Institution: University of Kent

Unit of Assessment: 8: Chemistry

1. Unit context and structure, research and impact strategy

The overarching strategic aim for Chemistry at Kent is to be an internationally leading centre for solid-state materials and outward-facing molecular chemistry. In pursuit of that aim, in this REF period we have invested significantly in staff, infrastructure, and support. Of the 18 Category A staff submitted to REF2021, 9 were appointed to new positions created since 2014. These appointments were made as part of a strategy to create an environment in which new. cross-disciplinary ideas from early career researchers can flourish, and in which our ECRs can develop their careers in a supportive and intellectually vibrant context. This strategy is bearing fruit, with a fourfold annual increase in research income since 2014.

At the heart of the University's research strategy over the REF2021 period has been a commitment to extending and deepening STEM research, and this has been reflected not least in the relaunching of the Chemistry degree programme (in 2013) and the opening of the Kent and Medway Medical School (KMMS) in 2020. In expanding Chemistry research at Kent, emphasis has been placed on the synthesis, characterisation, and understanding of matter across length scales. The framework for achieving this has been our Functional Materials Group (FMG), within the School of Physical Sciences (SPS), which spans Chemistry, Physics, and Materials, inclusive of experiment, theory, and computational modelling. The Functional Materials Group strategy identified four themes: Quantum Materials; Soft Functional Materials; Porous, Nanostructured, and Amorphous Materials; and Energy Materials. To develop these themes, the FMG's strategic goals were:

- *Increase staffing levels to ensure sustainability and expand into these new areas*. This has been achieved through an increase in FMG staffing from 17 (2014) to 23 (2019), of whom 18 are being returned in UOA8 (Chemistry) and 5 in UOA9 (Physics).
- *Continue improvement of research infrastructure*. Since REF2014, SPS has invested £4.95 million of internal funding in laboratory refurbishment and instrumentation.
- *Increase national and international collaborations*. Achievement of this goal is evidenced by 61% of our staff's papers being international collaborations.
- *Further develop our exploitation of national and international facilities*. We are now more integrated than ever with these facilities, receiving >£5.77 million worth of beamtime and holding influential positions on panels.

Given the success of FMG in achieving these goals, it was decided that even more ambitious goals should be set for Chemistry at Kent. In June 2019, the FMG was replaced by three new groups. Two of these three groups are included in the present submission: Materials for Energy and Electronics (MEE); and Supramolecular, Interfacial, and Synthetic Chemistry (SISC). The third, Physics of Quantum Materials (PQM), is submitted to UOA9 (Physics). The strategic aim of this sub-division was to enable each of the three themes to develop its own internationally recognised standing, which would better support participation in research consortia, and facilitate the management of resources. This reorganisation provided a rare opportunity for our ECRs to take on leading roles in shaping our research strategy.

Materials for Energy and Electronics (MEE)

This research group comprises nine academic staff (Alfredsson, Arnold, Bristowe, Corrias, Green, McCabe, Mountjoy, Saines, and Sayle), with a breadth of materials chemistry expertise that is deployed to develop new materials for energy and electronic applications. This includes techniques for design and synthesis, a swathe of capacities to investigate physical properties, and tools to understand atomic, magnetic, and electronic structures, crucial to optimising their properties for application. Expertise includes both experimental and computational approaches, including playing a major role in the use of central neutron, X-ray, and computational facilities.

Current materials of interest include those for Li and Na-ion batteries, photovoltaic cells, nanoparticles, and glasses for environmental remediation and assisting biomineralization; ferroelectric materials for energy storage and sensing; and multiferroics and magnetic materials for cooling and data storage. This research is necessarily interdisciplinary, with strong collaborative links with Physics staff being a core feature, this being reflected in productive collaborations with the Physics of Quantum Materials research group (e.g. a recent Leverhulme Trust Research award to Arnold and Ramos).

Since REF2014, staff in the MEE group have published over 180 articles across an array of Chemistry and Physics journals, including *Nature Chemistry*, *Nature Communications*, *Physical Review Letters*, *Journal of the American Chemical Society*, *Chemistry of Materials*, *Angewandte Chemie*, *Journal of Materials Chemistry A & C*, *Material Advances*, *npj Computational Materials*, and *ACS Applied Materials and Interfaces*. With 72% of our papers being collaborations across national borders, international cooperation is the norm for our staff. Several of these papers are also the result of collaborations between members of the group with distinct expertise (for example, nine papers blend experimental and computational approaches).

The MEE group is a rapidly developing materials chemistry group that is already showing influence both nationally and internationally. One indication of this growing influence is the group having contributed four members to the ISIS facilities allocation panels for one round in 2018, greater than the collective input of any other university. Since REF2014, the major achievements of this group have included:

- Identification of a new strategy to produce ferromagnetism, whose origin is compatible with ferroelectricity, such that the long-awaited multiferroic memory might be achieved (Bristowe).
- Solution of the dynamical structure of methylammonium lead iodide, including iodide migration, opening up the possibility of producing photovoltaic transparent films for use as coatings (Green).
- Development of a printable aqueous dry battery with applications in healthcare sensors (Alfredsson).
- First evidence that suppressing a structural quantum critical phase transition under ambient pressure improves superconductivity properties (Saines).
- Development of a glass material that strengthens teeth and is now used in a new brand of toothpaste (BioMinF) (Mountjoy).

The strategic goal of the MEE group is sustainable growth, leading to international recognition as a consolidated centre of excellence. Specific objectives for the next five years that underpin this goal are:

- Appointment of new academic staff, including one at the materials/machine learning interface.
- Recruitment of research fellows (for example, Royal Society) through offers of competitive support packages combined with the opportunity to join a lively and successful research group.
- Increased PhD student numbers through expansion of international links and external funding.
- Consolidation and expansion of the network of industrial and international collaborators through the hosting of conferences.
- Leadership of national and international research consortia.

