Institution: University of Sheffield

Unit of Assessment: 13C - Materials Science and Engineering

a. Overview

The Department of Materials Science and Engineering (MSE) is one of the largest centres for materials research in the UK (38.9 FTE Cat A staff), internationally recognised for its research excellence, and supported by £39.5 M spend in the REF period from a balanced portfolio. We collaborate with 114 commercial organisations, 19 government agencies and charities and 111 academic institutions world-wide, across the defence, environment, health, energy and transport sectors. Recognising the increasingly interdisciplinary nature of our research, we have realigned our research structure within three core clusters of excellence, to enhance collaboration:

- **Advanced structural materials:** metallurgy, nuclear materials and surface engineering.
- **Functional materials and devices:** ceramics, magnetics and nanoengineering.
- **Biomaterials and polymers:** biomaterials & tissue engineering and polymers.

MSE incorporates and leads 8 University Research Centres, enabling broad internal and external multidisciplinary collaboration within research hubs. These are: the Immobilisation Science Laboratory; Institute for Microstructural & Mechanical Engineering: The University of Sheffield (IMMPETUS); Mercury Centre for Innovative Materials & Manufacturing; Centre for Advanced Magnetic Materials & Devices; Ceramics & Composites Laboratory; Centre for Biomaterials & Tissue Engineering; Leonardo Centre for Tribology and Surface Technology; Sorby Centre for Electron Microscopy.

b. Research strategy

1. Forward vision and research strategy

Our overarching mission was established with our founding role in the modern University: to advance the great industries of the region, and beyond, through science and engineering. ***Our forward vision*** is to achieve research excellence, innovation and impact, as an internationally leading Materials Science & Engineering Department, translating fundamental knowledge into products and industrial practice, through collaboration with end users.

Our strategic research ambitions are concomitant with our three clusters of research excellence:

- *Paradigm manufacturing for nuclear futures*: To create a world first capability in manufacturing nuclear materials for fusion and Generation IV fission applications, through co-creation with systems architects (including the Culham Centre for Fusion Energy) and building on the platform of our internationally esteemed capability in metallurgy and nuclear engineering.
- *Future proofing materials resource efficiency*: To create novel functional materials, nanomaterials and devices by combining materials discovery with simulation and design for applications addressing socio-economic and sustainability challenges across the information technology, energy, healthcare and environment sectors. We will foster new cross-disciplinary capabilities working with end users such as AVX Ltd, European Thermodynamics, Faradion, Johnson Matthey.
- *Regenerative medicine to transform patient care*: To enhance strategic research in biomaterials and regenerative medicine, emphasising clinical delivery, addressing patient needs and commercial openings, establishing new translatable programmes underpinned by integration with novel approaches combining experiment and modelling (virtual physiological human). New capabilities will be established in partnership with end users (e.g. NHS, JRI, Philips, Xiros).

To drive this vision forward we aim to appoint high-level research chairs in each of these key areas collaborating, where appropriate with external funding bodies and partner organisations. These appointments will be charged with driving, growing and leading strategic initiatives within MSE, the Faculty and beyond: extending “best with best” research alliances, facilitating collaboration to foster innovation and impact, in particular with USA, Europe, Brazil, China, Japan and India.

2. Evaluation of progress against plans described in RAE 2008

We have exceeded our strategic plans in RAE 2008, as outlined against specific commitments below, and MSE continues to flourish as a multidisciplinary environment of research excellence:

We have won large research grants to maintain and establish centres of research excellence; highlights include: leadership of the £6.3M Advanced Metallics and £7.0M E-futures DTCs, and co-leadership of the £7.1M Nuclear First DTC; investment of £5.1M by ERDF to establish the Mercury Centre for Innovative Materials and Manufacturing; three EPSRC Large/ Programme Grants to support strategic, world class research: £4.6M for IMMPETUS (2nd renewal), £3.5M for CCL (1st renewal) and £5.4M for hard-soft interfaces in biomaterials; two highly competitive ERC grants: €2.5M Advanced

Grant for surface engineering research, €1.5M Starter Grant for cement materials; investment of £800k by NDA and RAEng to create a Research Chair to provide leadership for nuclear materials activity.
We have strengthened our research at the life sciences interface; through appointment of 3 new academic staff, as highlighted in § c.1. Additionally, the appointment of Haycock to a Personal Chair provides long-term continuity of leadership in this research field.
We have appointed full time research support staff on open ended contracts; Lowrie and Highett as Business Development Managers, to increase grant capture from the commercial sector.
Reaching beyond RAE 2008 objectives*,* we invested in 3 academic positions, enhancing key research strengths: Holland (Lecturer, now EPSRC Early Career Fellow) in biological polymers; Goodall and Jackson (both now Senior Lecturer) in metal foams and machining of aerospace alloys. Leadership in cement chemistry was consolidated by recruitment of Provis to a Personal Chair.
Additional expansion of our research space accommodated our growth in research capacity. MSE now occupies an extra 550 m^2 of space, a 9% increase, supported by investment of >£350k.

