Institution: Queen Mary University of London

Unit of Assessment: 8-Chemistry

1. Unit context and structure, research and impact strategy

1.1 Overview

The Department of Chemistry at Queen Mary University of London (QMUL) is a small unit (15.5 FTEs) that continues to successfully generate first-class and impactful research as evidenced by high quality outputs, excellent PhD students' numbers and research income. Post REF 2014, with the aim of further increasing research excellence in the key priority areas of materials, catalysis and computational chemistry, the unit developed a strategy focusing on:

- the appointment of new early- to mid-career academics in priority areas;
- diversifying gender representation, **significantly increasing REF-submitted female T&R staff**, from 14% to 25%, *vs* 17% Russell group (20% sector) national benchmark;
- increasing PhD student population: **more than tripled PhD completion numbers**, from 16.5 (REF2014) to 54.8 (REF2021);
- increasing research income: **25% increase of grant income** compared to last REF, and **doubled income in-kind from use of central facilities**. Overall income (including from use of central facilities) of ca £127k per submitted FTE/year, despite new appointments not having time to generate income at the level of their full potential: 68% of the REF submitted T&Rs were appointed in 2013-2019, and two joined only in 2019;
- diversifying income sources (from UKRI and EU, to Charities, overseas funding and new industrial partners);
- broadening impact, from commercialisation and industrial engagements, to impact on health, patient care, public awareness and debate, as well as changes in policy on environmental issues.

The research profile is aligned around three major thematic areas:

- **Functional Materials and Nanoscience**
  Abrahams, Giordano, Lu, Nielsen, Palma, Resmini
- **Synthesis and Catalysis**
  Arseniyadis, Cambeiro, Jones
- **Physical and Computational Chemistry**
  Chass, Crespo-Otero, Dimitrov, Di Tommaso, Fornili, Vlcek, Zarbakhsh

In this REF period, the Department has supported 35 PDRAs and 8 Marie Curie fellows (**2.7 per submitted FTE; 42% and 87% female, respectively;**) and an average per year of 35 PhD students enrolled (average **PhD awarded per submitted FTE: 3.5;** 95% on-time completion rate). 50% of our staff members (eight) were promoted at least once, of whom 43% were female, with one promoted to Professor.

1.2 Research Strategy

The Department's research ambitions are to promote diverse research, influence national and international research debates, produce and promote world-leading research that is conducted according to the highest standards of integrity and in line with QMUL's 2030 strategy (see also REF5a).

Since the last REF period the Department has:

- **Developed new research lines** including: single-molecule approaches in materials science, DNA nanotechnology, nanoscale sensors, organic- and bio-electronic materials, bio-inspired

catalysis, nanocatalysts for key electrochemical processes, and materials design for CO_2 sequestration.

- **Increased and diversified income**: 25% increase of grant income and doubled income in-kind, with new funding sources (see section 3). We coordinated 3 Marie Curie ITNs, 1 Marie Curie IAPP (Industry-Academia Partnerships and Pathways) and have enrolled multiple shared, internally and externally funded, PhD studentships, e.g. University of Muenster (DE), the Austrian Institute of Technology, University of Trieste (IT), Lilly and Servier.

- **Supported interdisciplinary research:** early-/mid-career academics were recruited to develop new research lines at the interface between chemistry, physics, engineering and biology, in line with the interdisciplinary nature of 21st century impactful research. This led to new and fruitful cross-departmental efforts with the Schools of Physics and Astronomy, and Engineering and Materials Science, as evidenced by co-led EPSRC funding and joint publications. The Department has taken an active role in the development of **structures to support interdisciplinary research with key roles** (Palma, Nielsen, Crespo-Otero) in the senior leadership teams of interdisciplinary centres within QMUL, namely the Materials Research Institute and the Institute of Bioengineering: Section 3.2.1. The Department has further examples of successful interdisciplinary collaborations with the School of Medicine and Dentistry and the Barts Cancer Institute (e.g. Palma with Prof Marshall at Barts, and Jones with Prof Denise Sheer at Blizard).

- **Contributed towards strategic challenges**, including: healthcare technologies (organic bioelectronics, nanoscale biosensors, nanogels for drug delivery, DNA nanotechnology); industrial (bio)technology and sustainability (bio-inspired asymmetric catalysis, sustainable organometallic catalysis); energy (alternative materials for cathodes, energy storage composites, water splitting, ammonia production, oxygen reduction reaction); manufacturing for the future (functional materials/nanostructures, bioactive glass ionomer cements); and computational strategies in the design of materials for CO_2 capture and utilisation.

- **Invested in core laboratories and equipment** including a state-of-the art scanning probe microscopy system, a high-definition mass spectrometer, NMR and X-ray facilities upgrades, and in Tier-1 (QMUL's supercomputer Apocrita) and Tier-2 (MMM, Jade and Midlands Plus consortia) High-Performance Computing centres.

- **Further embedded equality, diversity and inclusion.** The principles of equality, diversity and inclusion are embedded in our research strategy and during this REF period there has been a particular focus on improving the recruitment and progression of female researchers, (section 2.2.). This resulted in **significantly increasing the number of female T&R staff submitted for REF**, from 14% to 25%, *vs* 17% Russell group (20% sector) national benchmark.

- **Promoted research impact in society.** Research in this REF period informed the public debate on the environmental impact of plastic-based pollutants (see REF3), while collaborative research with the School of Physics and Astronomy led to a new spin-out company (Chromosol), which has obtained over £1M in funding and won the Royal Society of Chemistry Emerging Technologies competition 2020. Additionally, as a result of research performed by the Department, the healthcare company Baxter International developed a new synthetic bone graft product, with enhanced bone forming capacity, leading to improved health outcomes and patient wellbeing (ApaTech): see REF3.

- **Supported openness and integrity of research.** All the published papers are publicly accessible via QMUL's Elements database (see REF5a, section 2); we also upload publications to the arXiv. The Department has developed an open-source platform to characterise photo-phenomena in molecular crystals, "Fromage" (https://github.com/Crespo-Otero-group/fromage) and open source tools to characterise conformational changes and drug binding sites in proteins (https://fornililab.github.io/dfs/). We are aligned to the University's commitments of the UK *Concordat to Support Research Integrity;* our research integrity (mentoring, code of conduct) is underpinned by membership of (inter-)national grant panels and learned societies; we embed this culture in our staff via staff development activities and plans (Section 2.1).

- **Contributed to the research base, economy and society.** The Department has established new collaborations with industrial partners (from Sanofi and Servier, to BP, Illy, Symphony Environmental) and numerous world-class research institutions in the UK, the rest of Europe, China, Singapore and the U.S.A. (Section 4.1). Moreover, we established a national Tier-2 High-Performance Computing centre, the MMM Hub, for materials and molecular modelling (£4.5M), and were granted visiting and honorary Professorships at Hong Kong University and the California Institute of Technology among others. Through a dedicated Director of Outreach and Public engagement the Department has been exceptionally active and successful in the delivery of multiple outreach and public engagement activities (Section 4.2).