Supramolecular, Interfacial, and Synthetic Chemistry (SISC)

This research group comprises nine academic staff: Barker, Biagini, Clark, Hiscock, Holder, Murray, Palma, Serpell, and Shepherd. SISC represents a core of chemists who share a common vision of molecular chemistry as the central science – a discipline that is outward-facing, initiating and underpinning technologies that transgress classical disciplinary barriers. The foundational

strengths of SISC are synthetic, supramolecular, interfacial, macromolecular, biomolecular, redox, and soft materials chemistry. The areas of impact are:

- *Biomedical science:* transformative medicines (Hiscock, Palma, Serpell); drug delivery (Biagini, Holder, Serpell); and membrane interactions (Barker, Hiscock).
- *Sustainability:* synthesis (all); catalysis (Clark, Holder, Murray); electric materials (Murray).
- *Sensing:* chemical warfare agents (Hiscock, Holder); biomolecules and biological processes (Holder, Serpell); and environmental sensors (Holder, Shepherd).
- *Soft materials:* polymers (Barker, Holder, Serpell, Shepherd); and soft robotics, actuators, and microfluidics (Barker, Holder, Shepherd).

SISC is a young and dynamic research group, with seven of the nine members appointed to academic positions within the current REF period. The resulting research agility, in combination with the complementary and nationally unique blend of supramolecular, interfacial, and synthetic chemistry, means that SISC is already becoming an internationally recognised centre for chemical technologies – for example, reviewers' comments on an EU-funded grant identified the group as 'a centre of excellence for bio-inspired supramolecular research'. In this REF period, the academics comprising SISC have published more than 180 papers, in journals such as *Nature Chemistry*, *Angewandte Chemie*, *Chemical Science*, *Journal of the American Chemical Society*, *Journal of Materials Chemistry C*, *Chemical Communications*, *ACS Central Science*, *Nature Communications*, *Chemistry of Materials*, *Joule*, and *ACS Catalysis*. The group's major achievements since REF2014 include:

- Discovery of a family of amphiphilic molecules that enhance the efficacy of antibiotics (Hiscock).
- Development of a sponge for the immobilisation and degradation of chemical warfare agents, now being produced in multikilogram quantity for the Ministry of Defence's Defence Science and Technology Laboratory (DSTL) (Holder; see impact case study).
- Mechanochemical synthesis of spin-crossover materials, and determination of the elastic properties of such materials for applications in actuation (Shepherd).
- First example of a flow hydrogen peroxide generator using phase transfer catalysis (Murray).
- Establishment of automated phosphoramidite chemistry as a breakthrough for synthesis of multikilodalton non-natural sequence-defined polymers (Serpell).

The strategic objectives of SISC over the next five years are to:

- Expand the core underpinning science of the group through grants, fellowships (attracted through strong host support and the vibrant community), and new appointments.
- Identify the potential for, and forge, interdisciplinary collaborative partnerships relating to the identified target areas, which progress the group's research into technologies and other forms of impact, supported through annual sandpits to create partnerships with stakeholders.
- Act as a hub for expertise in synthetic, supramolecular, and interfacial chemistry, recognised in both academic and industrial spheres, through hosting conferences and participating in consortium research projects.

Collaboration and Interdisciplinarity

The School of Physical Sciences is an multi-disciplinary unit, hosting Physics, Astronomy, and Forensic Science, in addition to Chemistry. Interdisciplinarity lies at the core of our activities in the post-FMG framework. Members of SISC, MEE, and PQM share resources and collaborate on a regular basis. For example, recent papers include collaborations between Clark and Bristowe/McCabe; Hiscock/Shepherd and Saines; Sayle and Ramos (PQM); and Serpell and Podoleanu (Advanced Optics Group, UoA9). Shared facilities include the electrochemical laboratory used by Murray and Alfredsson, and the SQUID magnetometer used by Shepherd and MEE staff. We collaborate not only with Physics staff at Kent, but also extensively with other

researchers in adjacent fields (Biology, Engineering), and extend our research into areas such as historical conservation (see the Marie Rose Trust impact case study), ethnobotany, and the social sciences. These interactions are supported infrastructurally. We share a School with Physics, and are, as a result of the 2019-20 reorganisation of the University, are now closely aligned in the new Division of Natural Sciences with the Schools of Biosciences and Pharmacy, as well as the new Medical School (KMMS). Grants have been awarded in this REF period jointly with the Schools of Biosciences and Engineering and Digital Arts (EDA), and the Centres for Health Service Studies (CHSS) and the Study of Higher Education (CSHE). Sandpits and research-sharing seminars are held across the Division to facilitate interdisciplinary collaboration. This will further grow as the Kent and Medway Medical School develops its research profile over the next five years. University-level initiatives also facilitate interdisciplinarity, including the annual Maximise Your Research Impact conference, the Early Career Researcher Network, the GCRF-funded Global Challenges Doctoral Centre (GCDC), and the new Signature Research Themes, especially Future Human and Environment, Food Systems, and Natural Resources.

