Institution: Queen Mary University of London (QMUL)

UOA: 13B Electrical and Electronic Engineering, Metallurgy and Materials

A. Overview

Queen Mary has a long tradition of materials research having founded the UK's first Department of Materials in 1967. The increasingly interdisciplinary nature of modern materials research which spans fields such as chemistry, physics and engineering, as well as a focus on specialist applications, such as medical and dental materials, has shaped QMUL's research strategy over many years. This strategy, of forming interdisciplinary groups to work across the whole *'Chain of Knowledge',* from synthesis to devices, led to the formation of the faculty-wide Centre for Materials Research (CMR) in 2001 which was at the heart of our RAE2008 submission. It was the success of the strategy that defined the CMR that evolved into the Materials Research Institute (MRI) in 2012 where 44 academic staff from four Schools, Engineering and Materials Science (SEMS), Physics and Astronomy (SPA), Biological and Chemical Sciences (SBCS) and Medicine and Dentistry (SMD) were seconded to the MRI for their research activity, whilst retaining teaching and administrative roles within their Schools. Since RAE2008 the College has appointed 25 new members of staff who are within the MRI with an emphasis on younger academics. The expansion has also built on the College's strategic objectives such as the alliance with the University of Warwick (in materials modelling) and becoming a full member of the Thomas Young Centre. A core group are being returned through UOA13B (24.2 FTE, 92% return), mainly from SEMS and SPA, while a further group in healthcare materials (5) and materials simulation (3) from SEMS are being submitted with the bioengineering and modelling activity to General Engineering (UOA15). As a result of the recent growth and investment in Chemistry and the collective desire to be externally recognised as a research active centre, many of the MRI staff from SBCS (5) are returned through a separate Chemistry (UOA8) submission. MRI staff from SMD with activities in dental materials (3) are returned through Dentistry (UOA3).

B. Research Strategy

Materials research has prospered since RAE2008 with the establishment of two cross-faculty research institutes, the 'Materials Research Institute' and the 'Institute of Bioengineering'. This Research Strategy has developed around the research objectives set out in QMUL's Strategic Plan 2010-15 and its Research Strategy 2012-15. The core of the College's materials research strategy over the last five years (as set out in RAE2008) has been to enhance research excellence in core areas, develop new interdisciplinary research programmes, build new strategic alliances, strengthen links with industrial partners and appoint and nurture junior academics who will become future research leaders. The following highlights reflect the success of that strategy:

- Launched the MRI in 2013 with a direct budget for 4 new Academic Fellowships, 7 PhD studentships per annum, research support staff and infrastructure costs.
- Recruited a materials modelling group from Cambridge (Dove, Trachenko, Misquitta, Phillips)
- Made 25 permanent academic appointments to Schools who are members of the MRI, including 5 ECRs submitted through UOA13B (Becer, Bilotti, Misquitta, Phillips, Yan).
- Established a number of interdisciplinary research programmes such as a £4.3m Platform grant (with ICL, Loughborough), £2m Midplus consortium grant, £1.9m Graphene Engineering grant (with ICL) and a £1.1m ERC Starting Grant.
- Established strategic partnerships with the University of Warwick, joined the Thomas Young Centre to develop the materials modelling activities and established joint Research Institute in Sichuan University, China (with £0.7m start-up investment).
- Ran over 100 industrial grants (23% of total grant awards), 19 KTA, 8 TSB, 16 EU programmes, and won a Royal Society Industrial Fellowship.
- Increased PhD recruitment per annum by nearly threefold between 2008 and 2012.
- Eight staff held individual Fellowships during the REF period

MRI staff submitted to UOA13B published, over the REF period, >900 articles in peer-reviewed journals, generating 11,000 citations (Oct. 2013), 60 papers in journals with an impact factor >10 of which 10 were in Science or Nature Journals. Our output translates into 6.5 papers/FTE/annum and 12.2 citations/paper, which is well above the average number of citations of 6.9 in materials science over nearly double that period (10 years) as reported by Thomson Reuter in 2011. The

impact of our publications was also reflected in the 2011 QS World University Rankings by Subject, where we came 2nd in the UK for citations per paper.