3. Mechanisms and practice for promoting vitality and sustainability of research

MSE's Research & Innovation Committee (RIC) oversees research strategy, engaging in: scrutiny of new appointments and research investments; group research strategies; horizon scanning and foresight activities. The RIC is chaired by a Department Director for Research & Innovation (DDRI), it reports to the Department Executive Committee, and is supported by our Industrial Advisory Board. RIC has promoted vitality and sustainability of research in the REF period by:

- A Research Pipeline, managed by the DDRI, to stimulate, prepare and support research proposals, leading to 381 applications and 204 successful outcomes; our success rate with EPSRC applications improved from 27% to 39% over the REF period.
- A Departmental Strategic Reserve Fund was created, through provision of an MSE operating surplus (~£250k p.a.), enabling matched funding of, or sustainable investment in: research Fellowships; start ups; studentships; equipment upgrade / purchase; networking opportunities.
- Arrangements to return 10% of overhead to PIs on grants exceeding £1M, enabling staff to pump prime new research and receive recognition of success.
- Research away days (2 p.a.) to facilitate collaborative grant proposals; red lining weeks (2 p.a.) providing staff with an opportunity to focus exclusively on research outputs and proposal writing.

We promote a research culture amongst our staff through: Department research seminars (~25 p.a., 25% by international speakers); refurbishment of MSE social space for informal discussion and display of highly acclaimed outputs; allocation of staff time within our Workload Allocation Model to engage with learned societies, reviewing, and research community activities. Additionally, MSE benefits from 9 FTE research support staff of the Faculty of Engineering Research & Innovation Hub (FERIH).

4. Research achievements since 2008

4.1 Structural Materials. Highlights include:
Metallurgy. Reconstruction of high temperature deformation structure of Ti alloys to explain micro-structural origins of dwell fatigue cracking in gas turbine discs, applied in TIMET production schedules; understanding of shot peening mechanisms of Ti alloys for gas turbine discs led to changes in Rolls-Royce's production schedule; models for strain induced precipitation in steels, implemented by Tata.
Nuclear materials. Ground breaking research on glass dissolution mechanisms led to change of UK geological disposal concepts to accommodate vitrified intermediate level wastes; heat transfer models showed viability of the deep borehole disposal option, leading to world-first uptake in national disposal strategy by the Obama administration; innovation in glass formulations and processing was exploited by Sellafield Ltd. to change site strategy and apply thermal treatment process to plutonium wastes.
Surface engineering. Vacuum and liquid plasma diffusion hardening processes for duplex systems, with unrivalled tribo-contact performance, impacting aerospace bearing designs (Airbus and Wilksch Airmotive); plasma process (including liquid plasmas) and metallurgical developments to control grain size and phase composition leading to replacement of toxic coatings and new metal-on-metal and metal-on-polymer biomedical implants (Corin, Keronite, Plasma Coatings Group and Poeton).

4.2 Functional Materials & Devices. Highlights include:
Functional ceramics. Discoveries include: new ferroelectric and oxide-ion conducting materials; novel memristor behaviour in mixed ionic-electronic conductors; new electric & magnetic phenomena in RE-doped $BiFeO_3$. We designed new piezoelectric and microwave dielectrics for commercial applications in high temperature actuators and antennas (with Sarantel, Powerwave, Morgan Advanced Materials); and developed new atomistic simulations of the defect chemistry of $BaTiO_3$ confirming our oxygen-loss

and rare-earth doping model used to induce semiconductivity in commercial $BaTiO_3$ (with AVX Ltd). ***Magnetic materials.*** Modelling of bulk Nd-Fe-B magnets resulted in improved properties and their inclusion in Toyota hybrid vehicles; leading the development of new hard disk recording techniques (with Seagate), understanding of exchange biased hard drive sensors (with Hitachi) and the introduction of novel nanowire memories; pioneering new technologies using magnetic fields from nanowires to control magnetic particles, cells and ultra-cold atoms.
Nanoengineering. World-leading Basic Technology nanorobotic devices for real-time nanotesting of nanosized engineering components enabled nanoscale quantification of mechanical, electrical and magnetic properties, including powders (Unilever, Atomising Systems), functional nanowires (U. Lanzhou), MEMS components (QinetiQ); new 3D/4D imaging techniques; new capability in understanding 3D spatial metrology of nanoparticles and 2D/time atomic resolution tracking of surface atom dynamics using aberration-corrected TEM/STEM; nanoscale dopant mapping in Si (Carl Zeiss, FEI, Cambridge; Harvard) now applied to organic photovoltaic characterisation (Southampton).
4.3 Biomaterials & Polymers. Highlights include:
Biomaterials. Advances in biodegradable scaffolds for delivery of corneal cells for treatment of corneal diseases (clinical delivery through hospitals in India); regeneration of complex and challenging tissues, including peripheral nerve; ability to isolate and culture Schwann cells from adult tissue, never before achieved; novel 3D scaffold processing techniques for neural scaffolds and nerve repair with Xiros; advances made in novel biophotonic tools, aiding chemical and structural characterisation of tissues; world-leading simulations explained morphology control by proteins and self-assembled monolayers giving new insights into biomineralization and biomimetics.
Polymers. Discovery of the first nanoscale liquid quasicrystals, opening a new field of research; creation of the first highly ordered liquid crystal-directed superlattices of metal nanoparticles and new principles for building self-assembled metamaterials; development of metre-scale self-sensing and self-healing composite panels for Airbus; development of highly durable adhesives for wigs, enabling Mandeville of London to manufacture new off-the-shelf products; application of group interaction modelling for property prediction of polymer deformation, with US Air Force.