1.2.1 Mechanisms for promoting research

Strategic research decisions within the School are taken by the Senior Executive, with the support of the Research Strategy Group, which includes established and early career staff members from across our research themes (2 T&Rs and the Head of Department). The Research Strategy Group monitors grant applications, success rates and provides an important framework for internal peer review and mentoring. Given the large proportion of new and junior staff, a number of **initiatives have been introduced throughout the REF period**. These have included: i) grant and paper writing workshops, ii) research ideas pitches (bi-monthly), iii) specific support in writing, and iv) internal evaluations. Centralised support at the University level provides costings, grants management, and workshops on embedding impact into proposals. Active engagement to attract funding from industrial sources, is overseen by the QM dedicated Business Unit and its partner QM Innovation.

Researchers are expected to submit at least one large grant application a year and this forms a part of their appraisal process. Newly appointed staff are allocated at least one PhD studentship in their first year in order to build their research and help generate the preliminary data for grants; they are further assigned a **research mentor during their first three years** who helps with research or teaching issues; additional support is encouraged throughout an individual's academic career. Moreover, **10% of the overheads from grant income is awarded to researchers as a research enabling fund,** and additional PhD studentships are provided for grants over £750k. Projects are match-funded where industry contributes 50% of the total costs. Researchers are financially supported in the development of impact via proof of concept funds and the University's EPSRC Impact Acceleration Accounts (Section 1.3).

1.2.2 Research Themes

- *Functional Materials and Nanoscience*
  Abrahams (SL), Giordano (Reader), Lu (L), Nielsen (SL), Palma (Reader), Resmini (Prof). Summary of outputs (2014-2020);170 publications; £5.1M research grant awards; £1.7M income in-kind

The Department has expanded in the area of materials science with special focus on functional materials and nanoscience. The research is focused in three sub-themes: functional organic (bio)electronics, inorganic-based materials and hybrids, and nano-biomaterials. The research in these sub-themes has been successful in developing novel functional materials for different applications, including:

- soft colloidal nanoparticles for sensing and drug delivery applications: Resmini;
- novel energy storage materials: Abrahams;
- sustainable nanoparticles for oxygen evolution reaction: Giordano;
- solution-processable carbon nanoelectrodes for single-molecule investigations and biosensing: Palma;
- DNA Nanotechnology for single-molecule cancer cells investigations: Palma;
- advanced semiconducting materials for organic electronics and healthcare: Nielsen;
- new antifouling nanomaterials: Lu;
- environmental impact of (bio)degradable plastics: Resmini.

The research success has been reflected by publication in high profile journals (JACS, ACIE, Chem. Sci.) and has been made possible by the University's investment in new staff (Giordano, Nielsen, Lu) and new equipment, including a dimension icon AFM set-up, a UV plus spectrometer, and specific equipment for nano-ceramics synthesis. Funding for our research comes from: the EPSRC (e.g. in organic bioelectronics sensors, Nielsen; first grant scheme in molecular electronics, Palma); the European Commission under the Marie Curie schemes (Resmini coordinating three ITN projects on the topic of drug delivery , NANODRUG and NANOSTEM, and one European Industrial doctorate, IPCOS), in addition to the EU Marie Curie Industry-Academia Partnerships and Pathways project "Intelligent recognition materials for extraction devices", as well as three Marie Curie Individual Fellowships and will soon begin a further ITN as partner (Bio2Brain). Resmini's total awarded amount from Marie Curie Schemes is €9.5M including partners, €4.7M to QMUL. New funding sources for the Department were explored by staff appointed since 2013: e.g. the US Air Force (Palma) and the Academy of Medical Sciences and the Wellcome Trust (Nielsen). One particular strength is the access and in-kind support for use of the Science and Technology Facilities Council (Abrahams) in relation to the ISIS Neutron & Muon Source. Moreover, strong interactions with the Schools of Physics and Astronomy, and of Engineering and Materials Science, are evidenced by joint publications and EPSRC grants: e.g. Abrahams with Reece, Yan and Hao (Engineering); Nielsen with Drew (Physics); Palma with Gillin, Sapelkin, and Mol (Physics), and with Fenwick and Iskratsch (Engineering).

Recently, internal funding from QMUL in addition to financial support from the medical charity Life Arc is helping to take the nanoscale biosensors developed in the Palma group (UK, EU and US Patents filed) from the laboratory to "the field" - ambulances and home as point-of-care devices, from neurotrauma to antimicrobial resistance sensing- via the fabrication of a portable biomarker reader with Maddison limited product design company. Global Challenges Research Fund (GCRF) awards obtained (Palma, £48K) are allowing the development of biosensors that will benefit people in South-Africa and Mexico. Resmini co-leads a team of QMUL scientists with expertise in polymer chemistry, biochemistry, microbiology and ecology, to focus on the sampling and analysis of (bio)degradable plastics in the context of their environmental impact. Their research has led to impact in informing the public debate on oxo-biodegradable plastics and providing key references on the sampling and analysis of plastics for new UK and EU guidelines (see REF3). Furthermore, as a result of IPCOS (EC-funded project) the collaboration with DEMUS Spa has resulted in the development of a new protocol for the purification of caffeine; a pilot plant was set up and a new full-scale facility is currently being developed in Italy.

- *Synthesis and Catalysis*
  Arseniyadis (Reader), Cambeiro (L), Jones (SL). Summary of outputs (2014-2020); 46 publications; £1M research grant awards.

Research in Synthesis and Catalysis encompasses a wide variety of topics from target-oriented synthesis and new methodology development, to biology-inspired and photoredox catalysis. The Group works closely with other groups in the Department, notably Functional Materials and Computational Chemistry, as well as external academic collaborators and industrial partners. Since the REF 2014 two strategic appointments to the Synthesis group have been made: Cambeiro (Lecturer) and Arseniyadis (Reader). These appointments have significantly strengthened the group in terms of research capability, increased the international profile and broadened the research expertise in catalysis and methodology.

This has been reflected by publication in high profile journals (JACS, ACIE, Chem. Sci.), with examples of new successfully developed research areas including:

- DNA-based asymmetric catalysis: Arseniyadis;
- natural Product Synthesis: Arseniyadis;
- homogeneous transition metal catalysis and photocatalysis: Arseniyadis, Cambeiro;
- harnessing reactive intermediates: Jones;
- C-H activation and functionalisation: Arseniyadis, Cambeiro, Jones;

- in vitro chemical probes: Arseniyadis, Jones.