Impact Strategy

Our REF2021 submission includes two impact case studies. One of these shows how our research in hard materials (MEE core expertise) has enabled the preservation and display of artefacts from the ship the *Marie Rose*, giving the public unique insights into Tudor life. The other reveals how our research in soft matter (SISC core expertise) has created a polymer sponge that can absorb and destroy chemical warfare agents, materially improving the UK's chemical security. The selection of these impact case studies highlights the ability of MEE and SISC to achieve significant social impact. Our impact strategy is designed to enable us to achieve the following three objectives:

1. *Consolidate and expand links with industry and other applied agencies.* The School has an extensive network, aided by year-in-industry courses run for students, as well as the proximity to Discovery Park in Sandwich and Kent Science Park in Sittingbourne. We maximise opportunities for industrial relationships through an internal database of interactions, and sandpit events with industry. We are launching an industrial PhD programme that is cost-effective for both academic and industrial partners. Our scientific instrumentation is available for direct use by industry at cost, or can be accessed indirectly with support through consultancy contracts (e.g. Serpell's contract with ADEY on heating fluid additives). In collaboration with Pfizer, we are developing an industry/academia matchmaking service; this has been supported by an Innovation Voucher. These activities are coordinated by our Director of Innovation and Enterprise (Hiscock), in partnership with the University's Knowledge Exchange and Innovation team, which supports industrial collaboration and intellectual property. Kent's commitment to the thirty-year, £35 million *Mary Rose* project has been consolidated by the appointment of Dr Eleanor Schofield, Head of Conservation at the Mary Rose Trust, as an Honorary Professor.

2. *Engage directly with the public*. The School has appointed a Director of Public Engagement and Communication (Barker), who works with a team of academic and administrative staff. Under Barker's leadership, in 2020 SPS became the first School/Department in the country to be awarded a Silver Watermark by the National Coordinating Centre for Public Engagement (NCCPE). The award highlighted the 'Strong support for the role of PE within the mission and culture of the school from senior leaders'. Public engagement (understood as a two-way process) is embedded alongside research as part of our research groups' structures, with each expected to have at least one public engagement project live at any one time.

3. *Use the media.* Media training is being given to staff across the School, and each research group has a designated media liaison. We aim to be go-to commentators for topics within our research remit. We have collaborated with local and national media in this capacity.

Evidence for the success of this impact strategy is provided in Section 4 below.

Research Integrity

Research standards and ethics are core values in our work. All our researchers (Including our PDRAs and PGRs) are encouraged to attend the Ethical Researcher course designed to develop the knowledge of standards, requirements, and professionalism in research. Ethical approval of grant applications is first managed at the School level by the Research Ethics and Governance (REAG) Officer. A checklist assesses if an application needs to go to the University for approval or to a higher body such as the NHS, and a full application is then made if applicable, including examples of any questionnaires or procedures and participant information sheets and consent forms. These then go out to the University review panel for approval. Extensive information and online resources are provided through the University Research Ethics and Governance Committee (REGC).

Open Research

Kent's Open Access (OA) and data management policies mandate OA via any route. This is enabled by the Kent Academic Repository (KAR), in which authors deposit their manuscripts in the most open-access form permissible, if the papers are not already OA at the journal. Overall, 83% of our outputs have been OA, and 31% Gold or Hybrid Gold OA. We go beyond the REF's requirements in our use of preprint servers to share manuscripts on open platforms (ChemRxiv, BioRxiv, arXiv), with 29 posted in this REF period. We also make use of the Kent Data Repository to share datasets as part of our publications. We participate in many Read and Publish agreements, notably with the Royal Society of Chemistry (RSC).

2. People

Staffing Strategy

Since REF2014, nine full-time academic staff have been recruited, in line with our research strategy (see Section 1). These appointments were made on the basis of the appointees' internationally leading research and their capability to both consolidate longstanding strengths at Kent (MEE) and enable expansion into new areas that are currently under-represented within UK chemistry research groupings (SISC). Aiming to be a dynamic and forward-looking team, as well as wishing to give opportunities to early career researchers, we have recruited at the Lecturer level, and worked hard to support career development. As a result of this strategy, SISC currently comprises 57 full and associate members, including PDRAs, PhD and MSc students, and academic staff, while MEE currently comprises 29 members. We plan to continue with this approach to recruitment over the next five years.

Staff Development

Our research group structure provides a lively and productive research environment for the career development of all academic staff. Newly appointed lecturers are mentored by an experienced staff member, who guides them through their three-year probation period. As a team that is weighted towards early career researchers, external mentors are also engaged as appropriate. The probation period includes reduced teaching and administration workloads (normally, a 60% reduction in year 1, and a 30% reduction in year 2) to support staff in setting up their research groups and developing their impact. The research groups share best practice in research strategy, supervision, workload management, and administrative responsibilities, and aid applications for promotion. Regular grant-planning meetings are held within the MEE and SISC groups. Academic staff across the University are required to complete the University's Postgraduate Certificate in Higher Education (PGCHE), which includes PGR supervision training, and are part of the University's Early Career Researcher Network, helping them to kick-start their careers as independent researchers.

Staff training in transferable and general skills are run by the University, and all academics and PDRAs are required to attend at least one a year. The School has also conducted a bespoke Leadership and Management Development Programme (through the Learning and Organisational Development team) to boost the capabilities of those recently appointed and holding

administrative roles, including eight members of SISC and MEE.

Research success is recognised and supported through our workload allocation model, to ensure the requisite time for grant preparation, management, the supervision of PGRs and PDRAs, and the dissemination of research findings. The University studly leave policy grants one term's leave for every seven terms. In this REF period, Arnold and Green have each taken a year's study leave.

The success of our staff has been recognised through numerous promotions since 2014: to Professor (Corrias, 2018); Reader (Alfredson, 2018; Hiscock, 2019; Serpell, 2020); and Senior Lecturer (McCabe, 2015; Clark, 2018; Saines, 2018; Serpell, 2018; Shepherd, 2018; Barker, 2019). Our staff have received internal recognition through University Research Prizes: Hiscock (2017) and Barker (2019).