c. People, including:

1. Staffing strategy and staff development

Our ***staffing strategy*** during the REF period consolidated previous growth of academic staff (from 20.6 to 38.4 Cat A FTE in RAE 2008), through targeted appointments to renew and enhance our world leading research capabilities. MSE incorporates 38.9 FTE, of whom 34.8 FTE are submitted for REF 2014. 13 Cat A staff were appointed during the assessment period, with 9 Cat A staff retiring or departing to promotions elsewhere, 4 staff elected to move to part time contracts (to support childcare). We strengthened our capability in biomaterials, metallurgy and nuclear materials, exceeding expectations of our RAE 2008 forward strategy, (see §b.4.2). Our ***recruitment strategy*** has focused on attracting leading early career researchers to Lectureship positions, bringing creativity and vitality to established research themes, and developing this talent as future discipline leaders (see below). Of our 13 new appointments since 2008, 8 were Lecturers. All those appointed pre-2012 have been promoted to Senior Lecturer. All appointees have attracted significant external research funding: e.g. £1.5M EU, £836k EPSRC, 5 KTPs, 32 studentships, 6 personal Fellowships and £617k from various industries and funding bodies. This strategy enabled strong growth in annual research expenditure, from £4.5M p.a. to £7.9M p.a. over the REF period. At lectureship level: Goodall and Jackson expanded capability in metals processing, to foams and machining, respectively; Dean, Hayward and Rodenburg, brought new capability in multiscale simulations, electromechanical devices, nano-magnetic devices, and nanoscale imaging and manipulation, respectively; Claeyssens strengthened tissue engineering capability; whilst Holland expanded polymer expertise to natural materials. At Senior Lecturer: appointment of Chong, Chen, and Whittle strengthened and diversified our research in biomedical, nano-composites and nuclear materials research, respectively; whilst Rehman, as Reader, enhanced leadership in biomedical materials. Additionally, we invested in new leadership of cement chemistry, recruiting Provis, a world recognised authority in geopolymers, to a Professorial position. We not only focus on recruiting staff of the highest intellectual calibre, research excellence and leadership merit, but also on agile multidisciplinary capability to stimulate research success beyond extant specialisation. Examples: Goodall, expertise in processing of metal foams applied in biomedical materials; Freeman, expertise in computer modelling of condensed matter, applied to organisation of biological systems.

Our ***staff development strategy*** promotes a culture of research excellence, through a supportive framework of staff review, workload management, reward and promotion. ***All new appointments*** are supported through investing our own resource in provision of high quality research space, allocated PhD studentships, soft start up funds and other requirements (£277k over the REF period), and no-cost access to Department facilities (e.g. electron microscopy) (typical value £20k / appointment). Newly appointed early career staff engage in a ***formal probation process*** to launch them on the path to leadership. Through engagement with a personal mentor, and cohort based training, an understanding of the expectations of academic excellence in research, teaching, management and professional partnership is developed. We support our staff to aspire to meet demanding but realistic targets for research outputs, grant capture, impact delivery, teaching, and administration. Our success is demonstrated by an average grant capture of ca. £150k p.a., and 3.8 ISI outputs p.a., for staff completing probation during the REF period, and examples of significant achievement: leadership of a £1M EPSRC UK / US consortium project (Whittle), €1.5M ERC Starting Grant (Provis) and €770k EU Accelerated Metallurgy project (Goodall). We cultivate and retain the leaders of tomorrow; e.g. Hyatt, Inkson and Todd, all new appointments in RAE 2008, were appointed to the Professoriate.

Our ***Staff Review and Development System*** supports staff in career development and planning of academic goals, with a focus on ambitious research. Success is measured by formal review against key performance indicators designed to manage progression and build a track record for promotion. A ***workload allocation model*** moderates duties across MSE, recognising personal strengths and career ambitions, and giving research leaders reduced teaching loads to focus on strategic initiatives (e.g. Hyatt as RAEng Chair; Reaney as Leverhulme Senior Research Fellow), secondments (Matcher to Michelson diagnostics for 6 months, with an RAEng Secondment Award; Travis to NNL for 3 months with EPSRC KTA award), or sabbatical (e.g. MacNeil, 4 months 2010-11; Reaney, 12 months 2008-9). We reward success, emphasising research excellence, by ***promotion*** to senior grades by evaluation against clear but demanding criteria, including research metrics, with benchmarking and international peer review for promotion to Reader or Professor. 8 staff were promoted to Senior Lecturer and 7 to Reader, 6 staff were appointed to the Professoriate. Key to our staffing strategy is cultivating and enhancing leadership skills through the Sheffield Leader programme (Todd, Rainforth, Sinclair, Hyatt).

