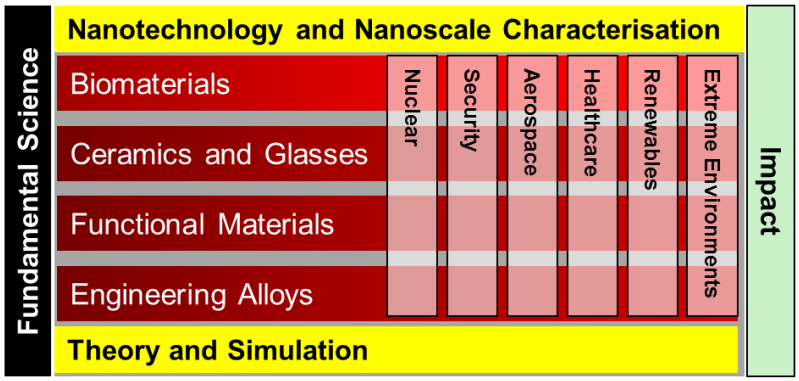
Institution: Imperial College London
Unit of Assessment: 13B Metallurgy and Materials
a. Overview

Aim: Over the REF period the Materials Department's aim has been to expand its scope and to focus on quality. We appointed 18 new academic members of staff, doubled PhD numbers, more than doubled PDRA numbers and tripled our research spend. Our prospects for future sustainability are excellent, with a strong pipeline of secured research funding for 3 years at least, and a current grant portfolio of £59.3M.



We achieve scientific and engineering leadership across the whole remit of contemporary materials science: from atoms to cells as building blocks and from structural integrity to stimulated emission of radiation in application. The success of our strategy is evidenced by the fact that the College is now placed 5th in the world for the Materials discipline (QS rankings 2013).

Structure: The Department is a vibrant and exciting place in which to work and there is well-developed sense of shared purpose. The Department's six research themes are Engineering Alloys (EA), Ceramics and Glasses (C&G), Biomaterials and Tissue Engineering (BTE), Nanotechnology & Nanoscale Characterisation (N&NC), Theory and Simulation of Materials (TSM) and Functional Materials (FM), with activities in all themes covering a range of commercial sectors shown in the vertical boxes in the figure. Crucially, TSM and N&NC, rooted in fundamental science and engineering, underpin the research in all the themes. The Department has evolved from primarily a metallurgy and mining department to an interdisciplinary Department of Materials, a centre of excellence in all areas of the discipline. All academics are active in two or more of the themes, reflecting the wide-ranging nature of materials science. The Department of Materials is located in 6,000m^2 of recently refurbished, contiguous, high-quality space. It is one of the nine departments in the Faculty of Engineering and is the hub for College-wide research in materials science. **All academic staff from the Department are being returned to REF:** 37 academic staff (34 FTE) and three independent researchers to UoA 13B and joint appointees Haynes and Mostofi to UoA 9 (Physics).

b. Research Strategy

The Research Vision

The long-term vision of the Department, as first set out in RAE2008, remains to:

- Deliver world-leading research and scholarship in all areas of Materials Science and Engineering.
- Maintain and grow a creative and supportive environment where research students receive first class training, postdoctoral researchers develop independence and all staff realise their full research potential.
- Position itself as collaborator of choice for industry and academe both nationally and internationally.

The Research Committee, with representation from the six research themes, sets and delivers the Department's research strategy, reviewed each year at the Departmental Away Day (held off campus and attended by more than 90% of the academic staff) and at the annual meeting of the External Advisory Panel (see section e.). To achieve its research aims the Department has undergone significant expansion over the REF period as illustrated by the data in the table below.

Research Objectives for 2008-2013

In the discipline of Materials Science and Engineering, where world class research needs access to state-of-the-art facilities, a critical number of excellent academic staff is required in all themes to generate a creative research environment and to provide the funds to purchase, maintain and utilize cutting edge instrumentation.