Materials Research Strategy: Since RAE2008, and before the launch of the MRI in 2013, the College invested >£13m in basic infrastructure and facilities to support materials research across the College. In 2011 the College appointed Dove from Cambridge to lead the new MRI and in 2012 provided an initial investment for the MRI of £1.7m to support 4 Academic Fellowships, 7 PhD studentships per annum, research support staff and infrastructure costs, with further investment expected in 2015. The MRI research strategy aligns with the strategic aims set out within the QMUL Strategic Plan 2010-15 and aims to attain a reputation as an Institute conducting materials research that is judged to be uniformly internationally leading. To achieve this aim the MRI aligns its research in selected areas with distinctive strength and critical mass, developing multidisciplinary groups in *Energy, Lightweighting, Sensors, Opto-electronics and Healthcare* that align with EPSRC's thematic areas. It also aims to build on its strong engagement with industry with a particular focus on SMEs, and to develop a culture of building research projects that leverage our wider shared capabilities to facilitate wider collaborative projects. Key indicators of performance are defined targets which are benchmarked against institutions with top performances in Materials in the RAE2008 for both quality and quantity of publications, research income, PhD student completion, and commercialization of research.

Research Management: The MRI was established with a Director who reports directly to the Vice-Principal for Science and Engineering. To help focus the Institute's strategic aims it has appointed an external Advisory Board to provide oversight and advice. The MRI has a Management Committee which is responsible for PhD recruitment and training, staff appointments, management of the research themes and business engagement. This is further encouraged by the integration of the College's Business Development Unit into the MRI Senior Management Team. Each research theme has an academic leader to direct the programme and provide input to the Senior Management Team. The research theme leaders oversee research mentoring of ECRs, Research Fellows and PDRAs, while the progression of PGRs is delegated to its Director of Graduate Studies. The Institute employs a Research Administrator who provides support for grant applications and grant management. An internal peer-reviewing process is installed for grant applications. The MRI hosts an active bi-weekly seminar programme, which attracts high quality external speakers and provides the opportunity for informal research discussions between staff on a regular basis. Recent speakers included Dr. Nigel Birch, Senior Physical Sciences Manager at EPSRC, and Dr. Pep Pàmies, Senior Editor of Nature Materials. A formal workload model allows staff contributions to be assessed to ensure a minimum of 50% of available time is protected for research. To encourage industrial collaboration and entrepreneurship these activities are being specifically addressed within the academic workload allocation model.

Research Themes: Research within the MRI is organised through five application themes: *Energy, Lightweighting, Sensors, Opto-electronics and Healthcare,* that align with EPSRC's thematic areas. The MRI with its broad interdisciplinary approach that brings together chemists, physicists and engineers within each application theme, allows us to cover the whole '*Chain-of-Knowledge*' ranging from synthesis, processing, characterisation and modelling, to device design. Our simulation capability, for modelling structure property relationships, was a new strategic development since RAE2008 and is now firmly established through cross-College collaborations as well as through the strategic alliance with the University of Warwick (e.g. the ~£2m Midplus consortium grant with Warwick, Birmingham and Nottingham) and membership of the Thomas Young Centre (Dove, Misquitta, Phillips, Trachenko). In the field of processing there is a focus on the development of materials with multiscale structures, such as bio-inspired nanostructured composite materials (Barber, Peijs, Pugno); textured ceramics and ceramics with non-equilibrium phases (Reece). This activity has benefited from recent investments in synthesis and materials chemistry (Becer, Binions, Titirici). We also have an excellent track record of developing new tools and capabilities, particularly in advanced materials processing through Nanoforce Technology Ltd. (see Case Study 1), and microscopy through our NanoVision Centre (Bushby) and the use of central radiation facilities (Dove, Drew, Philips) such as ISIS of which QMUL is now the 5th largest user in the UK.