Our research staff form a vibrant, motivated community, fully engaged in all aspects of our staffing strategy. The CROS survey showed real satisfaction with our support for early career researchers: 77% agreed that they are integrated into MSE's research community and 82% felt enabled to take ownership of their career development. We have instituted a pipeline approach to supporting aspiring and talented researchers in the submission of competitive Lectureship applications and Fellowship proposals. In the REF period this initiative supported appointment of Freeman and Rodenburg to Lectureships, and award of Fellowships to Hayward, Holland and Corkhill (see below). Contract research staff are developed through the 'Think Ahead' programme of skills training and career mentoring. Additionally, our flagship initiative, 'The Sheffield Crucible', established with an investment of £160k, provides 3 intensive residential workshops focusing on: public and policy engagement, networking and collaboration, and innovation and enterprise. The HR Excellence in Research award (European Commission, 2012) signifies that MSE has a high quality research environment for ECRs and is aligned with the 7 Principles of the UK Concordat for the Career Development of Researchers.

Fellowships. Our research environment is enriched by the significant number of personal research fellowships, won in open competition. *3 research fellows are currently on tenure track*: Holland (EPSRC Early Career); Hayward (EPSRC Career Acceleration); and Corkhill (Vice Chancellor's Fellow). *4 tenured staff completed fellowships during the REF period*: Allwood (EPSRC Advanced, 2005-9; Reader); Jackson (RAEng, 2005-10; Senior Lecturer); Claeyssens (EPSRC Postdoctoral, 2005-09; Senior Lecturer); Rodenburg (Dorothy Hodgkin, 2006-11; Lecturer). *3 staff held Fellowships within MSE, prior to promotion elsewhere*: Hrkac (Royal Society, 2009-12); Zhang (EPSRC Advanced, 2004-09); Calvert (Dorothy Hodgkin, 2006-11). All staff completing Fellowships progressed to tenured positions (exc. Calvert, retired). Additionally, Hyatt holds a Royal Academy of Engineering Research Chair; Reaney held a Leverhulme Senior Research Fellowship (2008-09). Early career fellows are mentored by experienced academics and supported to develop their research groups and competing for research grants: Holland, Hayward and Corkhill are all investigators on research grants.

Equality and diversity. MSE is committed to equality of opportunity, and promotes the University's *Excellence Through Inclusion Strategy* and *Female Academics' Progression Action Plan*. Inkson, as Director for Equality of Opportunity, led a comprehensive strategy to increase representation and

progression of female academics, recognised by an Athena Swan Bronze Award. The Successful Women in Materials (SWIM) group was established, as part of this strategy, to provide peer support in career and leadership development. This approach has proven successful in attracting and appointing candidates from a diversity of backgrounds, and 4 of our 13 staff appointments were from overseas. We support staff by enabling working parents and carers to adopt flexible hours and part-time contracts, with 4 Cat A and 5 research staff holding such part time positions. Staff returning from maternity leave may access funds of up to £10k to support research [text removed for publication].

Visiting & Emeritus Scholars. Our research environment is enriched by contracted support of 10 Visiting Professors and 3 Visiting Lecturers (e.g. from CEA, Tata, Philips), plus 9 Emeritus Professors and >40 *ad hoc* visiting academic scholars. For example, our research in deep borehole disposal of radioactive wastes, which forms an Impact Case Study, benefited directly from leadership and strategic vision of Gibb (Emeritus Professor from 2009; member of Government Committee on Radioactive Waste Management 2007-12) and Chapman (as Visiting Professor from NAGRA, since 2005).

2. Research students

We recognise the significant contribution that Postgraduate Researchers (PGR) make to research output. We have achieved sustained growth in PGR numbers during the REF period, with the ratio of PGR / academic FTE increasing from 3.1 to 4.1. Simultaneously, we maintained a healthy balance of 63% home and 37% overseas PGR students, supporting a vibrant multicultural research environment. Growth of our PGR base was supported by an apportioned award of £9.1M for 5 Centres for Doctoral Training (CDTs); growth in the proportion of externally funded studentships (including iCASE); and investment of £593k of MSE resource in PGR scholarships.

A key influence on development of our approach to PGR training was the award of 5 EPSRC CDTs: Advanced Metallics (£6.3M) and E-Futures (£7.0M), led by MSE; Nuclear First (£7.1M), a partnership with Manchester University; Nuclear Engineering (£4.6M) and Tissue Engineering & Regenerative Medicine (£7.0M), as members of partnership consortia. Institutional resource to support CDT creation included: £398k to refurbish study space; £150k of Roberts funding for skills development; plus £3.7M for additional studentships; we also appointed a full time learning technologist. Each CDT delivers a challenging 4 year programme of scholarly, research, and professional skills development designed to launch PGR students on the path to career leadership. We offer elements of the DTC programmes to all MSE PGR students, enhancing their quality of experience. EPSRC rated the Nuclear First and Advanced Metallics DTCs as “superb” and exemplars of “best practice” at mid-term review. Nuclear First was described as “an exemplar internationally” in evidence to the House of Lords Select Committee inquiry on Nuclear R&D and won a “Highly Commended Award” from the Energy Technologies Institute in 2012. The quality and innovation of MSE CDTs led transformation of the institutional PGR offering, with an Engineering Graduate School created to foster cohort based training. MSE is a leading partner in two new collaborative EPSRC CDTs, Next Generation Nuclear and Integrated Tribology, announced in November 2013 (indicative budgets of £5.7M and £4.2M).