Financial support for the research in this Group comes from a diverse portfolio: UKRI for the development of new catalytic and synthetic methodologies (EPSRC Early Career Fellowship, Jones) and new 1D channelled framework materials (EPSRC CAM-IES Network, Jones as Co-I); multinational pharmaceutical and agrochemical companies for asymmetric synthesis of small molecules (Sanofi, Lilly, Servier: Arseniyadis) and consultancy (Syngenta: Jones; Minakem, Novartis, Sanofi and Solvay: Arseniyadis); EU Marie Curie Individual Fellowship (Cambeiro supervisor), the Royal Society (Jones) and the Royal Society of Chemistry (Jones, Cambeiro) and from QMUL strategic research initiatives for small molecule drug development (Proof of Concept funding, Jones as Co-PI) and internal EPSRC strategic equipment grants for HPLC column collection. The group has benefitted from infrastructure investment in new high definition mass spectrometry and improved NMR capabilities: see Section 3.2.

Synthesis underpins discovery across a wide variety of chemistry and the Group has broadened its interdisciplinary research through external (inter)national academic and industrial partnerships and internal collaborations. The latter include, DFT calculations to support research on new reaction mechanisms (e.g. Jones with Crespo-Otero) and applied synthesis used in the preparation and validation of new materials (e.g. Jones with Palma). Intra-faculty partnerships have been established through QMUL's Materials Research Institute (Jones with Szilagyi and Titirici) and the Life Sciences Initiative with colleagues from the School of Medicine & Dentistry (Jones with Sheer, Lockley).

- *Physical and Computational Chemistry*
  Chass (FTE 0.5; Reader), Crespo-Otero (SL), Dimitrov (L), Di Tommaso (SL), Fornili (SL), Vlcek (Prof), Zarbakhsh (SL). Summary of outputs (2014-2020); 180 publications; £2.2M research grant awards; £ 4.2M income in-kind.

Research in Physical & Computational Chemistry at QMUL employs a wide range of empirical and theoretical/simulation approaches to characterize the chemical, physical and biological properties of molecules and materials and to identify the relationship between molecular structure and function. There is a synergistic interplay and active collaboration between the experimental and computational members and with academics from other research sections within Chemistry (3 grants, 3 studentships, 1 Marie Curie fellowship) and other QMUL departments (Physics, Materials, Engineering). The results of these collaborations have been reflected in high impact joint publications (JACS, Nat. Commun., J. Chem. Theory Comput., Chem. Sci., Advanced Sci. News, ACS Cent. Sci). Successfully pursued research directions of this section include:

- acceleration and control of long-range electron transfer: Vlcek;
- atomistic and vibrational origins of mechanical properties in (bio-)cements: Chass;
- solution chemistry effects on crystal polymorphism and nucleation: Di Tommaso;
- open-source platform to characterize photo-phenomena in molecular crystals, "Fromage" (https://github.com/Crespo-Otero-group/fromage): Crespo-Otero;
- adsorption of stimuli-responsive nanoparticles at interfaces, lubrication and Stem cell adhesion and nanosheets at the oil-water interface: Zarbakhsh;
- open source tools to characterise conformational changes and drug binding sites in proteins (https://fornililab.github.io/dfs/): Fornili;
- novel electron accepting organic semiconductors for organic solar cells: Dimitrov.

This research is strongly underpinned by diverse funding streams: UKRI (grants to Crespo-Otero, Fornili, Vlcek), EU (Di Tommaso, Chass), BHF (Fornili), Leverhulme (Crespo-Otero), Welsh Government (Dimitrov), Muscular-Dystrophy UK (Fornili), Royal Society (Di Tommaso), STFC Impact Acceleration Account (Di Tommaso, Chass, Zarbakhsh). Industrial support has been secured from BP Int. (Zarbakhsh), and Cambridge Carbon Capture Ltd. (Di Tommaso, Chass). Research has benefitted from access to world-leading national and international experimental facilities: ISIS neutron & muon beam source (Zarbakhsh, Chass), laser facility STFC (Vlcek), Canada's TRIUMF facility (Chass, see table 2, section 3), and computational facilities: ARCHER, UK's Tier-1 high performance computing centre, via the HECBioSim (Fornili

45,000kAUs) and HEC MCC (Crespo-Otero, Di Tommaso 63,000kAUs) consortia. Additionally, a contribution has been made to funding Thomas-2 (Crespo-Otero, Co-I, £4.5M), a 20k cores Tier-2 Hub for materials and molecular modelling, securing QMUL 10% of Thomas-2 over 2020-23.

1.3 Impact Strategy and Support for Impact Realization

The Department has developed a clear strategy, designed to embed impact in all our activities and to ensure a significant cultural shift among researchers. This has been implemented along three main action points, each supported by specific initiatives:

- Diversification of research funding, with the aim of achieving impact on policy changes, on the environment, health, and society, having a significant effect on UK's economy, e.g. research from the Department informed the public debate on the environmental impact of plastic-based pollutants (see REF3).
- Fostering and promoting excellent interdisciplinary research with productive impact by engaging with academics, charities, companies and a variety of stakeholders.
- Providing support to researchers with a combination of leadership and enabling tools.

Below are some of the key initiatives implemented:

- *Research manager*: highlights on a monthly basis all relevant funding calls, specific targets individuals on the basis of their expertise.
- *Business development Team*: institutional team with dedicated person focused on Chemistry and Biology, provides support in finding business/charity partners for multidisciplinary calls, identifies CASE partners, relevant academic expertise to meet commercial requirements.
- *School's Research Strategy Group (RSG*): meets every 3 months and considers all aspects of Research Impact including requests for "pump-priming" money and studentships.
- *Director of Impact:* as a member of the RSG provides leadership to staff, discusses research outcomes and evaluates their impact potential; reports to the Head of School and works closely with the Faculty Impact Team and the Vice Principal for research.
- *Queen Mary Innovation* (QMI), QMUL's wholly owned technology transfer company. This unit negotiates agreements with industry to commercialise innovations arising from the QMUL research base, including licensing and other royalty-bearing agreements in order to ensure the effective translation for societal and economic impact.
- *Impact acceleration awards:* internally managed awards designed to support and accelerate impact achievement. These include EPSRC and STFC Impact Acceleration Accounts (IAA) and Proof of Concept funding from HEIF

The Department has been successful in securing funding from Impact initiatives, e.g.: the development of microbial quality testing for drinking water (Zarbakhsh, £50k); the development of nanoscale multiplexed biosensors (Palma, £38k + £50k), the optimisation of a drug candidate for neurodegenerative diseases (Jones, £50k) and the development of a prototype high-precision flow cell for performing in-situ neutron scattering measurements of real-time CO_2 mineralization (Di Tommaso & Chass, £25k).