Energy: Energy materials research represents a broad range of activities targeted at batteries and supercapacitors, catalytic technology, solar energy and thermoelectrics. Heterogeneous

photovoltaic systems are being developed using novel low cost, low energy and low waste chemical processes for nanostructured surfaces (Dunn). Thermochromic thin films for energy efficient glazing and photocatalytic materials are being developed using electric field assisted CVD processes (Binions). A significant activity focuses on thermoelectric materials (Reece, Dunn, Yan) and is supported by 3 EU grants, TSB, Royal Society, charity and EPSRC including a recent Sustainability Award with Cranfield, Surrey, Manchester, totalling £1.9m. We are engaged in work on the problem of long-term encapsulation of high-level nuclear waste in ceramics and glasses, development of nuclear fuels, and the requirements of materials for both fission (in collaboration with the Nuclear Decommissioning Authority) and fusion reactors (Dove, Trachenko) with a unique capability in large-scale atomistic simulations of the formation of damage following nuclear disintegration. Research in sustainability is funded through TSB, EU and industry, totalling £800k. The group has a strong international reputation in 'green' composites that are bio-based, compostable and recyclable (Peijs) (see Case Study 1). To further strengthen our activity in sustainability, we recently recruited Titirici, who develops porous carbon materials using hydrothermal carbonization, a sustainable 'green' synthesis route, for applications in energy storage or fuel cells. We envisage maintaining the diversity of work that is on-going in this area but see further opportunities in sustainability, thermoelectrics, and the development of membranes for fuel cells and water purification.

Lightweighting: Work is focused around composites, either ceramic or polymer based, and is strongly linked to the modelling & simulation activity within SEMS where novel analytical/numerical design tools are being developed for composites (Wen, Barbieri; UOA15). A distinct activity is around the development of recyclable composite materials based on oriented tape and film rather than fibres (Peijs, see Case Study 2). A large activity is on the utilization of nano-scale architectures in polymer composites. Here, through the study of biological systems, we aim to develop new design rules for optimized materials based on nanoscale architectures (Barber, Pugno). This work is complemented by activities in polymer fibres (Bastiaansen, Barber, Peijs), and the development of lightweight composites based on renewable resources (Peijs). Extensive research activity involves the application of carbon nanotubes and graphene in nanocomposites (Baxendale, Bilotti, Peijs, Reece), supported through, among others, 3 EU, 2 EPSRC and one TSB grant totalling £1.7m. To further support this activity we recently appointed Pugno, who brings in expertise in graphene nanomechanics, and an involvement in the Graphene Flagship. Future research is here expected to grow in smart composites with integrated sensing, actuation, self-healing, and energy storage capabilities.

Sensors: Activities span synthesis, processing, characterisation and modelling to device fabrication. Research on oxide functional ceramics is focused on ferroelectrics and brings together expertise in electromechanical properties and ferroelasticity (Reece, Yan). Research topics include the effect of ferroelectric/ferroelastic switching on mechanical properties and degradation, the development of new ferroelectric ceramics with super high Curie points (>1000°C), and rapid spark plasma sintering (SPS) to produce functional ceramics with nanoscale microstructures, high texture and non-equilibrium phases. This work has led to a £4.3m Platform Grant with ICL and Loughborough. Conductive polymer composites, incorporating carbon nanotubes or graphene, are developed to sense external stimuli such as chemicals, gases, vapour, mechanical strain, and temperature (Baxendale, Bilotti, Busfield, Peijs) for application areas such as smart textiles, smart elastomeric devices, structural health monitoring and medical applications, supported by 3 EU grants and industry. Polymeric sensors and actuators based on liquid crystals are also being developed for stimuli like light or chemical environment (e.g. humidity, CO_2) (Bastiaansen, Peijs).

Opto-electronics: Many of the activities in this area are integrated into the EPSRC Doctoral Training Centre for Plastic Electronics (with ICL). Organic electronics research within the MRI is primarily focused around the dedicated organic electronics clean room facilities. Usage of these facilities is supported by a significant programme of work, including a £3.2m FP7 project on spin injection in organic systems (Drew, Gillin), and a £1.1m ERC Starting Grant (Drew) using muon spectroscopy. This has enabled us to become one of the world leaders in organic spintronics and spin-interactions in organic electronics and establish a joint Research Institute at Sichuan University (SCU) with >£700k of start-up funds from SCU. We are also active in large-area transparent-conducting electronics (Gillin, Baxendale) with a KTA with M-Solv Ltd to develop solution processed conductors and semiconductors on glass. Future development will include

organic photonics based on recent work (supported with a RAEng Fellowship) on organic optical amplifiers which is the subject of a Proof-of-Concept grant.