The MSE PGR Committee (which includes student representation) deals with all aspects of student recruitment, training and progression. We tailor the training experience of all PGR students through an early appraisal of personal development needs embodied in a personal Doctoral Development Plan, with targets for personal, academic and professional skills development, subject to six monthly review. The PRES/PGRQA survey demonstrated >94% of PGRs were satisfied with supervision arrangements (above sector and institution average). To improve completion rates we have introduced a more rigorous supervision and monitoring framework: each student has two supervisors, formal meetings on a minimum monthly basis. Student progression involves a written report and viva voce by two independent assessors each year. Students who do not progress as expected are supported to develop a remedial action plan, with enhanced monitoring of subsequent progress.

We promote a culture of aspiration amongst our PGRs, encouraging and supporting participation in competitive events leading to recognition of research excellence. 3 MSE PGRs were awarded EPSRC Doctoral Prize Fellowships (in 2010, 2012, 2013). Our PGRs have received numerous external prizes for research in the REF period, exemplars include: Jon Squire as a team member, winning the First Prize of Engineering Young Entrepreneurs Scheme, and IChemE Chemical Engineering Project of the Year, in 2012; Feng Liu**,** 2009, Chinese Government Award for Outstanding Self-financed Students Abroad ($5,000); and Rossukon Kaewkhaw 1st prize poster TERMIS-EU, Grenada, 2011 (€1000).

d. Income, infrastructure and facilities

1. Income

MSE has internationally leading research in each of its three research clusters, supported by a balanced funding portfolio (in the assessment period 204 grants awarded of value £39.9M: Charities: £3.15M; EU: £9.17M; Govt: £4.6M; industry: £4.72M; overseas: £611k and RCUK: £16.9M). In addition, we have received £9.1M (apportioned) income from the 4 CDTs. The grant income is spread between large grants (e.g. IMMPETUS (£4.6M), CCL (£3.5M), Hard-soft interfaces (£5.4M), Mercury (£5.1M), ERC (£2M)) and a plethora of smaller grants. Annual research expenditure increased from £4.5M p.a. to £7.9M p.a. over the REF period, with total expenditure of £39.5M. Our diversity of income, as a Department, and within research groups, reflects our multidisciplinary culture and provides us with agility to respond to changing market demand, RCUK strategy, and funding priorities.

2. Provision and investment in specialist infrastructure and facilities

We have taken a strategic approach to investing in key facilities that will allow an expansion in research activity as well as that to ensure the "well found laboratory". Equipment purchase was funded from a range of sources: Industry: £277k, RCUK £1,376k, EC £2,678k, Royal Academy of Engineering £33k, Royal Society £11k, and other sources £152k. Additionally, MRC Regenerative Medicine Capital Funding of £750k was awarded to support tissue engineering research. Internal funds of £1.1M have been used for equipment purchases and related expenditure. 368 m^2 of additional space in the Kroto Research Institute and Bioincubator was secured for expansion of biomaterials and polymer research; 140 m^2 of study space was refurbished for our DTCs; and the Turner Museum was refurbished as a focal social space for MSE (120 m^2). ***Overall equipment expenditure was £5.6 M, and £3M was spent on updating specialist facilities and infrastructure as summarised below.***

Nuclear Materials Laboratory: A complete refurbishment of the Nuclear Materials facilities is currently underway, providing enhanced capability to handle radioactive materials (ca. £1M, completion 2014). Distinctive in the academic sector, this will provide specialist facilities for radiomaterials science in controlled and supervised areas (e.g. using MBq DU, 100 kBq ^{99}Tc [text removed for publication]); dedicated equipment and glove boxes for processing cements, glass, ceramics (to 1800^{o}C), characterisation by BET, AFM, ICP-OES, Ion Chromatography, Mossbauer & γ-spectroscopy, TGA/DSC, liquid scintillation. Unique UK facilities: single pass and anoxic dissolution set up; Hot Isostatic Press for radiomaterials.

***Mercury Centre for Innovative Materials and Manufacturing*:** We have completely refurbished our Quarrell laboratory to house this prestigious centre which is now one of the largest University-based metals processing facilities in Europe, benefitting from a £3M investment in industrial scale processing equipment, Additive Layer Manufacturing (3x Arcam Electron Beam, Renishaw Laser), electron beam welding (Probeam), Spark Plasma Sintering (FCT), Aerosol jet deposition, extensive melting facilities (argon arc, vacuum), hot rolling; complementing our world leading thermomechanical test laboratory, which allows laboratory simulation of all forms of industrial hot metal working. Associated mechanical test facilities have been refreshed with purchases of impact testing machines and tensile testing.

The Sorby Centre for Electron Microscopy was inaugurated in its new high specification (£1.3M) site, comprising a doubling of space to 550m^2, with investment in 3 SEMs, 1 TEM. The Centre offers outstanding facilities: 7 SEMs (including ultra-high resolution), 2 FIBs and 5 TEMs. The Faculty boasts a world leading 300kV cold FEG double aberration corrected TEM, 0.05nm resolution.