The University is committed to the Concordat to Support the Career Development of Researchers, and this informs our approach to PDRAs. The Researcher Development Programme run by the University's Graduate and Researcher College (formerly the Graduate School) ensures that all aspects of the Researcher Development Framework are met, specifically:

1. Researchers are recruited for their potential to carry out the highest-level research through mandatory interview-trained and gender-balanced panels.
2. We value researchers as essential partners in the organisation through the inclusion of PDRAs in staff committees (e.g. Research and Innovation; Public Engagement and Communication; EDI).
3. We have a dedicated Careers Officer within the School, and career development for PDRAs is facilitated through the Researcher Development Programme training courses in technology transfer, obtaining grants, EDI, and transferable skills.
4. We support lifelong learning and development in the appraisal system, and researchers are given space to develop their interests, take part in teaching, and undertake grant management, as needed.
5. We fully appreciate the importance of diversity and equality (see below).
6. We annually review the implementation of the programme within the group structure.

The success of our support for staff is evidenced in particular by their ability to attract awards and fellowships. Our work has been recognised by fellowships for Bristowe (Royal Commission for the Exhibition of 1851 Research Fellowship) and Green (National '111' plan from the Chinese government; Royal Society Wolfson Research Merit Award, 2012-17), and prizes, including the Physical Crystallography Prize of the Institute of Physics (Saines, 2016). In 2020, Hiscock was awarded a prestigious UKRI Future Leaders Fellowship, and Corrias was awarded a Leverhulme Research Fellowship.

Equality and Diversity

SPS is deeply committed to equality of opportunities and diversity, and has a dedicated Equality, Diversity, and Inclusivity Committee, which receives support from an administrator. We also have a School Equal Opportunities Representative and Harassment Officer to ensure that we identify potential weaknesses requiring action. The EDI Committee has its own budget. SPS has an excellent track record of equality and diversity, with an academic staff body that reflects this. Our female to male ratio is 1:2 (better than the sector average), and, crucially, 1:1 at the professorial level, far better than the 1:9 sector average (Royal Society of Chemistry, 2018). Our PhD student population is 55% female (well above the sector average of 39%). Furthermore, 25% of our staff are international. As part of our strategy to achieve an Athena SWAN award in the next three years, all staff now require EDI training before serving on interview panels.

SPS is fully committed to flexible working and family-friendly working conditions, limiting key meetings and teaching to between 10.00 a.m. and 4.00 p.m. Though the University runs lectures and seminars for students from 9.00 a.m. up to 6.00 p.m., our staff can request timetable changes and flexibility that will facilitate school pick-ups or other caring responsibilities on an annual basis.

The School's EDI Committee can use its budget to assist with the costs of childcare and other caring responsibilities to support attendance at meetings and conferences. In SPS, the collegial environment means that staff often cover each other's commitments on a voluntary basis, through a curated list of 'understudies'.

Academic staff are usually appointed on full-time contracts, but we do agree part-time contracts to suit family requirements (for example, post-maternity leave), with the opportunity to increase hours once staff feel able to do so. We also facilitate part-time PhD study, which has been adopted by both male and female students for family/caring reasons. We implement University-wide maternity, paternity, shared parental, parental and adoption leave policies, and actively encourage male staff to take the maximum shared parental or paternity leave. Redefined work is covered by fixed-term appointments wherever possible. This extends to PDRAs, with the School honouring the full extent of the award upon a PDRA's return to work. During maternity/adoption leave, staff have up to ten 'Keeping in Touch' days, for which they receive full pay. Staff may return to work whenever they wish, up to the statutory maximum. They may come back full-time, part-time, or staggered, this being agreed in consultation with the Head of School. For example, when a PI is on maternity leave, a second supervisory staff member will be provided for all PGRs and PDRAs under their guidance.

There is extensive support on campus through the Women's Network, Early Career Researcher Network, and the Graduate and Researcher College, as well as regular diversity awareness workshops, including on autism awareness and unconscious bias. Support and training for grant applications is provided by the Research and Innovation Services team, and by internal peer review provided at research group level to ensure that individuals with protected characteristics have the same opportunities for research success.

We are also working to improve diversity within the wider chemistry community. Hiscock is founder and chair of the Women in Supramolecular Chemistry (WISC) network, which aims to increase diversity across the global supramolecular community by providing support and creating opportunities. WISC has run workshops at two recent RSC Macrocyclic and Supramolecular Chemistry conferences, the International Symposium on Macrocyclic and Supramolecular Chemistry (Sydney, 2019), as well as taking part in the RSC Inclusion and Diversity, and running an international workshop at the University of Cagliari. WISC provides a peer mentoring network which matches small groups of early career researchers with a more advanced mentor. Biagini has pioneered support for the visually impaired in chemistry, leading to the Times Higher Education Award in 2018, and the 2020 RSC EDI Award for supporting visually impaired students, and an invited talk at the RSC Inclusion and Diversity Forum 2020.

With regard to our REF2021 submission, all eligible staff in Chemistry have been submitted. We have been careful to minimise bias in the selection of outputs for submission by involving all staff in the initial ranking process, using external referees, and ensuring gender parity on the REF Working Group. Staff were consulted about the ranking of their outputs throughout. When two outputs were ranked similarly, the choice between the two was made in favour of the female/male submitted author ratio most representative of the unit as a whole.

Research Students

In addition to receiving EPSRC DTA and Industrial CASE awards, our staff have also secured PhD studentships through grants (Leverhulme Trust, Rosetrees Trust, CARA, DSTL), the ALISTORE Network of Excellence, and from SEPnet (testifying to interdisciplinarity). Additionally, there is typically internal funding of 2-5 Chemistry PhD students each year. New staff have all been provided with a studentship in their start-up package. Studentships are advertised online at School and research group level, as well as being promoted through social media. Recruitment is stringent, with candidates undergoing a School-level panel interview.