Healthcare: The impact of MRI research on Healthcare is so widespread that it spans several academic areas and has been submitted in multiple UOAs. Within this UOA we have a significant collaborative activity in dental materials (Bushby), fibrous tissue engineering scaffolds (Bastiaansen, Peijs), biointerfaces (Azevedo) and drug delivery (Becer), while disposable biosensors for the detection of enzyme activities (Krause) and diabetes (Bastiaansen) are also developed. This activity is strongly linked to clinical research and activities in SMD.

C. People

Staff Strategy: The College's staff development strategy has rested on the principle of employing leading scholars with internationally recognised research profiles (e.g. Dove, Pugno) and using them to attract and develop junior staff with potential to attain that level, while also encouraging those in mid-career towards advancement. Its strategy is informed by QMUL's career development policies which received the European Commission HR Excellence in Research Award in 2012. It also follows the QMUL 2011 plan for the implementation of the Concordat to Support the Career Development of Researchers and its policy on Equal Opportunities and Diversity. The appointment strategy is to recruit only staff with an internationally recognised research profile and the potential to be world leading. Appointments are only made in areas directly linked to our existing research themes with selected recruitment to fill particular areas of research need. For example, there was a strategic requirement for a materials modelling and central facility users activity and this led directly to the recruitment of Dove and three colleagues from Cambridge and Drew from Fribourg. During the REF period the College has made 25 appointments of permanent materials active research staff including 15 in SEMS, 5 in SPA, 3 in SBCS and 2 in SMD. Of these 13 are returned through UOA13B (Azevedo, Univ. Minho, Portugal; Becer, Univ. Warwick; Bilotti, Yan, QMUL; Binions, UCL; Dunn, Cranfield Univ.; Titirici, Max Planck, Germany; Pugno, Univ. Trento, Italy; Dove, Misquitta, Phillips, Trachenko, all Cambridge and Drew, Fribourg, Switzerland) while another 8 with activities in biomaterials (5) and materials simulation (3), are submitted to UOA15. New MRI staff in SBCS and SMD are being returned through UOA8 and UOA3. This recruitment strategy has been supported by College investment of >£3m for start-up packages. The MRI played a critical role in the recruitment process of these staff, with cross representation of participating members of the MRI Senior Management Team on all selection and interview panels. The MRI will appoint a further 4 Academic Fellows in 2014 to support strategic developments. These Fellows will have 4 year contracts with no teaching or administrative duties. Success as measured by research performance will lead to permanent academic positions.

Career Development for Established Staff: A work-load model is used to equalise loads and achieve a balance between colleagues' responsibilities; all staff are appraised and mentored by a senior colleague who discusses research plans, publication placement, research funding, public engagement and professional development through the Centre for Academic and Professional Development (CAPD). Staff promotion aspirations are encouraged and in the REF period, 14 staff have been promoted: 2 Lecturers to Senior Lecturer (Barber, Kreouzis), 5 Senior Lecturers to Reader (Barber, Busfield, Drew, Dunn, Krause) and 4 Readers to Professorships (Busfield, Gillin, Reece, Resmini). Research theme leads operate a system for peer review of research grant applications. The Schools also nominate academic staff for a College wide 'High Potential Leaders' programme which involves workshops, masterclasses and coaching to support their development.

Career Development for ECRs and PDRAs: In 2011 the College was shortlisted for the Times Higher Award for 'Outstanding Support for Early Career Researchers'. We have adopted a faculty specific approach based on feedback obtained from Careers in Research Online Surveys (CROS). ECRs are allocated a Probationary Advisor who meets with the probationer every 3 months. We hold an annual Queen Mary Fellowships Day with speakers from various funding bodies to support researchers looking for independent fellowships. There are also Science and Engineering Winning Grant Funding Master-classes and Mock Panel Days to provide specific support on how to write Fellowship or Grant proposals. All new staff receive start-up funding, with at least one PhD studentship each and appropriate running costs. Initial teaching loads for ECRs are light (usually 1/3 of a full load, building up to a full load by the third year) with no significant administrative duties. Research Fellows and PDRAs receive the same mentoring support as ECRs. The College's Concordat Implementation Plan has adopted a Faculty specific approach to supporting the training

and development needs of PDRAs. As a result, a Science and Engineering Postdoc Network was established to provide a bespoke approach to development activities. PDRA representatives from different Schools and Institutes participate in monthly Forums to advise on the topics to be covered and the speakers to be invited for a series of Masterclasses designed to address development needs. The College organises an annual Fellowship Day, which attracts over one hundred PDRAs and academic staff from across the College in which speakers from various funding bodies showcase their Fellowship Schemes. In the REF period, the UOA hosted 8 externally funded personal fellowships including ERC, EPSRC, RAEng, Royal Society, Leverhulme and Marie Curie. We have attracted visiting researchers from around the world including many from China following the EPSRC Global Engagement project. Seven staff have visiting positions at international universities including part-time positions.