1.4 Future Strategic Goals

The Department will build on its strengths and successes of the last 7 years to consolidate and grow a diverse and research-intensive Chemistry unit, characterised by excellent interdisciplinary research areas, diverse portfolio of funding streams and strong impact-driven culture. This vision is developed around four main areas:

Interdisciplinary research addressing societal needs aligned with the UKRI/UKRI research priorities	*Enhanced collaborative research with industry and diversification of research income*	*Impact-driven research and educational activities*	*Diversity of staff and research students*

For each of these areas specific measures will be implemented, in line with the QMUL's 2030 strategy (see also REF5a, section 2):

Interdisciplinary research addressing societal needs aligned with the UKRI research priorities

- Strategically appoint 3 new academic staff (20% increase in FTEs) in key interdisciplinary priority areas: functional materials, energy, healthcare technologies, and catalysis.
- Infrastructure investment in particular in the broad area of materials chemistry, applied to energy and healthcare; committed investment is in line with this: e.g. a Nanofrazor Explore (Heidelberg Instruments, £250k) nanolithography system was purchased in 2021, only the third of its kind to be set-up in England (third in the UK).
- Strengthen our interactions across the Faculty, in particular with the School of Physics and Astronomy in the aforementioned priority areas. Increase collaboration with the Schools of Engineering and Materials Science, and of Medicine and Dentistry, will help the development of multimillion interdisciplinary research bids: we will also organise institution-wide sandpits for this.
- Support current research addressing strategic societal needs such as biodegradable plastics (see REF3), CO_2 transformation into added-value materials, and nanotechnologies for biomedical applications.
- Link the synthetic chemistry in the Department to recent developments in machine learning and artificial intelligence, with the potential to streamline and automate chemical synthesis.

Enhanced collaborative research with industry and diversification of research income.

- Appoint an *Industrial Engagement Board* composed of both academics and industry members to identify new industrial collaborative links with the Department, (involving Queen Mary Innovation).
- Host roundtables with industrial partners to encourage industry/academia collaborative funding opportunities inviting them to our annual PhD symposia and for guest lectures.
- Increasing industrial secondments for PhD students.
- Increase our portfolio of Innovate UK grants and Knowledge Transfer Partnerships (in line with the recent KTP awarded to Chromosol, spin-out company from work in Chemistry that has hired a recent Chemistry PhD graduate, Dr Parr).
- Through the School's joint degree programme with Nanchang University (China), develop even closer ties with China and opportunities to secure China Scholarship Council PhD studentships.
- Develop a CDT scheme in "Functional Materials with Atomistic Precision".
- Establish an *International Research & Development Group* comprising academics and representatives from QMI and QMUL Business Development Office to identify potential partnerships & establish links in developing nations; in this regard global development opportunities (e.g. GCRF) will be developed for example building on the recent seed funding obtained for nanoscale biosensors (infectious diseases, Palma).
- National funding will be directed at our traditional schemes bodies as Leverhulme Trust, Royal Society and Royal Society of Chemistry, as well as exploiting existing and future collaborations to access more diverse organisations such as charities (e.g. BHF, Alzheimer's Research UK, Parkinson's Trust).

Impact-driven research and educational activities

- From 2021 the Department will create an impact-database designed to collate information about all impact-potential activities.
- Dedicated impact-driven workshops for all researchers.
- 1:1 meetings with members of the Faculty impact team.
- Time allocated in workload model for pursuing impact-generating activities, which could result in lower teaching/administrative load.
- Dedicated support for teaching staff in the development of impact-generation educational activities.

Diversity of staff and research students

- From 2021 the Faculty has committed to provide PhD scholarship to academically deserving BAME students, encouraging our diverse undergraduate cohort to continue postgraduate studies at QMUL.
- Advertise positions on targeted (e.g. BAME, WISE) platforms: we have made good progress with gender equality and plan to improve BAME representation.
- Enhance existing policies for unbiased recruitment of PhDs and staff.
- Introduce mentors for under-represented students, PDRAs and junior staff to enhance progression rates to higher levels.
- Work closely with EDI committee to regularly assess and update policies and procedures.

2. People

2.1 Staffing strategy and staff development

Recruitment

The recruitment strategy has been based around the consolidation of distinctive clusters of research excellence in the Department based in the three areas of strength. New academic staff recruited during the REF period include Dimitrov, Giordano, Lu and Nielsen in the area of Materials and Physical Chemistry; Arseniyadis and Cambeiro in Synthesis and Catalysis; and Crespo-Otero and Fornili in Computational Chemistry, while Di Tommaso, Jones and Palma were recruited in September/October 2013. Two of the appointments, Arseniyadis and Giordano, are outstanding international scientists (France and Germany) recruited at Reader level, to provide leadership in their areas of expertise. The Department now has a T&R academic staff composition as follows: 2 Full Professors, 4 Readers (one at 0.5 FTE), 7 Senior Lecturers and 3 Lecturers.

Staff development

We continue to carefully mentor our staff so they develop as strong, independent researchers.

- The University hosts the Centre for Academic and Professional Development that offers support and a variety of opportunities to staff at all levels;
- There is a mentorship scheme targeting researchers at the early stage of their careers in particular (postdoc, fellows and lecturers).
- Research active staff are required to attend training courses on PhD supervision and a refresher every two years.
- Residential writing retreats led by specialists are offered to staff, to support grant and papers writings.
- Leadership courses for staff (in particular courses developed by the Aurora Leadership Foundation).
- The Department supported staff development to promotion: 50% of the submitted FTEs have been promoted since the last REF period, and two staff members were granted sabbaticals.
- Staff have been supported to achieve impact with specific funding schemes: Impact Acceleration and Proof of Concept funds: Section 1.3

Personal Research Fellowships

During the REF period we have hosted a number of outstanding research fellows who have performed well in securing subsequent funding and producing high quality outputs, resulting in their appointment.

- Fornili held an Intermediate Basic Science Research Fellowship ("*Nanomechanics of heart disease")* by the British Heart Foundation: 2012-2016 (£319,395). 1-year extension to PDRA support by the British Heart Foundation: 2016-2017. Additionally, Dr Fornili is a PI on a BBSRC Research Grant**.** Her work resulted in more than a dozen publications and the hiring of two PDRAs.
- Jones was awarded an EPSRC Early Career Fellowship entitled "Catalytic generation and harnessing of reactive intermediates" (2015 to 2020, £675,133 fEC, 80% salary, 36-month PDRA, one PhD studentship levied from QMUL), leading to 5 publications so far. Prior to this, Jones held a Ramsay Memorial Fellowship (10/2013 to 09/2015, 50% salary). He secured PDRA funding as Co-I on a CAMS-IES grant.
- Di Tommaso held a Royal Society Industry Fellowship (2011-2015) on the development of atomistic simulation techniques for molecular crystal polymorphism during solution crystallization. This was conducted in collaboration with AstraZeneca (Macclesfield), resulting in 9 publications. He was awarded an EU grant in 2019, through the ACT funding scheme ("Accelerating CO_2 Capture and Storage Technologies": €878k, €517k to QMUL), leading the five partners from across Europe, including SME Cambridge Carbon Capture Ltd. Di Tommaso has been awarded funding from the Impact Acceleration Account, the Royal Society and Tohoku University.
- Nielsen was awarded an academic fellowship (2016-2019) sponsored by the Materials Research Institute which included start-up funds and a PhD studentship. Nielsen is a PI on a Springboard grant from the Academy of Medical Sciences and the Wellcome Trust (SBF002/1158), a PI on a grant from the Royal Society and a Co-I within the Centre for Advanced Materials for Integrated Energy Systems (CAM-IES), a £2M EPSRC funded network (EP/P007767/1) bringing together researchers at University of Cambridge, QMUL, Newcastle and UCL (£162k to QMUL). He obtained an EPSRC grant on Additive-Stabilized Polymer Electronics Manufacturing (£570k, of which £211k to QMUL 2018-2021).