The day-to-day training of our research students takes place within the research groups, and extends beyond baseline informal interaction between students, supervisors, and PDRAs. SISC operates a group-wide induction, covering health and safety, record keeping, and scientific

presentation and writing. With its smaller PhD cohort, MEE conducts its induction on a personalised one-to-one basis. Formalised training for major instrumentation is also provided, and skills workshops occur regularly on experimental techniques, literature and databases, software, etc. All students take part in weekly research group meetings, during which they present both their own work and the literature. PGRs are required to attend all colloquia arranged by their research group.

Our PGRs are assigned a supervisory team consisting of their primary supervisor(s) and a secondary supervisor not directly involved in the project. At least one of the team members will hold Supervisory Chair status, but all members of the team are required to have completed the requisite supervisory training. The second supervisor takes the lead role during reviews, which occur in months 2, 11 (probation), 24, and 34, each accompanied by a report by the student. Before graduating, all PGR students must have given both poster (Y2) and oral (Y3) presentations at the annual SPS Postgraduate Colloquium, have presented at national or international conferences (with School funding available if needed), and are expected to have published at least one paper.

The Graduate and Researcher College organises transferable skills training for PGRs, aided by our School Careers Officer, equipping them for future work within or beyond academia. PGRs also take the lead in organising training; in 2020, for example, one of our students secured a grant from the RSC to run a Science in Sign Language workshop with an emphasis on polymer language, which tied into the School's Plastic Unwrapped project (see Section 4).

3. Income, infrastructure and facilities

Income

Our research income has increased dramatically since REF2014, as a result of successful strategic planning. Income has increased from £448k (2013-14) to £1.6 million (2017-18) to £1.8 million (2018-19), and £1.5 million (2019-20), the 2019-20 period being affected by Covid-19. Major funders have included research councils (EPSRC, the European Commission, BBSRC), governmental bodies (DSTL, DEFRA, US Army Research Office), charities (Royal Society, Leverhulme, Rosetrees Trust), as well as industrial collaborations. There have also been highly valuable time allocations at national and international central facilities (Diamond, ISIS, ESRF, ILL, NIST, ANSTO, ALS). Noteworthy recent awards include a UKRI Future Leaders Fellowship (Hiscock), a highly competitive EPSRC New Horizons award (Mountjoy), and GCRF (Serpell). Given that half of our researchers are early in their independent careers (<6 years), these income figures are particularly welcome.

Infrastructure and Facilities

The University has invested significant resources in infrastructure for our staff, particularly in support of new appointments. This has enabled all staff, not only our early career researchers, to increase the number of grant applications across SISC and MEE. Since 2014, the University has invested in staff, doubling the number of academic staff in SPS, and has spent £3.12 million on building upgrades and £1.83 million on instrumentation accessible to scientists in Chemistry. We benefit from comprehensive synthetic and analytical laboratories – access to all of these instruments is available for internal use at no cost to researchers. The wide selection and availability of equipment means that these facilities are much more accessible to SPS staff than is often the case in larger departments. This investment in facilities has been closely aligned with our strategic aims; representative examples of the benefit of this alignment are given below.

For synthesis, we are equipped with 74 fume hoods, two glove boxes, eleven ovens, eighteen furnaces, automated DNA and peptide synthesisers (underpinning four grants for Serpell and Palma), a microwave reactor, a ball mill, and a 70 L reactor for scale-up (currently used to produce superabsorbent materials for containment of chemical warfare agents by Holder), and supported by a solvent purification system.

Materials processing and device construction are enabled by vacuum ovens, 3D printers, heat press, freeze drier, film applicator, spin coater, UV-ozone cleaner, Langmuir trough, and tools for fabrication of batteries – these support our world-leading energy research (Alfredsson, Green). We regularly fabricate microfluidic devices in-house, and are equipped to run them. Such devices are integral to projects such as Optimising Me Manufacturing Systems (a £1.5 million EPSRC project led by Barker).

Molecular characterisation, primarily supporting SISC, is enabled by a comprehensive instrumentation suite. We have a brand-new NMR facility, which includes two 400 MHz machines. Both machines operate broadband solution-state probes and are capable of conducting variable temperature measurements from -150 to +150 °C. One is a Bruker Neo, the most up-to-date instrument on the market, which operates both a broadband smart probe (for extra proton sensitivity and $^{1}H/^{19}F$ 2D experiments – a rare capacity in the UK, which enables the antimicrobial research of Hiscock) and a $^{1}H/^{13}C$ HRMAS probe, which underpins the characterisation of polymeric materials (used by Holder in collaborative work with DSTL). This is complemented by a CMS8400 EPR spectrometer. Structural determination is enabled by a new dual-source (Cu, Mo) Rigaku SuperNova single-crystal diffractometer equipped with an Atlas detector. We run 3 x HPLC (standard, chiral, preparative, a facility instrumental to grants awarded to Palma), a GC, and we provide mass analysis through LC-MS and GC-MS. Polymers are measured using a GPC, and trace analysis occurs through ion mobility spectrometry and ion chromatography. Spectroscopy is covered by extensive UV-vis (including Nanodrop and plate-reader formats), fluorescence (with plate reader, Peltier insert, solid-state capacity), FTIR, and Raman instruments. Gel electrophoresis capacity enables characterisation of biomolecules.