Equal Opportunities: The College is committed to ensuring equality and promoting diversity in all its practices and has put in place initiatives to support this goal. This includes diversity policies in the recruitment and selection of staff. In 2010 QMUL successfully renewed its Bronze Athena SWAN Award for excellence in recruiting and advancing the careers of women in Science, Engineering and Technology. In 2013 SBCS received a departmental Athena Swan Silver Award in recognition of the initiatives in place, while SEMS was awarded the Bronze Award. SPA has Project Juno practitioner status and is working towards Juno Champion status. This is an IOP initiative to increase the representation and participation of women at all levels in HE. The College has included an Athena SWAN session in the induction program for new staff that raises awareness of the College's commitment to gender equality. During induction, staff are informed about flexible working, child-care and staff development programs at the Centre for Academic and Professional Development. QMUL has a long history of supporting flexible working and part time work has not excluded academics from promotion. The College is also part of the Stonewall Diversity Champion program, which helps employers promote equality for Lesbian, Gay, and Bisexual people. QMUL has also partnered with leading London institutions to set a scheme where senior academics mentor Black and Ethnic Minorities (BEM) academic staff. MRI is also engaged in the faculty wide Women in Science and Engineering (WISE) initiative which started in 2008 as a networking platform for female undergraduates, postgraduates and academic staff in science and engineering, seeking encouragement and advice on managing their careers and tackling life important questions such as work-home balance. In 2013, Krause joined the 'Women into Leadership Programme' which was created, with Ashridge Business School, to develop leadership potential of female academics.

Postgraduate Research Students: In 2012 the College established a Doctoral College to support both PGR students and PDRAs. Strategically led by a Doctoral College Management Group which includes its Director (Prof. Bill Spence, Vice Principal for Research) and Deputy Deans from each of the three Faculties, its activities are delivered and coordinated by two dedicated Research Development Officers (Centre for Academic and Professional Development) and a Careers Adviser for Researchers (QM Careers). These staff work with the Faculty to ensure that PGR development activity aligns to specific needs. The Doctoral College ensures that outstanding research students are recruited and developed through fair selection. The MRI adopts a robust approach for recruitment and training of PGRs which is overseen by the Director of Graduate Studies (Barber). All funded studentships are advertised both internally and externally. Shortlisted applicants are interviewed by two members of academic staff to ensure recruitment of the highest quality students. During the REF period we achieved a nearly three-fold increase in annual PhD recruitment, which will start to come through in our completion data from 2014. This was supported through EPSRC, Industry and College funded positions but also through engagement with international schemes such as China Scholarship Council (CSC), with whom QMUL is the largest partner, and Science without Borders (Brazil).

Table 1. PhD recruitment in UOA13B.

Year	2008	2009	2010	2011	2012	2013
PhD	8	9	18	26	29	16 (to date)

The total number of materials PhD students completing over the period is 87.7, which translates

into 0.72 PhD/FTE/annum (0.51 for RAE2008). For PhD students starting studies within the period, 91% of the students submitted within 4 years and 100% completed within 5 year, highlighting the robust approaches taken in completing Materials students through a supportive environment.

PGRs are all allocated two supervisors (who will have undergone recent training in current best practice in supervision, and at least one of whom will have a proven track record of supervisory success). Progress is monitored by regular meetings with supervisors and formally assessed after 9 months of registration. Students also submit reports and have interviews at the end of the 2nd and 3rd years. The latter report must include a thesis plan to ensure that submission will be within 4 years. Workshops are available to help students prepare for each stage of their progression. Materials PGRs have retained a distinct identity within QMUL through the MRI (and former CMR). This provides a focal point for materials PhD students from SEMS, SPA, SBCS and SMD, through the MRI seminar series, and networking events with industry. Many PGRs are on interdisciplinary projects to encourage broader interactions while their experience is based on working in state-of-the-art research laboratories totalling over £7m of internal and external investment.