2.2 Equality and Diversity

There is a strong culture supporting equality, diversity and inclusion (EDI) within the Department, which is fully supported by the University. The main objectives are to create and maintain a community in which all people can learn, work and interact freely without fear of discrimination, prejudice or harassment. There is a drive to ensure that all staff and students are treated equitably and that age, marital/civil partnership status, gender, gender identity, disability, race, colour, ethnic or national origin, sexual & gender orientation, family circumstances, religious or political beliefs and transgender status does not have any impact. **SBCS holds the Athena SWAN Silver Award (2020)** for excellence in recruiting and advancing the careers of women in science, engineering and technology, marking the progress made in equal opportunities during the REF period (https://www.qmul.ac.uk/sbcs/about-us/athenaswan/). In support of the strategy, recruitment panels are trained on 'fair interview skills' and since 2016 all academic staff have received training on 'Unconscious Bias'. Of the appointed academic staff since 2014, over 37% are females which demonstrates commitment to addressing the gender imbalance in the discipline of chemical sciences and our provision of a supporting environment. Since the last REF, we have **significantly increased submitted female T&R staff**, from 14% to 25%, against a 17% Russell Universities (20% sector) national benchmark. Moreover, our **PDRA/Marie Curie Fellows are 42% and 87% female respectively,** while our PhD student population is 35% female**.**

Flexible and remote working is supported for new parents returning to work or for health/disability issues (all requests were approved in the past three years). We have a least one woman on each

appointment panel and committee, and are working towards **50% representation on all committees**. EDI is included in every committee agenda, exemplified by 40% female external seminar speakers throughout the period. A fully-funded research assistant is provided for 12 months to allow T&R staff to maintain research vibrancy during periods of single or shared parental leave (called upon by 2 staff in the past 3 years). We have recently written and adopted menopause guidelines and revised the PhD recruitment guidelines to reflect EDI principles. Additionally, **the Head of Department, Prof Resmini, is a Trustee of the Royal Society of Chemistry and Chair of its Inclusion and Diversity committee.** She ensures that best practice and 'inclusion and diversity' culture is implemented throughout the Department, and was furthermore directly involved in the research in the publication of the RSC's 'Breaking the barriers' report (2019), and a PhD focus group was held in the Chemistry Department.

2.3. Research Students and Postdocs

2.3.1 Postdocs

Within the REF period the Department employed 35 PDRAs of which 43% were to female candidates, and 8 Marie Curie fellows **of which 87% are female: total post-doc researchers of 2.7 per submitted FTE.** This was done from a diverse source of funding such as the EPSRC, EU, US Air Force, Leverhulme, and the BHF: see Section 3. Each PDRA has an academic mentor and formal progress meetings are held every six months

2.3.2 Research Students

The priority of the Department of Chemistry is to promote excellence in research and ensure outstanding career progression for the PhD research students it recruits. Taking into consideration the size of the Department (15.5 FTEs) significant efforts have been devoted to ensuring a growth in the number of PhD studentships awarded. As Table 1 below shows, compared to last REF we have **more than tripled PhD completion numbers** with an on-time completion of 95% **and 40% female PhD student population.**

	REF 2014	**REF 2021**	'13 '14	'14 '15	'15 '16	'16 '17	'17 '18	'18 '19	'19 '20
PhD Students enrolled	<25> average p.a.	<35.5> average p.a.	40	27	32	43	36	37	34
PhD Students completed	16.5	54.8	4.3	7.8	13.6	4	6.4	8.6	10.1
Average PhD awarded per submitted FTE during current REF period									3.5
Average PhD annual completion per submitted FTE during current REF period									0.5

***Table 1**: PhD students' enrolment and completion*

Research students have been recruited through a diverse range of funding strategies, (EU UK and international governments, Industry and university contribution). The Department contributes to the BBSRC-Lido PhD funding scheme in collaboration with KCL and UCL, is involved with the Plastic Electronics CDT (ICL), and successfully recruited PhD students via different competitive allocation processes in interdepartmental and inter-faculty initiatives at QMUL (10 studentships).

PhD graduates from the Department of Chemistry have pursued successful and diverse career paths, from academia [postdocs at national (e.g. Imperial, Cambridge) and international (e.g. Lund) universities] to industry, *e.g.* Dr McMorrow cofounded "Clean-Kit" (Unilever); Dr Saito (Senior Scientist, GSK); Dr Mirata (Project Manager & Co-Founder of Shoreditch-son Co. Ltd); Dr Attanzio (Cambridge Display Technology); Dr Gaines (Ingénieur R&D at Arkema, France); Dr Sun

(Biosostere , China); Dr Katsina (Domainex, UK); Dr Duchemin (Idille, France), Dr Idris (Pharmaron,UK) Dr Dommett (Heetch, France); Dr Parr (staff scientist in QMUL's spin-out company Chromosol).

International Recruitment

The majority of PhD students in the Department are international students, both EU and non-EU, highlighting the international nature of our outreach recruitment strategies. We recruit through different means, including senior academics visiting overseas institutions (e.g. China): we have secured 20 PhD students though CSC studentships. We have established co-funded projects with the University of Munster (Germany), the Austrian Institute of Technology, the University of Trieste (IT), Lilly and Servier, that allowed us to recruit PhD research students. The coordination of Marie Curie ITNs further allowed us to recruit 9 students.

Training and support

The supervision and progression of research students is overseen by the Director of Graduate Studies. Training support for PhD students is provided by the QMUL *Doctoral College*. Research students have access to QMUL's development programme via Queen Mary Academy, where a points-based training system supports the delivery of the research students training strategy. This also supports PhD students in a range of activities, from scientific and thesis writing, to career planning and advice. Research students have opportunities to undertake laboratory teaching and demonstrating, after specific training from academics and technicians; this represents further support to their career development. The Department, via the Materials Research Institute, organises specific training courses for PhD students in a diverse range of topics and research instrumentation, such as: electrical transport, X-ray methods, chromatography, NMR, EPR, electrochemistry, spectroscopic methods, thin film growth, and scientific publishing.