Success in delivering the Vision: table indicating growth of the Department since RAE 2008

	RAE 2008	REF 2014
Staff Returned (FTE)	27	37
Research Income	£18.4M	£47.6M
PhD Awards	75	157
Average Journal Impact Factor (JCR 2011) of Submitted Outputs	6.2	8.2
% Submitted Outputs in Top Quartile Journals (JCR 2011)	77	95
	July 2007	**July 2013**
PDRAs	40	84
PhD Student Body	100	150
Fellowships, including Marie Curie	7	26
Research Officers and Technicians	13	19
Income per academic staff FTE pa	£154K	£349K

The strategic objectives of the Department over the REF period have been to:

Introduce Functional Materials: a new theme to develop activity across the entire discipline

In RAE 2008, the Department returned five themes, with activity across all length scales but with limited work in the area of Functional Materials. We expanded our expertise in FM appointing two professors, Professor Klein from Juelich with expertise in electromagnetic nanomaterials and Professor Roger Whatmore FREng, previously CEO of Ireland's Tyndall National Institute, bringing particular expertise in ferroelectric materials. We also appointed five staff including two Royal Society URFs (Oxborrow, Stingelin, Mattevi, Moram and Xie) to complement Alford and Heutz who were both appointed in 2007. This new group of academics has rapidly established the Department as a leading centre in the field of FM, illustrated by its success in obtaining funds to support its emerging research activity: two EPSRC programme grants, Active Plasmonics with the Department of Physics - £4.5M, Energy Materials - £3.9M, one Platform Grant of £0.9M and 2 EPSRC grants to develop the room temperature Maser (one Manufacturing Fellowship and one Critical Mass responsive mode – total value £2.3M), an ERC Starting Grant (£1.2M), a Leverhulme award (£0.95M), a new EPSRC Electron Beam Epitaxy Facility (£0.72M) to develop new device materials, three EPSRC awards to develop technologies based on graphene and related two-dimensional materials (£3.2M) and shared activity in the CDT in Plastic Electronics.

Ensure critical mass in all themes creating a stimulating environment for research

To evolve the five established themes the Department has recruited strategically and developed funding stability. This has enabled teams of researchers to secure large-scale projects and work with greater flexibility and creativity.

- **Engineering Alloys**: The theme has been strengthened at all levels by the appointments of Dunne, Qin, Wenman, Gourlay and Britton to complement Dye and Shollock. Professor Dunne FREng, formerly at the University of Oxford, was appointed in 2012 to a Chair in Micromechanics as well as Director of the Rolls-Royce Nuclear University Technology Centre. Members of the group have recently won an EPSRC Programme Grant (total value: £5M) on Heterogeneous Mechanics in Hexagonal Alloys, which aims to create a step-change in our understanding of such alloys and advance British manufacturing of products formed from such materials.

- **Biomaterials and Tissue Engineering:** During the REF period, Dunlop and Weaver (Lecturer, deceased 2012) were appointed to work alongside Stevens, Jones and Porter in this theme. We have also recently appointed Dr Theoni Georgiou, a polymer/bio-scientist who starts in January 2014. This theme remains extremely successful: two Challenging Engineering grants, MRC Regenerative Medicine Hub, funding from i4i (Dept Health) as well as Wellcome, BBSRC and industrial project funding to a total current value in excess of £12M. The team has expertise in tissue engineering, biomaterials and regenerative medicine.

- **Ceramics and Glasses:** Activities in this area span from structural ceramics to conducting oxides. Kilner and Atkinson along with Skinner established a highly successful conducting oxide group that led to a successful spin-out, Ceres Power. In 2008, a £5.5M grant from the EPSRC, spearheaded by Lee and Vandeperre, created the Centre for Advanced Structural Ceramics (CASC), specialising in characterisation and high temperature processing and the modelling of ceramics. Saiz, formerly of Lawrence Berkeley National Lab, and Giuliani were recruited to the

Centre and a new EPSRC Programme Grant (£5M), "Materials in Extreme Environments", with Loughborough and QMUL and the ERC BioBone European consortium on Bioceramics (£3M) led by Professor Saiz have begun. The Department continues to be recognized as world leading in the area of ionic conducting ceramics, with four Marie Curie International Fellows choosing to undertake their research activity in this group. Dr Ainara Aguadero was appointed lecturer in 2013 strengthening our activities in solid state ionics and batteries.