The Doctoral College runs an interdisciplinary PGR induction, which is compulsory for all students who are also encouraged to attend annual Interdisciplinary Cohort Training courses. QMUL operates a Points-Based Training system to support delivery of our College-wide training strategy for PGRs, based on the RCUK endorsed Vitae Researcher Development Framework. This allows disciplinary flexibility, ensuring that all students receive appropriate transferable skills and research training. MRI students have a choice of courses available from all Schools within the MRI as well as access to University of London courses provided through the Intercollegiate Masters Programmes. Since 2013 PhD students also benefit from GradNet, a PGR network that is being set up as part of SEPnet2 and will specialise is condensed matter training. Science Communication Training ('Junk the Jargon') is provided through a cross-college Competition where PhD students present their work to a public audience in 3 minutes and are judged by an external panel. Doctoral Transitions: Careers Beyond Academia are QM Careers events that support researchers who are considering alternative careers options into industry. Former QMUL alumni are invited to speak about their new careers outside academia. In addition, QMUL's Centre for Academic and Professional Development has an excellent track record of developing and delivering training programmes to support externally funded projects. A particular highlight in the REF period was the £3m EPSRC funded KTA award 'ImpactQM', which allocated 16 internships to PhD students in a range of companies, of which 10 benefitted MRI staff. QMUL recently committed to a significant capital project to celebrate its 125th Anniversary. This £36m Graduate Centre will include dedicated space and infrastructure for doctoral training to provide a 'one-stop-shop' and is expected to be completed in 2016. All these training and progression aims are supported by a state-of-the-art IT system as a result of the recent £21m invested in QMUL's IT strategy.

D. Research Grant Income:

The total value of awards to the UOA has grown significantly in recent years, totalling £16m, equating to £120k/FTE/annum (£92k/FTE/annum for RAE2008). This includes £2.78m of grant awards won by MRI staff through Nanoforce. Awards came from EPSRC, Royal Society and RAEng. (36%), EU (26%) and Industry (23%), the remainder coming from charities and other sources. Although this is a 30% increase compared with RAE2008, this number is even more remarkable in light of the large number of recent appointments. Discounting these 13 appointments and their associated income, the average grant income equates to £207k/FTE/annum. Grant awards have particularly increased since 2011 with average grant awards over this period of £169k/FTE/annum based on all UOA13B staff (£242k/FTE/annum excl. new staff).

Table 2. Grant awards in UOA13B (excl. EPSRC DTA).

Year	2008	2009	2010	2011	2012	2013*	Total
k £	2,229	1,825	1,749	3,593	3,151	3,486	16,033

** Grants to date*

Examples of some major research grants include: an EPSRC Platform Grant 'Materials Systems for Extreme Environments' with ICL, Loughborough (2013-18, Reece, £980k); an EPSRC Sustainability Award with Cranfield, Surrey, Manchester (2013-17, Reece, £750k); an EPSRC

Graphene Engineering Grant with ICL (2013-17, Peijs, Reece, £350k); the EPSRC DTC in Plastic Electronics with ICL (Bastiaansen, Dunn, Drew, Peijs); EPSRC Global Engagement (£350k, Gillin), ERC Starting Grant (£1.1.m, Drew) and the South East Physics Network (SEPnet, Dove). The aim of the MRI is to achieve a research grant income of £200k/FTE/annum across all staff during the period 2014-2019 whilst maintaining the high (23%) level of contribution from industrial sources. The REF period has also seen a substantial increase in research spend compared to the previous RAE period. Total spend for REF2014 was £9.5m, equating to £78.5k/FTE/annum (£65k/FTE/annum for RAE2008). Financial data returned through the HESA system for REF2014 did not include income generated through Nanoforce Technology Ltd.