The Department further promotes and requires the involvement of PhD students in the research seminars that are held weekly during term time, with a substantial presence of prominent national and international speakers, from both academia and industry Recent speakers include: Anderson FRS, Howard FRS, Aggarwal FRS, Leigh FRS, Brimble FRS, Price FRS, Nuckolls (Columbia University), Hoye (University of Minnesota), Ackermann (Goettingen University), Hardouin (Servier), Vors (Bayer CropScience), Demont (GSK), Gallou (Novartis), Davies (Pharmaron), Whiting (GSK), and Samori's RSC award lecture 2018.

Progress Monitoring

In addition to the primary supervisor, each PhD student is paired with a second member of staff and a senior academic that follow the student's progression **through formal panel meetings held at 2, 7, 19, 30 and 36 months**, with a formal progression point at 7 months. This further ensures overall timely submission of the thesis. Moreover, an online progression monitoring system is in place with formal supervision summaries uploaded by the students and approved by the supervisor. These progression monitoring systems have assured a high rate of PhD thesis completion within the four-year deadline, with an on-time submission rate of 95%.

3. Income, infrastructure and facilities

3.1 Income

Compared to REF2014, we **doubled central facility funding** and achieved a **25% increase in research grant income** (see Figure 1). In this REF period the overall income of the Department has been ca £13.8M equivalent to ca. £127k per submitted FTE/year: £7.9M from research grant income and ca. £5.9M from in-kind awards at central facilities (national and international), reflecting the composition and area of expertise of the department.

The research funding through the REF period is closely aligned to the strategy of increasing and diversifying external funding. Specific initiatives have been established during the REF period to support this, including:

- *Research support fund* – a structured approach to provide institutional support for large, strategic or early career funding bids where researchers can request institutional support equivalent to 40% of residual overhead on a grant to be invested in equipment, PhD studentships etc.
- *Research enabling fund* – QMUL provides Principal Investigators with flexible funding from institutional sources equivalent to 10% of residual overheads to support pump priming/ preliminary studies that enhance the likelihood of a successful grant application.
- Internal peer review of grant proposals and grant writing workshops/retreats.

The Department obtained external research funds from a wide variety of sources including: the UKRI, the EU, the Leverhulme trust, the Royal Society, the US Airforce, the Welcome trust, the Nuffield foundation, the British Heart Foundation, the Science and Technology Facilities Council, and universities in Europe. Overall, the grant funding breakdown was: 38% from UKRI, 42% from the EU, 6 % from UK Charities, 5% from other overseas funders (e.g. US), 3% from Industry, 2% from UK government and 4% from other sources, (see Figure 1 for comparison with last REF). Notably, the Department has coordinated 3 Marie Curie ITNs and 1 Marie Curie IAPP (Industry-Academia Partnerships and Pathways), with another ITN awarded in the REF period and due to start imminently.

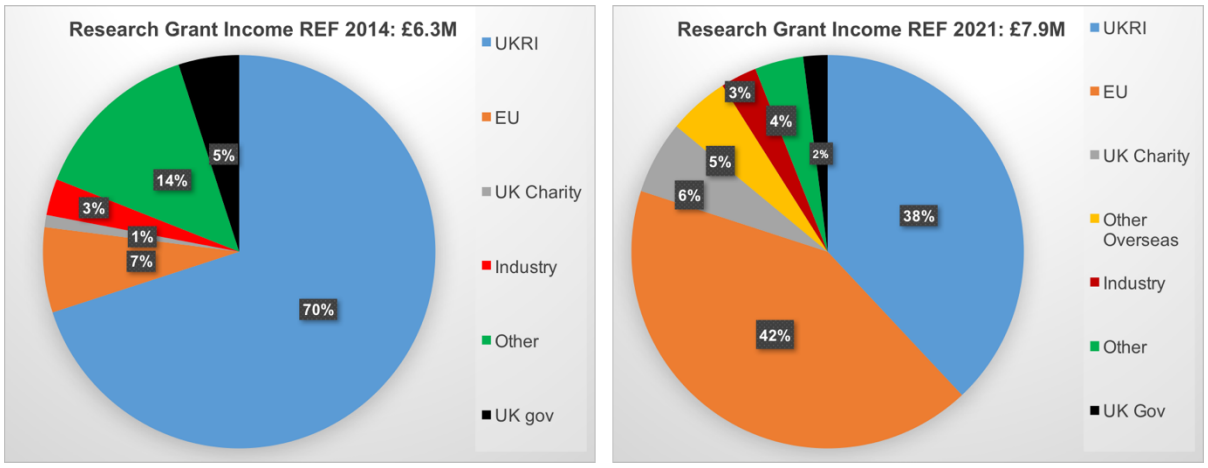

Figure 1 *Research grant income and its diversification: REF 2014 vs REF2021*

The Department has further significant income in-kind from UK and International central facilities, from ISIS neutron and muon source beam time, to TRIUMF (Canada's particle accelerator centre): Table 2.

VALUE	DESCRIPTION
£3.8M	ISIS neutron & muon source beam time, STFC
£1.42M	The Institut Laue-Langevin (ILL) (neutron reflectometry), STFC
£36k	CLF, central laser facility, STFC
£410k	Diamond Light Source, STFC
£238k (11days/experiments)	Muon source at TRIUMF, Vancouver, British Columbia, Canada
£9.4k	Thomas High Performance Computing
Total £5.9M	

Table 2 *Income-in-kind from access to research council supported and international facilities.*

3.2 Infrastructure and Facilities:

The Department is housed in a state-of-the-art building that was built in 2004; there was a further expansion with the development of a new 10 fumehoods lab in 2014 to support an increase in staff numbers (£175k). The current spend in maintaining the infrastructure to date is >£375k; this is supported by 5 dedicated technicians (and 4.5 shared with the School).

Investment during this REF2021 period include:

- high-definition Synapt Mass Spectrometer (>£350k) used across faculty and the medical school;
- state-of-the-art Scanning Probe Microscope (Bruker Dimension ICON-PT; £170k) to perform nanoscale topographical and electrical investigations, including Atomic Force Microscopy (AFM), Conductive-AFM, Liquid-AFM, and piezoresponse AFM;
- PANalytical CUBIX-3 X-ray diffractometer (£150k);
- new electrical and microfluidic (Kleindieck) coupled probe system that allows for real-time biosensing measurements in flow (£50k);
- Infiniband computing nodes on QMUL supercomputer Apocrita (£100k); a gel permeation chromatography (£41k);
- Upgrade of the NMR (£550k) and X-ray facilities (£190k);
- State of the art dynamic light scattering instrument from Malvern (zetasizer) (£60k) loaned as acting as Demo Lab for London.