- **Nanotechnology and Nanoscale Characterisation:** Two early career lecturers have been appointed to reinforce this theme: McLachlan and Payne. Substantial EPSRC support has been awarded to obtain instruments to characterise at the nanoscale: a TOF-SIMS LEIS system (McPhail, £2.3M) and an Ambient Pressure Photoelectron Spectrometer (Payne, £1.2M). The applications of nanomaterials in photovoltaics has been a major activity in the REF period with Professors Ryan and Riley attracting over £1.8M of government support (TSB Technology Programme, EPSRC Grand Challenge, EPSRC SUPERGEN).
- **Theory and Simulation of Materials:** Staff numbers in this theme are buoyant with all three RCUK fellows appointed in 2007 being awarded permanent lectureships (Mostofi, Tangney, Horsfield). There is strong leadership in the theme from Professors Finnis, Grimes and Haynes. The group simulates materials at length scales ranging from the electronic to the macroscopic, maintaining leadership by continuously developing new simulation methods and software. The TSM theme underpins research across the Department, providing insight into properties and processes for metals, functional oxides, high temperature ceramics, nanostructured materials, organic molecules, elastomers and combinations thereof. The TSM theme is strengthened by the College's Centre for Doctoral Training on TSM (£6.4M EPSRC funding) directed by Professor Peter Haynes, a joint appointment between Physics and Materials, as well as by their participation with the Thomas Young Centre (of which Finnis is deputy-director).

Establish diverse range of income to support strategic research activity across all themes

In the 2008 RAE, the panel noted correctly that "*research income per FTE was lower than might be implied by the research environment but […] that this was probably related to the large proportion of new staff."* Over the REF period the Department's research spend has increased significantly, now standing at £349K in comparison with £154K per FTE per annum for RAE 2008. To increase our research portfolio, we grew our funding from RCUK and the European Commission and developed new funding streams with industry. The Department was selected as partner in the field of Materials by the King Abdullah University of Science and Technology (KAUST) in Saudi Arabia. As well as providing $15M for collaborative research activity, KAUST donated $10M to the Department which has been placed in the College Investment Fund. The interest and capital are available to support strategic departmental investment in research activities and will ensure financial sustainability in the future. To date, the investment of this fund has returned £1.77M which has contributed to our refurbishment programmes and PhD student scholarships. Strategic spend of funds generated by the Department in the REF period is detailed in section d.

Over the REF period there has been a very strong emphasis on increasing the quality of research outputs with active involvement by the Research Committee and theme leaders. The success of our strategy is evidenced by the significant increase in the quality of our research outputs, with 95% of papers submitted to REF published in journals ranked in the top quartile for their discipline (JCR 2011), cross reference 77% in RAE 2008. We note that Imperial is ranked top in "Advanced Materials & Nano Technology" in the recent Witty Review 2013.

Published research highlights include:

- Room temperature MASER: World's first demonstration of solid state, room temperature, Earth's field maser (*Alford Nature* 2012).
- First report of cell-specific differentiation in engineered bone (*Stevens Nature Materials* 2009).
- Novel polymer semiconductors by nucleation for transistors (*Stingelin Nature Materials* 2013).
- Spintronics with molecular semiconductors (*Heutz Nature* 2013).
- First accurate determination of the bandgap of indium phosphide (*Payne Phys Rev Lett* 2008).
- First determination that single-walled carbon nanotubes are non-toxic (*Porter ACS Nano* 2009).
- Development of nanoparticle cancer therapy capable of mimicking the transendothelial migration of leukocytes, now taken up by industry (*Chiappini Nature Nanotechnology* 2013).

Future Strategy: Having completed its transformation from a Department with a strong emphasis on metallurgy to a Department of Materials Science and Engineering with a breadth and depth comparable to the top institutions in the world, our key strategic aims for the future are to:

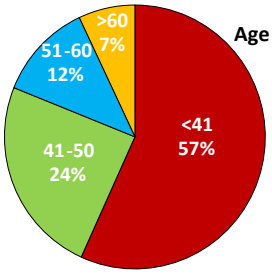
- Support fully the range of activity in all themes. In August 2013 we filled 3 new lectureship positions (Ceramics, Nano and Bio) with activities across all our themes to ensure continued sustainability and expansion of our portfolio.
- Develop the leadership potential of our staff. The expansion in staff numbers has resulted in a young, dynamic department (see data in section c.). We recognise that it is essential that the individuals recruited in the REF period are given every opportunity to develop their potential and become leaders in their chosen fields of expertise and we proactively encourage this with mentoring, support and workshops.
- Ensure that our instrumentation continues to allow our staff to undertake cutting edge research. To remain at the forefront of the discipline of Materials Science and Engineering, we will continue to purchase and develop instrumentation to allow researchers to fabricate materials and study their performance *in-situ* and *in-operando*.

c.I People, including: Staffing strategy and staff development

The **key priorities** of our staffing policy are to attract a diverse community of the highest calibre staff; to develop the potential of staff at all career stages; and to foster a stimulating environment befitting world-class research and teaching. The interdisciplinary nature of the subject has led to six joint appointments: Finnis, Haynes, Tangney and Mostofi with the Department of Physics, Giuliani with Mechanical Engineering and Stevens with Bioengineering.