NanoLAB Centre has created unique facilities for *in-situ* nanoscale electro-mechanical testing and nanotomography in the FIB/SEM and TEM. A unique *in-situ* TEM Tribology facility enables real-time nanoimaging of Friction/Tribology, together with TEM nanoindentation, SEM/TEM nanoelectrical testing, nanorobotics drives for nanoparticle manipulation, nanoprobe fabrication, and energy-filtered SEM imaging. World-class 3D/4D tomography capability includes the first 360° rotation and translation TEM tomography holder.

Functional Materials Laboratories now boast new specialist facilities including: Spark Plasma Sintering and tape casting for processing of bulk and thick film ceramics (enabling prototyping of multi-layer actuators/ capacitors, solid oxide fuel cells, and other devices); state of the art instrumentation for Raman spectroscopy and fabrication and characterisation of magnetic thin films and nanostructures (including ultra-high resolution lithography, multi-source sputtering/evaporation deposition, high speed/high spatial resolution magneto-optical instruments and magnetoresistance capabilities).

Kroto Research Institute and Confocal Imaging facility now has leading facilities to integrate biological analysis with scaffold material synthesis, processing and characterization (e.g. polymer synthesis, 3D laser stereolithography, inkjet printing, electrospinning, plasma polymerization, SIMS,

XPS, goniometry, cell culture suite (for human and animal primary, stem and cells lines with integrated HTA license), histology suite, protein analysis, RNA analysis, bioreactors, biomechanical suite with physiological flow system). Unique facility for parallel 2-photon, confocal, and TReM microscopy.
Computational facilities: Beowulf clusters (480 nodes) with technical support and benefit from the N8 high performance computer (Polaris; Sheffield 1/8 share) supporting substantial usage of HECToR.
The Research Centre in Surface Engineering: now houses a range of plasma-assisted coating equipment, including: 2 Tecvac PVD machines, one with 2 EB vapour sources, 2 large magnetrons and integral vacuum furnace, another with 4 independent EB sources for high-rate deposition; a remote RF plasma sputtering system to deposit loosely packed powder materials, and two unbalanced magnetron machines one with species energy/ mass analyser (all with reactive gas feedback control and pulsed/DC power modes). A plasma immersion ion implantation system was also refurbished.
Composite Systems Innovation Centre (CSIC) and Polymer laboratories: now has specialist facilities for synthesis, processing, characterisation and testing of polymers and polymer composites, including: twin-screw extruder, injection moulder, hot presses, a freeze-drier, an electrospinning system, an autoclave, cryomills, pre-preg, wet lay-up pultrusion, and vacuum bagging facilities, a melt flow indexer, mechanical testing facilities, a dynamic mechanical thermal analyser, a rheometer, and a varifocus X-ray beamline for small / wide-angle and grazing incidence diffraction.
Materials characterisation laboratory, newly equipped with: Thermal Conductivity Analyser, Differential Scanning Calorimeter, Thermogravimetric Microbalance, Particle Size Analyser, Gas Pycnometer, High temperature X-ray Diffractometer, ion lithography, cryogenic magnetic system. The XRD suite benefits from a new high temperature diffractometer, adding to the high resolution transmission-mode STOE diffractometers with position sensitive detectors for accurate determination of the unit cell and quantitative phase analysis using Rietveld refinement.

3. Access to shared and central facilities

Our multidisciplinary research demands access to state of the art shared equipment and facilities, including: 10% allocation of EPSRC funded £2.5 M ebeam lithography equipment hosted at Leeds University; £3M of access to STFC facilities (e.g. DLS, ISIS, SuperSTEM); 60,000kAu computing time awarded and used on HECToR (value £1.0M); >30 days at overseas facilities (e.g. SINQ, APS).

4. Future investment

Current financial forecasts indicate we will recruit at least 3-4 additional staff in the next assessment period, targeted against our strategic initiatives outlined in §b.1, and we aspire to attract and retain internationally leading appointments. We will continue to invest in PhD studentships, supporting the vitality and sustainability of MSE and the national research base (£1M forecast to 2018). Current or planned equipment expenditure from internal funds exceeds £3M to 2018. To deliver our ambitious strategy, and expansion of research capacity, we aim to increase our research space by at least 10%. Space within the Hadfield Building and Kroto Research Institute will be released by relocation of: teaching labs to the New Engineering Building, providing 19,500 m^2, through investment of £84M; and consolidation of postgraduate activities in the Engineering Graduate School, providing 5355m^2, through investment of £19.7 M. Additionally, we will refurbish 700m^2 of space for functional materials and polymer research within the Hadfield building in 2014/15, through further investment of £4.5M.

5. Future income plans

Our future funding plans are tailored to deliver the ambitions outlined in §b.1. Through strategic and targeted growth of staff and capability, balanced across our three research clusters, we expect to grow our overall research income significantly. MSE has a high success rate in RCUK (39%) and EU (68%) applications, which shows the excellence of our applications. We therefore aim to increase the number of applications per staff member, without compromising quality, to increase our substantial market share of EPSRC income (3rd in the UK for mainstream materials departments). MSE recognises and welcomes the paradigm shift in EU funding strategy in Horizon 2020, coupling research to innovation and market, with a strong focus on materials engineering to meet societal challenges. We will utilise the newly appointed EU funding specialist within FERIH to assist us in targeting substantial growth of our EU portfolio in the next period. Our clear and focused Impact Strategy now provides a platform to grow and expand our commercial research income, through more effective strategic and targeted engagement with end users. At the heart of our approach will be a mission to develop selected high value end-user strategic partnerships. Across all income streams we will maintain a focus on securing large/programme grants to support sustainability of research clusters, whilst supporting vitality and diversity of research through medium scale funding. We will also place special focus on supporting

aspiring early career staff in First Grant and Fellowship applications, through proactive mentoring.

