natural Sciences at Cambridge, and a PhD with Professor Anthony Cheetham FRS, Tom was a Research Fellow at Trinity Hall, and now holds a Royal Society University Research Fellowship.

Xavier Moya Obtained his BA and PhD from the University of Barcelona. He has held various research fellowships, most recently a Royal Society University Research Fellowship. He is a Fellow at Churchill College.

Congratulations

Ruth Cameron, *Suffrage Science* award
Paul Midgley, Elected as a Member of Academia Europaea
Sohini Kar-Narayan, *Top 50 Women in Engineering*
Manish Chhowalla, ERC Advanced Grant
Colin Humphreys, 2021 Queen's Medal of the Royal Society
Emilie Ringe, *Chemical & Engineering News* Talented 12; *The Journal of Physical Chemistry* (JPC) and PHYS Division Lectureship Award
Rachel Oliver, Fellow of the Royal Academy of Engineering
Bartomeu Monserrat, UKRI *Future Leaders Fellowship;* IoP 2021 *Maxwell Medal*
Juncheng Fan, third place at the IOM3 *Young Person's World Lecture Competition 2021*

Editorial team: Zoe Barber, James Elliott, Lindsay Greer, Nalin Patel and Lianne Sallows **Comments to:** alumni@msm.cam.ac.uk

DMSM is also on Linkedin, Twitter and Facebook
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Figures at top from left to right:
Plasma Laser Deposition of Lithium for solid state batteries, Adam Lovett. Dried solvent deposits on an in situ TEM chip, Jedrzej Morzy. Luminescent solar concentrators for solar-harvesting, Morton Lyu. Structures created by human dermal microvascular endothelial cells co-cultured with primary human osteoblasts, Nima Meyer.