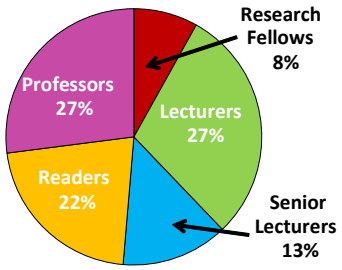
Staff Profile

From 2005 to RAE 2008 the UoA grew from 17 to 27 academic staff and now stands at 40 (37 FTE) 57% of whom are under the age of 40 (see pie-charts). Our recruitment continues the trend commended by the 2008 RAE panel: *"The sub-panel noted that the UoA had been in transition, effectively re-building itself over the assessment period and that a large number of very good appointments had been made."* We have a very good track record of appointing independent research fellows to permanent academic positions with 9 such appointments out of a total of 18 in the REF period.



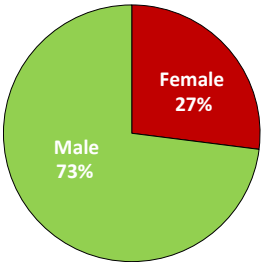
Recruitment of Academic Staff

The quality and quantity of applications for academic vacancies has grown considerably over the REF period: we now receive more than 100 applications for each advertised vacancy. The interview process is rigorous and highly selective comprising presentations, meetings with students and RAs and a final panel assessment with academics. Feedback is obtained from across the Department before any offers of appointment are made. Our ability to recruit excellent staff is demonstrated by the fact that 61% of staff recruited to academic posts in the assessment period presently hold competitive fellowships, some transferred on appointment and others obtained post-appointment.



Development of Early Career Academics

We ensure that new staff can develop their research programmes by a reduced teaching (<25%, our average lecture load for a full-time academic is 32 hours per annum) and administrative load, typically ramping up to a full load over three years. A start-up package includes funds to purchase consumables and, before a first grant is won, new capital equipment up to £140K (OJEU limit) being provided, a PhD student and unlimited access to the Department's facilities at no cost. All new academics attend training courses in Teaching and Learning, PhD Supervision and Personal Tutoring and, through their academic mentor (a senior academic working in the theme) and the Director of Research, are provided with guidance on applying for funding and managing research output. 81%



Profile of Returned Staff

of the new academic staff appointed between 2008-2012 have been successful with an EPSRC proposal as PI with the remainder finding success with other sources.

Staff Development and Promotions

The Head of Department carries out annual appraisals for all academic staff providing an opportunity to identify areas where support and training is needed, evaluate research plans, discuss promotion prospects and review applications for fellowship of learned societies. The College's Learning and Development Centre provides a suite of programmes tailored for the academic community including proposal workshops, mock interviews and scenario planning. Since RAE 2008 there were 8 promotions from Lecturer to Senior Lecturer, 8 promotions from Senior Lecturer to Reader and 2 promotions from Reader to Professor with no unsuccessful candidates.

Funded Research Fellowships

Of the 40 returned staff, 33% currently hold prestigious Fellowships, including EPSRC, Royal Society, ERC Awards and an AWE William Penney Fellowship. The Department has also obtained funds to endow the BCH Steele Chair in Energy Materials. In addition, we have 2 researchers who hold personal research fellowships that allow them to undertake independent investigations, 12 Marie Curie Fellows and one Imperial College Junior Research Fellow. These fellowships provide the brightest and best early career researchers from across the World the freedom to focus, for three years, on their research and career trajectory, with no obligatory teaching or administration. Over the REF period the Department has hosted 36 non-academic staff on personal research fellowships 25% of whom have been successful in obtaining academic positions within the Department.