Materials characterisation, primarily underpinning MEE research, is enabled through a SQUID magnetometer (supporting grants for Arnold, McCabe, and Saines), two SEM instruments (Hitachi S3400 SEM, and Hitachi S4700 FEG-SEM, both with EDX), four powder X-ray diffractometers (the Empyrean/PheniX instrument allows data collection down to 12 K, forming the basis of a collaboration between Corrias and Sichuan University), a gas absorption porosimeter, a rheometer (supporting Holder in analysis of samples for Ametek, leading to the fulfilment of REACH legislation and sales), a contact angle analyser, two dynamic light-scattering and zeta potential instruments. Compositions can be determined using MP-AES, two XRF spectrometers, and spatial analysis can be achieved using both IR and Raman microscopes (underpinning beamtime awards to Arnold). Thermal analysis by TGA and DSC is also available. Battery materials are analysed using three potentiostats, an electrochemical flow cell, and rotating disc electrode.

We also have access to powerful computing facilities. Kent was one of the six full partners of the EPSRC-funded Tier 2 Materials computer Hub for Materials and Molecular Modelling (MMM), with reserved ‘gold’ access to around 12M CPUhrs every year, enabling large-scale high-performance computing (HPC) materials and molecular modelling. Researchers in Chemistry at Kent have used the hub for MMM to test internationally leading simulation codes, greatly accelerating research. In addition, the Hub has enabled important scientific breakthroughs on disparate areas such as nanocatalysis, enzyme-mimetic design, ionic conductivity, unusual thermal expansion photovoltaics, and ferroelectricity.

Chemistry at Kent also has full access to instrumentation in the neighbouring School of Biosciences. The Biomolecular Analysis suite includes high-end mass spectrometry capable of ion-mobility measurements, sequencing of peptides, oligonucleotides, and other sequenced polymers used by Palma and Serpell, and proteomics with HPLC and nanoUHPLC front ends, circular dichroism spectroscopy, and cell sorting (used for artificial selection experiments by Serpell in collaboration with Centauri Therapeutics). The Image Analysis facility provides transmission electron microscopy used by staff in Chemistry for the characterisation of nanoparticles (e.g. biocontinuous nanospheres produced by Holder), atomic force microscopy also used for examination of nanomaterials, and confocal microscopy assisting the examination of cellular interactions with produced materials.

In addition to such instrumentation at Kent, we also make extensive use of national facilities:

Diamond and ISIS in the UK (Alfredsson, Arnold, Barker, Corrias, Green, McCabe, Mountjoy, Saines), and the UK-funded X-MAS beamline, and other beamlines, at the ESRF in Grenoble (Alfredsson, Barker, Green), with a total in-kind value of £5.77 million. In addition, we have made use of the NIST Centre for Neutron Research in the US (Arnold, Green), and ANSTO in Australia (Saines). These facilities have been key to our ability to contribute to the preservation of the *Marie Rose* (see impact case study).

Support Infrastructure

Research impact is proactively supported through the School's innovation culture, facilitated by strategic investment in opportunities for industrially focused sabbaticals (e.g. Barker's Royal Society Industrial Fellowship with Infineum), match-funding for industry-focused studentships, and career rewards for innovation and enterprise. Our Director of Innovation and Enterprise (Hiscock) oversees School policy in this regard and guides academics with their interactions with industry.

Our research is also supported by an administrative team (12.4 FTEs) who assist with PGR programmes, student support, marketing, outreach, finance, organisation and documentation of meetings, student administration, and other tasks. The technical services team (17 FTEs) supports large research instrumentation (e.g. diffractometers, NMR spectrometers), ensures functionality of the building, including essential facilities such as fume hoods, keeping track of chemical inventory. Expert support is offered by Dr Andrew Morrell, who runs our analytical suite and provides services such as LCMS, GCMS, and AA analysis. Our technical team also provides IT support and organises maintenance, improvement, and refurbishment works on the building as required.

4. Collaboration and contribution to the research base, economy and society

Given our outward-looking ethos, we benefit from a diverse set of external stakeholders. We work closely with other academics in Chemistry, Physics, Biology, and Engineering, with industries (biomedical, materials, energy), national agencies (agriculture, defence), and the general public. Our research contributes to both national and international priorities. For example, our work in battery technologies (Alfredsson, Arnold, Murray) meshes with the UK's strategic commitment (2019) to bring greenhouse gas emissions to net zero by 2050. The UK plans to see antimicrobial resistance contained and controlled by 2040 – Hiscock's research speaks directly to this aim. Our research runs in parallel with UKRI Strategic Priorities, specifically the Physics of Life (Barker), Nucleic Acid Therapies (Serpell), and Quantum Technologies for Fundamental Physics (Arnold, Bristowe, Green, McCabe, Saines). At the research council level, we address EPSRC's themes, such as: Healthcare Technologies (ranging from Holder's RFID sensors for bacterial growth on prostheses, to Barker's on-the-body T-cell therapy factories); Energy (photovoltaics from Bristowe and Green, and Saines's magnetocaloric cooling); Robotics (Shepherd's responsive soft materials), and Quantum Technologies (Arnold, Bristowe, Green, McCabe).

Chemistry at Kent also addresses international concerns, with a particular focus on the UN's Sustainable Development Goals (SDGs) and work with partners in ODA countries. This is underpinned by the University's investment in global challenges, hosting conferences at Kent and overseas, providing support through the GCRF Partnership Development and Emergency Response Funds (which have funded networking trips for Hiscock and Serpell), and operating the Global Challenges Doctoral Centre (GCDC). For example, a GCDC student works with Serpell on the identification of biological mechanism of action of natural products with anti-cancer and anti-obesity activity with collaborators from Malaysia, thus addressing SDG3 (Good Health and Wellbeing) directly, and also speaking to SDG8 (Decent Work and Economic Growth), and SDG9 (Industry, Innovation, and Infrastructure) through the training and potential for technology transfer in southeast Asia, and SDG15 (Life on Land) by collaborating with Sarawak Biodiversity Centre and their mission to show the value of the local biodiversity. Serpell also holds an EPSRC/GCRF grant to conduct related research with partners in Vietnam. Another GCDC student works with Barker on developing a portable diagnostic platform for detection of virus within poultry populations in Brazil (the third largest producer of poultry worldwide). This is directed towards the GCRF challenge areas of Equitable Access to Sustainable Development (by providing farmers with

technology to prevent disease outbreaks), and Sustainable Economies and Societies (through prevention of devastating loss of stock). Arnold has a further GCDC student working with partners in India and Botswana on water purification, assisting SDG6 (Clean Water and Sanitation).