Infrastructure and Facilities: During the REF period the MRI has benefited from significant investment in infrastructure to support research. The College is investing in a phased programme of refurbishment of both the Engineering and Physics building with a planned total investment of £30m over 10 years from 2009. Investment within the REF period to date has been around £10m. Some developments in built infrastructure that specifically support materials research include:

- Investment from a Wolfson Royal Society laboratory refurbishment grant (Bastiaansen, £350k) to create a Plastics Electronics laboratory in the Chemistry building (2011).
- Investment from the College (HEFCE, £455k) to create a high quality PhD Student Hub in the Engineering building providing desk space for 70 PhD students with break-out space (2009).
- Development of an integrated administrative hub in the Engineering building (HEFCE, £550k), including research support services for academic staff (2009).
- Investment from the College (HEFCE, RCIF, £150k) to create a ~100 m^2 Nanostructured Materials laboratory in the Engineering building (2011).
- Refurbishment of ~500m^2 Functional Materials Research labs in the Engineering building to support new academic staff with funding of £2.7m from HEFCE (2012).
- Refurbishment of laboratories, lifts, lobbies, offices and lecture rooms in the Physics building with total capital expenditure since 2008 totalling £6.5m.
- The College has earmarked a further £12m of investment for the period 2013-2015 for refurbishment of the Physics building, incl. new offices and labs for the MRI (~45% of space).

Other significant investments in facilities and research equipment includes:

- CIF investment totalling £1.3m in high performance computing facilities between 2008 and 2011 to support modelling and simulation activities.
- The recent EPSRC £2m Midplus Consortium grant with Warwick, Birmingham and Nottingham, a major e-infrastructure investment providing a national High Performance Computing Cluster, involving £350k EPSRC funding for QMUL, matched with £250k College funding.
- Examples of additional College investment in research infrastructure since 2008 include a new probe for the 600 MHz NMR (£130k), a new console for Brüker AV(3)400 NMR (£130k), a new dual source single crystal XRD with small molecule and protein capacity (£230k), a new powder XRD (£290k) and the upgrade/replacement of mechanical testing facilities (£400k), refurbishment of workshop in SPA including new CNC facilities (£240k).

MRI members are significant users of central facilities (5th largest UK users of ISIS). Drew has regularly been awarded beam time on large-scale muon production facilities at the Paul Scherrer Institute (Switzerland). Multiple members of the group (Dove, Drew, Phillips, Trachenko, Barber, Peijs) have been awarded time at ISIS at the Rutherford Appleton Labs, Diamond Light Source, and ESRF Grenoble. The notional value of beam time since 2008 allocated to MRI members is around £1.3m. Staff are also on instrument building groups at Diamond and ISIS (Dove).

The majority of the consultancies within the UOA are conducted through Nanoforce Technology Ltd. which was established as our *'Portal to Industry'* for these type of activities. It has operated over 100 consultancies during the REF period (see Case Study 1).

E. Collaboration or contribution to the discipline or research base

Academics returned in this UOA have numerous international collaborations with leading groups. Some examples incl. Max-Planck Inst. Leibniz Inst. Dresden (Germany); Univ. Stockholm, KTH Stockholm (Sweden); Kyoto Univ., Kobe Univ. (Japan); Tsinghua Univ., Shanghai Inst. Ceramics, Sichuan Univ. (China); Univ. Minho (Portugal); NYP, IMRE A*Star (Singapore); Univ. Mons, KU Leuven (Belgium); TU Eindhoven (Netherlands); ETH Zürich, EPFL (Switzerland); INSA Lyon,

Univ. Pierre et Marie Curie (France); Univ. Patras (Greece); Univ. Trento, Univ. Naples (Italy); Rice Univ., MIT, UCSB, Northwestern, Air Force (USA). Seven academics held visiting or part-time professorships incl. Trachenko (Inst. High Pressure Physics, Moscow); Peijs (TU Eindhoven, Patras); Bastiaansen (TU Eindhoven); Reece (Shanghai Inst. Of Ceramics, China); Gillin (Sichuan Univ., Fudan Univ. China); Pugno (Northwestern. Brown, MIT); Drew (Sichuan Univ., China). The group has over 100 industrial links, either through FP7, KTA or TSB funded collaborative programmes, or through direct industrial funding, many of which through Nanoforce.

Awards: Contributions of materials researchers returned in UOA13B have been recognized through prizes and awards incl. Reece (Verulam Award, IOM3, 2010); Busfield (Sparks-Thomas Prize, American Chemical Society, 2010; Colwyn Medal, IOM3, 2009); Peijs (Dutch Polymer Award, Polymer Technology Netherlands, 2008; Swinburne Medal & Prize, IOM3, 2010); Titirici (Desty Award for Innov. in Separation Sci., Royal Inst. London, 2010); Dennis (London Furusato Award, Japan Soc. Prom. Sci., 2009) and Binions (Advanced Materials Letters Scientist of the Year, 2010). Busfield was also awarded a National Teaching Fellowship in 2009 from the HEA.