6. Knowledge transfer and professional services

We strongly encourage knowledge transfer and consultancy activities as a mechanism for working with end users to achieve research impact. Collectively we achieved 136 consultancy activities since 2008, total value >£417k, incentivised by low overhead and streamlined contracting. Building on consultancy, end users often engage us in larger scale and more ambitious knowledge transfer research through KTP, KTA and direct sponsorship, yielding income of £3.1M, £634k and £4M respectively since 2008.

e. Collaboration or contribution to the discipline or research base

1. Collaborative & Interdisciplinary research.

As summarised in §a, we have focused our research groupings within three major clusters to foster enhanced interdisciplinary collaboration; examples in MSE include: Freeman/Todd on DFT applied to high entropy alloys (Nature Materials, accepted); Haycock / Allwood on magnetic trapping of Schwann cells (BB/F015844/1). Collectively, MSE published collaborative research with >150 organisations, across 53 countries, with >800 ISI publications: >300 outputs with 32 UK universities; >350 outputs with 79 international universities; and >160 outputs with 42 non-academic organisations worldwide. MSE led collaborative research involving UK and international partners supported by leadership of >60 grants and partnership on >30 grants with a focus on research collaboration. MSE also supports collaboration by staff sabbaticals / secondments (§ c.1) and PDRA / PhD secondments to translate research. Exemplars of the scale and reach of collaborative and interdisciplinary research are:

- The Institute for Materials and Mechanical Process Engineering: The University of Sheffield (IMMPETUS) is a multidisciplinary institute integrating physical metallurgy, mechanical and systems engineering to advance the processing of metals. With ~£5M EPSRC support, the research strategy was integrated with that of 28 industrial companies (e.g. Tata Steel, Timet, Rolls-Royce, Airbus). The project yielded 372 publications (197 journal papers, 158 conference papers and 5 editorials) and was presented at 91 conferences. In addition, IMMPETUS hosted two international conferences: 4th International Conf. on Thermomechanical Processing of Steels and Recrystallisation & Grain Growth IV. 36 PhD students completed; >50% of completed students were recruited by industrial partners.
- Harding leads an EPSRC programme grant, “Hard-soft matter interfaces” (EP/I001514/1, £5.3M plus £3.4M leveraged contribution), involving 10 investigators, 35 early stage researchers,16 international collaborators, including 6 UK institutions (Sheffield, Leeds, York, UCL, Warwick, Cambridge) and 6 overseas universities (in Denmark, USA, Germany, Netherlands, Australia). This world leading consortium has developed new understanding of the biomineralization processes; to date: 20 journal publications, 28 invited talks, 8 international symposia organized, 3 media presentations.
- A collaborative project on nano-ceria, EPSRC (with Bath, Cranfield), and NSF (Florida state) has enabled us to model and characterise surfaces at atomic resolution (Co-P.I. Moebus, EP/H0001298, £269,979; total EPSRC £817,085). Differences of surface dynamics on various active surface facets and particle shape dependence are amongst the key results, DOI: 10.1021/nn2037576.
- Ungar led the ESF funded SCALES project involving 6 EU institutions, pioneering polyphilic liquid crystals for constructing complex 2d and 3d structures in soft matter (05-SONS-FP-024, 2007-10, €2.1M). 31 collaborative publications, including Zeng et al. Science 331 (2011) 1302.
- Sinclair is CI on an EPSRC Programme Grant, "A Coordinated, Comprehensive approach to Carbon Capture and Utilisation" (EP/K001329/1, £4.5 M) involving 10 investigators and 21 early stage researchers across 4 UK institutions (Sheffield, Manchester, QUB and UCL).
- MSE is strong in collaborative CDTs, working in bilateral / consortium partnership to deliver doctoral training in metallurgy, nuclear fission and tissue engineering in 3 CDTs and 1 IDC. We exploit the combination of unique expertise and facilities to provide the very best research training experience, e.g. collaborative PhD combining micro-spectroscopy and soil chemistry expertise to demonstrate remediation of DU contaminants at MOD Eskmeals DOI:10.1016/j.jhazmat.2013.08.013.

2. How research collaborations have informed research activities

An Industrial Advisory Board informs MSE research strategy, giving expert guidance on development of our research capacity and capability, to meet future end user needs. Major MSE initiatives benefit from external advisory boards (EABs), engaging end users to shape the strategic research aims and maximise translation and uptake. Advised by its EAB, the Immobilisation Science Laboratory approached NDA and the Royal Academy of Engineering to establish a Chair in Radioactive Waste Management, unique in the UK. Strong engagement led to >80% of PhDs funded and co-supervised

by industry, and uptake of research by Sellafield Ltd. Direct collaboration with end users influenced our strategy and activities by identifying, growing and exploiting opportunities for mutual benefit. Working with and funded by the European Cosmetics Agency (an industry consortium), Haycock and MacNeil developed a 3D in vitro human skin model for allergy testing as an alternative to animal testing.