Collaboration and Leadership

Chemistry at Kent has a wide-reaching academic network, encompassing national and international partners, supported by the School and the University through funding for travel, invitation of speakers and hosting of conferences, and provision of seed-corn funds for initial research (~£10k per annum). These activities ensure that our research findings are shared with key academic users.

Academic-academic interactions are facilitated in a variety of ways. We have formal links with regional partners (University of East Anglia, University of Essex) through the Eastern Academic Research Consortium (Eastern ARC); this provides funding to support new collaborative research projects between the centres. Clark has used this funding to run a workshop, leading to three new collaborations. Through our institutional cotutelle agreement with the University of Lille, Green and McCabe are currently supervising PhD students. Serpell has two students and a PDRA who receive co-supervision from the University of Vienna, and his links with Taylor's University and Universiti Malaysia Sarawak in Malaysia have resulted in one co-supervised student at Kent and two at Taylor's. Bristowe, with Luxembourg Institute of Science and Technology, co-supervises a student at Imperial College London. In this REF period, we have taken part in more than ten cross-School supervisions of graduate students. Joint research with industrial partners (Defra, Public Health England, BMG Labtech, and Centauri Therapeutics) also provide training for our postgraduate researchers.

Wider support for collaboration is obtained through grants and awards. We have been awarded funds for collaborations with 13 UK universities and nine international universities. We have further collaborations with another UK institutions, and 24 institutions worldwide, covering every populated continent. Noteworthy successes of our collaboration strategy include Barker's £1.5 million EPSRC-funded Optimising Me Manufacturing Systems consortium, bringing together Imperial College London, University College London, and the universities of Bath, Cambridge, and Surrey, to enable the rapid production of personalised anti-cancer T-cell therapies in an on-the-body unit. Serpell's GCRF project brings together agriculturalists, bioscientists, and chemists in Vietnam with cancer biologists and social scientists at Kent. Although retired (and not returned as current staff), Prof Alan Chadwick remains active and linked with Kent, and the Block Allocation Group which he led provides access to XAS studies at Diamond Light Source B18 for researchers in energy materials.

Impact Beyond Our Impact Case Studies

Given the current staffing profile of Chemistry at Kent, with a large percentage of outstanding early career researchers, the support that we are putting in place now to enable research impact will lead to a significant increase in impact activity over the next five years. That said, there have also been considerable developments on the impact from in the REF2021 period, examples of which are included below under the categories of healthcare, materials, and energy and environment.

Healthcare. Mountjoy's research has enabled the launch of a new toothpaste (BioMinF), which slowly releases calcium, phosphate, and fluoride ions to strengthen tooth structure and prevent decay. Hiscock is working with Public Health England and Kent NHS Trust on the development of molecules that enhance the efficacy of existing antimicrobials. Serpell worked with Centauri Therapeutics on chemical optimisation of therapeutic aptamers, and with academic and industrial partners in southeast Asia on natural products for cancer therapy. Alfredsson has a contract with Mylogic for development of batteries for more sensitive lateral flow testing for SARS-CoV-2.

Materials. Holder has worked with Duravac to enable fulfilment of REACH legislation for European sales. With Merck Chemicals, he developed a copolymer stabiliser for use in the synthesis of coloured PMMA particles in non-aqueous dispersions (e-Inks), which was patented. He has

worked extensively with DSTL (beyond the activities described in the impact case study), and is currently engaged on the production of RFID sensors for monitoring maritime platforms. Mountjoy has performed consultancy for Morgan Thermal Ceramics, simulating glasses as brake pad components.

Energy and environment. Green has recently submitted a patent covering the EU, the US, and China for perovskite photovoltaics. Barker has been awarded a Royal Society Industrial Fellowship with Infineum, built upon three years of prior consultancy. He has developed a neutron-based method for analysis of lubricants that are used in one-third of all vehicles, meaning that incremental changes can reap huge global benefits in terms of energy use. Alfredsson has partnered with the Centre for Process Innovation (CPI) for the scale-up of electrolyte materials. Hiscock has contributed significant work on detection of chemical warfare agents to Defra and the Home Office.

Public Engagement

Barker was joint creator of the 'Feet Investigation' section on the BBC's Terrific Scientific website, providing experiments that were used in schools across the country. This research, in collaboration with an NHS podiatrist, could inform future precision medicine and aid footwear design. Teaming up with Discovery Planet – a grassroots organisation that won a Heart of the Community Award from Kent Media and London Array – Barker and the School's outreach team have delivered a series of drop-in workshops in nearby communities with high levels of deprivation (Thanet and Poplar). Entitled 'Plastic Unwrapped', the workshops explored how cutting-edge chemical research can contribute to solving the problem of plastics pollution. Participants had the chance to take part in exciting hands-on experiments, complemented by creative activities to explore the ideas raised in different ways. Nearly all our participants could be considered 'underserved' in terms of access to STEM enrichment activities. Young people from schools for children with special educational needs were able to attend all sessions and engaged very well. Approximately 2,000 schoolchildren from schools across the Thanet area, aged 8-14, attended the sessions. We generated four local newspaper articles, a blog piece by a local educational organisation, and were featured on ITV Meridian News.