The investments in this REF2021 period allowed the newly and recently hired staff to explore new research lines and all staff to generate impactful research. The new mass spectrometer (MS) has been of benefit across all the different research themes of the department; the NMR investment has been particularly pivotal to the generation of outputs by the "synthesis and catalysis" group; the X-ray upgrade has been key for the functional materials research groups; the AFM has allowed the characterisation of the novel nanomaterials assembled and explored by the members of the Functional Materials and Nanoscience theme; and the computing nodes have underpinned the expansion of the computational research in the department.

Additional support is provided by a series of research facilities, each in the charge of a skilled technician/experimental officer: Analytical Laboratory; Bioinformatics Clusters; Confocal and Epifluorescence Microscopy; NMR spectroscopy; EPR spectroscopy; Protein Purification; X-ray diffraction. Computational chemistry is well supported by QMUL's Apocrita HPC cluster, while members of the department have access to Tier-1 (Archer) and Tier-2 (Thomas) supercomputer through the EPSRC-funded HPC Materials Chemistry Consortium and the Materials and Molecular Modelling Hub (Crespo-Otero Co-I). Additional new departmental facilities include a new Cary300 UV-Vis spectrophotometer, and a new Shimadzu FT-IR with ATR accessory for the study of plastic and environmental contaminants (see REF3).

3.2.1 Structures to support interdisciplinary research

Outstanding infrastructures within QMUL allow opportunities for networking and new interactions, encouraging staff in the Chemistry Department to undertake interdisciplinary research. In particular, two virtual institutes at QMUL contribute to foster interdisciplinary research efforts between researchers from different departments, schools, and faculties.

Materials Research Institute (MRI)

A centre of excellence created in 2013, spanning several schools and expertise covering materials science, chemistry, processing, characterisation and modelling and applications in energy, light weighting, sensors, optoelectronics and healthcare. It provides the ideal platform to support inter-disciplinary materials research, in collaboration with academia, research councils and industry professionals. Three members of the Department (Crespo-Otero, Nielsen and Palma) are part of the Leadership Team. The MRI offers a dedicated seminar series and organises workshops on a regular basis, designed to promote interdisciplinary research. Its financial budget has allowed the funding of 7 joint PhD studentships with the Department of

Chemistry (collaborative between at least two schools) and in 2016 the funding of five research fellowships, two of which were awarded to Chemistry.

Institute of Bioengineering (IoB)

This is a cross-faculty initiative bringing together more than 50 academics from the faculties of Science & Engineering and Medicine & Dentistry. The Institute provides a focus for ground-breaking research aimed at the development of new medical technologies to meet the key healthcare challenges of the 21st century. Palma was a co-director of research strategy (2015-2019) for the Institute.

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

4.1 Research Collaborations, Networks and Partnerships

Interdisciplinary links are encouraged by the award of inter-departmental co-supervised PhD studentships (10 during the REF period). The Department has further close links with London-based doctoral training initiatives (BBSRC-LIDO with KCL and UCL, and ICL's Plastic Electronics CDT), as demonstrated by shared studentships. Moreover, strong links with the CSC led to the award of 20 PhD studentships over this REF period.

The Department has established **new links with numerous world-class research institutions** (Table 3 and Figure 2) in the UK [*e.g.* University of Cambridge £2.1M EPSRC Network Grant, BP Institute, Europe (*e.g.* ESPCI Paris 3 co-supervised PhDs, the University of Munster and AIT Vienna co-funded studentships), China (Chass Honorary Professorship, University of Hong Kong), the U.S.A. (California Institute of Technology, the Air Force Research Laboratory at Wright-Patterson), South-Africa and Mexico through a Global Challenges Research Fund award.

Staff in Chemistry are engaged in a significant number of multidisciplinary projects and have developed a very strong network of **collaborations with both large international companies and SMEs** (Table 3 and Figure 2): Illy caffè and MJR PharmJet (www.ipcos.qmul.ac.uk), Sanofi (ITN project www.nanodrug.qmul.ac.uk; £100k towards studentship), BP International (joint studentship,10% Zarbakhsh's salary), Cambridge Display Technology (partners EPSRC First Grant), Astra Zeneca (partners Royal Society Industrial Fellowship), Lilly and Servier (joint studentships); SME on Horizon-2020 award (Accelerating CCUS Technology). ONO Pharmaceutical Company provided our Mass Spectroscopy lab £131k for the analysis of sterol lipids in 200 individuals affected by amyotrophic lateral sclerosis.

Additionally, staff hold professional consultancies with Syngenta, Servier, Novartis, Solvay, Sanofi and Minakem (Arseniyadis), as well as BP (Zarbakhsh), and has further links with charities such as the medical charity LifeArc, supporting an Impact Acceleration Project on nanoscale biosensors (Palma).

Table 3: *Worldwide collaborations of the Chemistry Department at QMUL*

Examples of institutions with whom our staff has long-term established collaborations	
Imperial College London, UK	Northwester University, USA
University College London, UK	California Institute of Technology, USA
University of Cambridge, UK	Air Force Laboratory, USA
Technical University of Berlin, Germany	Tohoku University, Japan
Institut Laue-Langevin, France	Seoul National University, South Korea
EPFL, Switzerland	KAUST, Saudi Arabia
Université Paris-Sud, France	Nanjing University of Science and
Utrecht University, the Netherlands	Technology, China
Chalmers Institute of Technology,Sweden	Hunan University, China
Warsaw University of Technology, Poland	Central South University, China
McMaster University, Canada	IMRE, Singapore
Examples of industrial enterprises with whom our staff has long-term established collaborations	
Lilly, UK	CRO Aviano, Italy
Servier, France	Sanofi Aventis, France
Syngenta, Switzerland	illycaffè, Italy
Johnson Matthey, UK	Demus Caffe, Italy
MJR PharmJet, Germany	Cambridge Display Technology, UK
Panaxium, France	Cambridge Carbon Capture Ltd, UK
BP International	

Figure 2: *map of worldwide collaborations of the Chemistry Department at QMUL*

Strong contributions towards the discipline is evidenced by participation in a variety of activities: Member of the RSC Board of Trustees and Chair of the RSC Inclusion and Diversity Committee (Resmini); Chair of the SCI Young Chemists Panel (Jones); Member of the RSC Faraday Council (Zarbakhsh); Chair of the Neutron Scattering Group (Zarbakhsh)' Thieme Chemistry Journals (Award: Arseniyadis 2014, Jones 2017); **CNRS Bronze Medal 2015 for outstanding research** (Arseniyadis).

Invited/Keynote lecture and conference organisation: During the REF period staff in Chemistry have engaged significantly with the scientific community, attending conferences and delivering invited and keynote lectures worldwide. Notable examples include: plenary speaker Amer. Cer. Soc. (Chass); keynote speaker at European Congress on Advanced Materials (Palma); plenary talk at Frontiers in Nanomaterials for healthcare (Resmini); keynote speaker MIP2016 International conference on imprinting (Resmini); Invited speaker Photo4Future workshop (Giordano); invited speaker at a Gordon Research conference, Telluride Research Center conference, and 2nd Frontiers in Photochemistry conference (Vlcek); invited speaker at the IEEE Research and Applications of Photonics in Defense conference U.S.A. (Palma); invited speaker at Organic Electronics Workshop in China, and Macro2020 in South Korea (Nielsen).