3. Participation in advisory, funding, professional, learned or standard setting bodies.

- ***18 staff are/were members of 36 international advisory, funding or standard setting bodies***, including: MacNeil- International Advisory Board for Australian Centre for Collaborative Research in Chronic Wound, and Swiss NRP Stem Cell Committee; Rainforth- External Adviser in Research Assessment Exercise for Materials Department, Monash University, Australia; Provis- Member of the Peer Review Advisory Board, Center for Nanoscale Materials, Argonne National Laboratory.
- ***6 staff were members of 7 RCUK advisory boards***, including: Rainforth- EPSRC Technical Opportunities Panel; MacNeil- MRC Stem Cell Translation Committee, Harding- EPSRC Strategic Advisory Team for the Physical Sciences, Reaney- EPSRC Mid-Range Facilities Advisory Panel.
- ***4 staff were members of commercial, industrial, or government advisory boards***, including: Palmiere- Industrial Advisory Group, NPL; Tsakiropoulos- Yorkshire & Humber Advanced Engineering and Metals Advisory Panel; Inkson- Professional Consultancy Committee for Imaging Solutions Centre at Harwell; Hyatt- Review Group for the ad-hoc Nuclear R&D Advisory Board.
- ***12 staff hold leadership roles on (inter)national advisory groups,*** including: Rainforth- President, Royal Microscopical Society; Matthews, Board of Directors of the Society of Vacuum Coaters, SVC (USA); Provis- Chair of RILEM Technical Committee, and Inkson- Chair of the EPSRC UK NanoFIB Network; Todd, Chair of British Standards Institution Committee on Additive Manufacture.
- ***25 staff are/were members of 32 committees of 16 learned societies or professional groups***, including: Freeman- Executive Committee of CCP5; Allwood- IOP Magnetism Group Committee; Moebus - RMS Committee for Electron Microscopy.

4. Conference organisation and programme chairs. MSE supported the delivery of >100 national and international conferences, symposia and other meetings, as members of organising committees or advisory boards. Exemplars include: Palmiere, Recrystallization & Grain Growth IV, 2010 (in Sheffield), 2012; Rainforth-Wear of Materials 2009 & 2011, Reaney- International Symposium on Applied Ferroelectrics, 2010. Also, MSE staff chaired > 170 conference sessions.

5. Invited and keynote lectures. MSE staff gave >380 invited lectures, including 51 keynote / plenary presentations at conferences and meetings. Exemplar keynotes: Tsakiropolous- EuroMat, Spain, 2013, Hyatt- British Embassy, Japan, 2012; MacNeil- European Conference on Biomaterials, Ireland, 2011; Ungar- 6th IUPAC International Symposium, China, 2010; West- International Conference on X-ray & Neutron Scattering, Malaysia, 2009; Haycock- The Royal Society, London 2008.

6. Externally funded fellowships. Full details are given in §c.1 & §c.2.

7. Awards prizes and honours. Prestige honours: West, RSC John Goodenough Prize 2013, Matthews, IOM^3 Gold Medal 2011; West, IOM^3 Griffith Medal & Prize 2008, Notable awards: Provis, RILEM Robert L'Hermite Medal 2013; Wynne, IOM^3 Harvey Flower Prize 2012; Hyatt, IOM^3 Pfeil Award 2012;Dean & Allwood, Kroto Prize for Science Education 2008. Matthews elected to Fellowship of Royal Academy of Engineering. 4 staff elected as Fellows of: IOM^3 (2), RMS (2), HEA (1). 9 staff elected as new members of learned societies.

8. Peer review activities.16 staff members of RCUK peer review colleges and 25 staff acted as peer reviewers for RCUK. 27 staff peer reviewed for 43 international sponsors, e.g. Moebus, Agence National de Recherche; Harding, National Science Foundation; Provis, Australian Research Council. 8 staff provided peer review to 11 other sponsors, e.g. Reilly for Wellcome Trust. 3 staff peer reviewed international programmes, e.g. Tsakiropoulos, Research Assessment Exercise, University of Oulu.

9. Expert evidence. 6 staff gave expert evidence to 13 inquiries or consultations; e.g. House of Lords Science & Technology Committee, Nuclear R&D (Hyatt) and Regenerative Medicine (Haycock).

10. Journal editorships etc. 8 staff are (associate) editors for 10 journals, 14 staff serve as members of 25 Editorial Advisory Boards (EABs), 11 staff were as guest editors for 14 special issues / publications; examples include: Rainforth, Editor, Journal of Microscopy; Allwood, Board, Journal of Applied Physics D; Reilly, Journal of Biomechanics, special issue on bone tissue (v.44, 2011).

11. Visiting Appointments. 8 staff hold 10 visiting chairs (8 overseas); e.g. Reaney, Pennsylvania State, USA; Ungar, Seoul National University, Korea; Rainforth, Graz Technical University, Austria. 3 staff hold visiting research positions at overseas organisations. Hyatt is Senior Visiting Fellow, National Nuclear Laboratory; Ungar is a Distinguished Foreign Expert, Zhejiang University, China.