Since 2016, we have offered a summer Chemistry Residential Course to students through the Engineering Development Trust. This course is for 30 students aged 16-17 who have an interest in creativity, problem solving, and STEM. The courses increase confidence, help students make informed decisions about their future, and show STEM career paths to be accessible and exciting, and involve hands-on laboratory experience, as well as workshops and challenges based on the research within SPS, and lectures from academics and PGR students about research.

We host the Salters Festival of Chemistry, which has involved Palma, Saines, and McCabe, working with secondary-school pupils on an extended practical investigation. Shepherd has given a Soapbox Science public presentation on the chemistry of colour. We host work placement students and produce YouTube videos as part of the 'Think Kent' outreach series. McCabe has contributed to the Big Bang Science Fair (with the British Crystallographic Association), and the Science and Technology Facilities Council (STFC)-sponsored *Illuminating Atoms* exhibition at the Royal Albert Hall (2014).

Wider Scientific Influence

Editorial boards. Our staff contribute to the health of the research base through their membership of journal editorial boards (five staff) and editing of special issues (six staff).

Funding panels. Our staff regularly serve on funding panels. Arnold, Barker, Holder, Mountjoy, and Serpell have between them served on nine EPSRC grant allocation panels and two fellowship interview panels. Holder was chair of EPSRC CDT Panel M in 2018. Mountjoy is a member of the STFC Physical Sciences and Engineering Advisory Panel, and the Facilities Allocation Panel (FAP) for Disordered Materials at ISIS. Green is a member of the Royal Society funding panel. Arnold chairs the ISIS facilities access panel for diffraction, having sat on the panel since 2013, as well as being a member of the Diamond Light Source FAP for diffraction. McCabe sits on the

RSC's Materials Chemistry Division funding panel and on panels for ISIS and ILL.

Committees. Corrias is a member of the User Working Group Panel for Diamond beamline BLI20, advising on its development, a member of the User Working Group for the SWIFT Flagship beamline proposed for Diamond-II, and a member of the Review Panel for ESRF BM08 Beamline. She is also a member of the International Advisory Board of the Non-Crystalline Materials (NCM) Conferences and of the International Committee for the International Conference on Aerogel Inspired Materials. Shepherd is on the Strategy and Allocations Panel for the EPSRC National Crystallography Service and a member of the Early Career Panel of the Directed Assembly Network (EPSRC Grand Challenge Network). She is a committee member of the Chemical Crystallography Group of the British Crystallographic Association. Hiscock is a member of the RSC Macrocyclic and Supramolecular Chemistry committee. Saines is a longstanding committee member of the dual Physical Crystallography (PCG) group of the BCA and Structural Condensed Matter Physics group of the Institute of Physics; he is also a committee member of the RSC Solid State Chemistry group and is on the FAP for diffraction at ISIS. McCabe is part of the RSC-IOP's 'Neutron scattering group' and has served on the RSC's Solid State Group committee, the PCG committee, and IUPAC's 'solid state' working group. Barker sits on the Scientific and Technical Advisory Panel, and Arnold on the Laboratory Review Team for the European Spallation Source, the £2 billion future of neutron research that is being built (supported by STFC) in Sweden.

Reviewing. We regularly review grants for UKRI (Arnold and Serpell are members of the EPSRC Peer Review College), the Leverhulme Trust, ERC, NSF, US Army, Royal Society, and British Council, as well as beamtime applications for Diamond Light Source, ISIS, and ANSTO. All members of staff are active peer reviewers for journals across the RSC, ACS, Nature, Science, Wiley, Elsevier, and IUCr collections.

Conferences. Over the REF2021 period, our staff have delivered numerous invited talks at major conferences and departments nationally and internationally, as well as being in involved in the organisation of conferences both at Kent (Arnold: Europhysical Conference on Defects in Insulating Materials; Arnold, Green, McCabe: RSC Solid State Group Christmas Meeting; Mountjoy: Partnerships in Multidisciplinary Studies of Disordered Materials and Biomaterials; Hiscock, Palma, Serpell: RSC Macrocyclic and Supramolecular Chemistry; Holder: Macro Group UK Young Researchers' Meeting; Serpell: London Polymer Group Symposium) and beyond (Mountjoy: 2nd International Conference on Phosphate Materials, Oxford; Bristowe: MMM Hub Conference, London; Arnold: European Solid State Conference, Glasgow; Serpell: PDB60, Oxford; Shepherd: BCA Autumn Meeting, Leeds). Arnold chaired the ISIS Neutron and Muon User Meeting for two years and McCabe has been Programme Chair of the BCA spring meeting.

Learned societies. Our staff are fully engaged with learned societies, including the RSC, IUPAC, the BCA, the Institute of Physics, the British Association of Cancer Research, and the British Society for Nanomedicine.

Policy. Serpell took part in a BEIS-UUKi roundtable discussion on the provision of research funding in the UK in the context of Brexit and the GCRF. Outcomes from this meeting informed the UK Government's response to the Adrian Smith Report. Barker took part in a national 'strategic conversation' around the six Grand Challenges in Forensic Science Transfer and Persistence, alongside delegates representing forensic practice and the legal system of the UK, shaping the future direction of forensic research in support of the legal practice in the UK. Sitting on the EPSRC Early Career Forum in Manufacturing, he has also been in policy sessions with the SAT to help steer the future direction of EPSRC manufacturing funding, as well as feeding directly into the ongoing review by UKRI of PhD student support.

In summary, Chemistry at Kent is outward-facing and proactive in forming links with end users across the whole of society, from disadvantaged coastal communities in the UK and farmers in developing nations, to the prevention of chemical warfare attacks, the development of high-end batteries, and drug discovery.