Fellowships: More than 20 per cent of academics returned in this UOA have held individual fellowships during the period: Drew (Leverhulme Early Career Fellowship; ERC Fellowship); Pugno (ERC Fellowship); Trachenko (EPSRC Advanced Fellowship); Azevedo (Marie Curie Outgoing Intern. Fellowship); Binions (Dorothy Hodgkin Fellowship, Royal Soc.); Reece (Industry Fellow of the Royal Soc.).

Leadership in the Academic Community: Six MRI staff returned in UOA13B are current members of the EPSRC Peer Review College (Binions, Drew, Dunn, Dunstan, Trachenko, Reece). Staff are reviewing for NSF, Depts. Defence and Energy (USA), NSERC (Canada), DFG (Germany), SNSF (Switzerland), FCT (Portugal), AERES (France), FWO (Belgium), STW and NWO (Netherlands). Peijs, Pugno, Resmini, Titirici and Azevedo provide significant leadership within the European Commission as invited panellist for calls under FP7. Experimental researchers are active on facilities governing bodies (Dove, Drew, Dunstan), while Dove is also chair of the STFC Futures Advisory Panel and a member of the STFC Science Board.

Journal Activities: Staff in this UOA have the following journal activities. Reece is the Editor-in-Chief of 'Adv. in Appl. Ceramics: Structural, Functional and Bioceramics' (Maney Publ.), while Peijs has been recently appointed as the Editor-in-Chief of the newly formed journal 'Nanocomposites' (Maney Publ.). Becer is an Associate Editor of 'Frontiers in Biomimetics' (Nature Publ.), Busfield is an Associate Editor of 'Plastics Rubbers and Composites: Macromol. Engn.' (Maney Publ.) and of 'Rubber Chem. Techn.' (ACS). Editorial Board memberships are held by Titiricy (ChemSusChem, J. Nanoscience); Busfield (J. Rubber Research); Becer (RSC Polymer Chem., Click Chemistry), Barber (MRS Conf. Proc.), Baxendale (Int. Mat. Rev., Mat. Lett.). Peijs is an Editorial Board member of 11 journals in the field of polymers and composites incl. 'Composites Sci. and Techn.' and 'Composites Part A'. Pugno is on the Editorial Board of 41 journals, incl. 'J. Adhesion' and 'BioNanoScience'. Dunstan has been the Guest Editor for a special issue of 'High Pressure Research', while Peijs has been Guest Editor for 'Polymers' for a special issue on electrospinning.

Conference Activities: Staff in this UOA were involved in numerous conference activities. Some examples are: Peijs was the elected chairman and organiser of the 2008 Gordon Research Conf. (GRC) on Composites (Ventura, USA), which for the first time in nearly 35 years attracted the maximum (150) allowable attendees; Busfield is the chairman of RubberCon2014, a global rubber conference with an anticipated audience of 300 delegates, and is the President of the European Conf. on the Constitutive Modelling of Rubber (2011, 2013), typically attended by 200 delegates. Trachenko was a programme chair at the American Ceramic Society conference in St. Louis (2011) and a symposium organizer and programme chair of the meeting in San Diego (2013). QMUL hosted two conferences, 2013 European High Press. Res. Group Conf. (EHPRG51) with 200 attendees (Dunstan) and the 4th Spins in Organic Semiconductors conference (SpinOS2012) with 150 attendees (Gillin). Over the period members of this UOA have also given 35 keynote presentations and over 100 invited talks at international conferences, incl. Gordon Research Conf. (Peijs, Bushby), Falling Walls (Pugno), American Chem. Soc. (Busfield, Becer), Graphel (Pugno), MIP (Resmini), SpinOS (Gillin, Drew), Adv. Sim. Techn. Total Scatt. Data (Dove), DFG (Gillin, Drew), APS (Drew), MRS (Bushby, Drew, Peijs), E-MRS (Barber, Dunn), IUPAC Macro (Becer, Peijs), and High Polymer Conf. (Peijs).