Journal Editorships: *J. Chem. Res.* (Abrahams), *Mater. Res. Bull.* (Abrahams), *Mater. Today Nano* (Giordano), *Sci. Rep.* (Giordano and Crespo-Otero), *Coord. Chem. Rev*. (Vlcek), *Inorg. Chim. Acta*, (Vlcek), *Letters in Organic Chemistry*, (Arseniyadis), *Springer Nature Applied Sciences* (Nielsen) *Coord. Chem. Rev*. (Vlcek, 2017 Guest Editor), *Acc. Chem. Res*. (Vlcek, 2015 Guest Editor), Molecules (Arseniyadis, 2020 Guest Editor).

4.2 Supporting collaboration with organisations beyond higher education

The Department of Chemistry has a **dedicated Director of Outreach and Public engagement** who oversees the delivery of activities; a number of staff are actively engaged in outreach and public engagement activities (http://www.sbcs.qmul.ac.uk/undergraduate/schoolliaison/chemistryactivities/). Activities are supported by QMUL's Centre for Public Engagement. QMUL holds an Engagement Watermark Gold Award (awarded by the National Co-ordinating Centre for Public Engagement), demonstrating that QMUL is a beacon of excellence in public engagement. The outreach and public engagement activities offered by the Department of Chemistry are logged centrally and amount to >200 hr per year.

4.2.1 Outreach and Public Engagement

QMUL's diverse student population (90% home students from state schools, 59% BME and 42% first in their families in HE), has over 30% coming from households with annual income <£15,000. The Department's engagement and outreach activities with schools and colleges in London and the South East have increased over the past REF period, building **a database of more than 100 teachers/schools with whom we regularly communicate with.**

We work with Institutions and Professional Bodies such as The Salters Institute and the Royal Society of Chemistry (RSC) to host events such as the *Salters' Festival of Chemistry* (Y7/8 and Y9, 80 students per year) and the *Schools' Analysts Competition* (Y12). We offer *Spectroscopy Masterclasses - theory and demonstration of IR, NMR and GC/LC-MS* (Y12/13), *University Taster Days (Y8-11), Lecture/Demonstrations-Chemistry is Kool!* (Y3-Y13), UCAS, careers and research talks (a combined total of 500 students per year for these events). **We draw on current research from the department to create content for these events.**

We hosted *Nuffield Research Placement* students (Y12) and *Work Experience* students in our laboratories, some subsequently joined the Department as undergraduates. We visited schools and colleges in the UK to deliver talks, workshops in continental Europe (Spain) and engaged with government officials in Bulgaria including the British Ambassador and the Deputy Science and Education Minister of Bulgaria (2019).

The **Department partnered with the Charity *In2Science UK*** to provide young people from low-income/disadvantaged backgrounds opportunities of practical experiences within STEM (2020). Furthermore, **Prof. Resmini was a panellist at an event organised by the charity focused on "promoting diversity in STEM"** (2020).

Over the current REF period the **Department has engaged annually with 600+ participants,** with an upward trajectory in engagement (Figure 3).

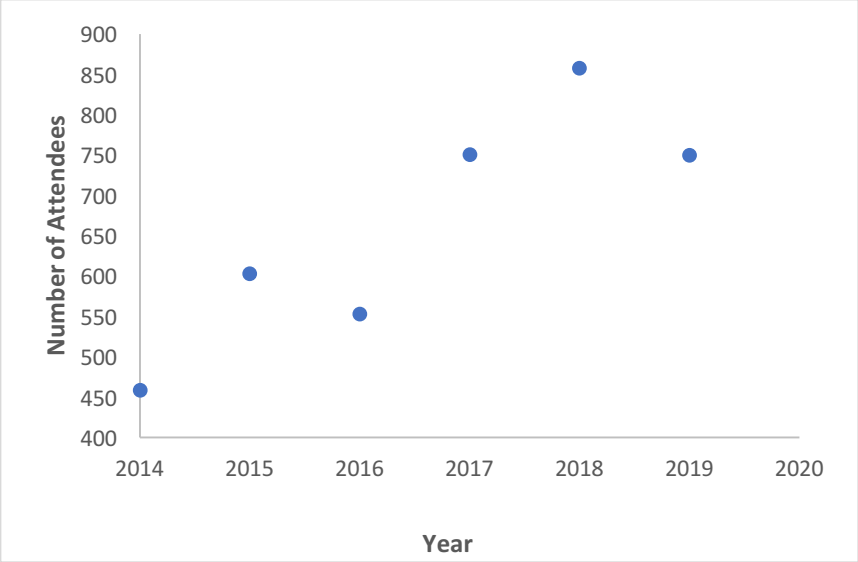

Figure 3: *number of attendees at outreach events in the REF period*

In 2016, the Department received an award of £17,525 from QMUL's Access Agreement grant to purchase an infra-red instrument and maintenance grants to support UG students to make 3D models of a bombardier beetle self-defence mechanism; the Spectroscopy Masterclasses attract >200 A-level students per year.

We successfully bid to become a provider of the RSC's *Spectroscopy in a Suitcase Program (*engaging with >150 Y12/13 students*)*; PhD students help with the delivery. Furthermore, the **RSC Inclusion & Diversity Fund was awarded** (£5000) for '*Student generated teaching resources as a tool to enhance inclusivity and diversity*' to highlight role models from under-represented minorities within the scientific community.

The Department **obtained further funding from the RSC**: £1750 to run "*Bringing Chemistry Alive - Lotions, Potions, Murders and Slime!"* (REF: 54961664); £1800 for "*Promoting the Study of Chemistry Amongst Y9/10 Students*" (REF: 90471125); £1685 to organise a "*Year 12 Chemistry in Higher Education Conference"* (REF: 122783643).

The Department hosted its first *International Summer School* (2019, 11 students) and *Chemistry Residential Summer School (*30 students). We draw on one of our strengths–functional materials– focusing on novel methods in chemistry, nanotechnology, green and flow chemistry: a combination of lectures, workshops, practicals and scientific programming linked to the Department's research.

Additional activities include the annual *Festival of Communities* created by QMUL in collaboration with our local community in Tower Hamlets, giving 3500 local residents the opportunity to try hands-on experiments/demonstrations linked to our research. We participated in the Swansea Science Festival and the Sofia Science Festival (2017-19) where activities included solar cell making workshops. Further demonstrations on photochemistry have been carried out in the London Science Museum Skills Fair (2019).

We **hosted professional development courses for** (20) **secondary school teachers and technicians in collaboration with the RSC**. We further organized 'twilight courses', targeted at teachers in London whose schools are not able to fund overnight stay.