Post-Doctoral Research Associates (PDRAs)

From July 2007 to 2013, the Department has more than doubled the number of PDRAs from 40 to 84. The career development of this cohort of PDRAs is a priority in the Department: RAs complete a yearly appraisal with their line manager and can also seek advice from Dr Natalie Stingelin, the Department's RA mentor. Dr Stingelin chairs the PDRA Committee, which meets quarterly to discuss relevant issues and organises an annual symposium featuring seminars and career development workshops. Our researchers' personal and career development, and lifelong learning, is supplemented by the work of the College's Postdoc Development Centre (PDC) which has implemented fully the 7 principles of the Concordat to Support the Career Development of Researchers and was awarded the European HR Excellence in Research Badge in December 2012. A tailored programme of support is provided to postdocs, ensuring they spend at least 10 days per year on professional development. The Department and the PDC provide bespoke skills and career development training including personal development programmes (some designed specifically for female staff) and a range of individual support, including coaching and mock interviews. The PDC also publishes a range of guides on postdoc issues and hosts the multidisciplinary Postdoc Representatives Network. The work of the PDC has been recognised within the sector, for example winning the "Outstanding Support for Early Career Researchers" at the Times Higher Education Awards 2008. Over the REF period PDRAs have left to academic positions at prestigious institutions including for example EPFL, Switzerland and NUS, Singapore.

Support Staff

The Department employs an excellent team of Research Officers (ROs), Technicians and Administrators to support its research activity and ensure RAs and academic staff maximise the time spent on research. The Department now has 9 Research Officers (6 in 2008) in computing, AFM, XPS, XRD, Thin Film Technology, electron microscopy and TOF-SIMS. To ensure sustainable support of our facilities, we have recently appointed a "roving" RO to develop skills on a range of facilities and cover leave. The ROs, most of whom hold doctorates, attend staff meetings and are central to the Department's research strategy, helping to develop, maintain and provide training on our central facilities. The research mission is also supported by a team of 9 technicians (7 in 2008) providing laboratory-based support for particular themes, specific instruments and our Department Engineering Workshop, which fabricates specialised items, at no charge to members of the Department. In light of its expanded research activity, the Department now employs the equivalent of 2 Research Administrators to help academics with the costing, administration and reporting on research programmes. This is in addition to the 3 administrators employed on Research Council funding to manage our major project grants.

Equality and Diversity - A Stimulating and Inclusive Environment for All

The Department is fair and open to all with a diverse staff and researcher profile in terms of nationality, race, age and gender. 10 of the 37 staff and 34 of 84 PDRAs are female. The Department actively engages with a wide range of initiatives that promote equality in the workplace. The Department was awarded Silver Athena SWAN status in 2010 in recognition of its support for women and the College achieved the Silver institutional award in 2012. The College's Elsie Widdowson Fellowships enable female academics to concentrate fully on their research upon returning from maternity/adoption leave by relief of teaching or administration duties. 3 academic staff from the Department held one of these fellowships in the REF period. The College has a nursery, classified as "outstanding" by Ofsted, which is used heavily by staff from the Department (currently 8 children of staff in the Department are in the nursery); we also operate a system of flexible working. The dedicated Equalities Unit operates support networks for staff from minority groups: iLead and Calibre are leadership programmes for black and minority ethnic and disabled staff respectively. HEFCE has supported the expansion of the former across a number of HE institutions. The College was also one of the first Higher Education Institutions to join the Stonewall Diversity Champion programme, designed to promote understanding and good practice around issues of sexual orientation in the workplace and in 2012 earned Two Ticks accreditation in recognition of its commitment to employ and develop staff with disabilities.

c. II. Research students

The total number of PhDs awarded in the REF period was 157 (75 in RAE 2008), or 1.2 students per annum per FTE. Of the students completing PhDs since 2008 approximately half have continued in academia and half have taken up positions with industry. Our PhDs have been awarded prizes at major international conferences, including for example the Lloyd's Science of Risk Prize for the best paper on 'Biological Risk' (Labbaf, 2009), the Graduate Student Award at the European Materials Research Society Spring Meeting in Strasbourg (Kim, 2012) and the Best Poster Award at TMS, San Antonio, USA (Belyakov, 2013).

Recruitment

Demand for our postgraduate research programmes is strong with an application to PhD start ratio of 6:1. All prospective research students are interviewed by two members of staff and a report submitted to the PG Recruitment Committee which comments on the individual's academic ability and motivation to study for a PhD. Where a student is seeking funding from the College Doctoral Training Grant, the individual is also interviewed by a member of the PG Recruitment Committee. The number of students recruited each year has increased steadily over the REF period, from 45 for academic year 2008-2009 to 59 for 2012-2013. 38% of the postgraduate students are female. The Department has an extremely diverse graduate population with 35% overseas students from over 20 countries including USA, Canada, Vietnam, Nigeria, Taiwan, Malaysia, Israel and China.

Student Support

Financial support for students comes from a variety of sources: for the 2012-2013 intake 28% were funded from RCUK (including CASE, DTA and projects), 29% from industry, 9% from CEC, 14% from College or Independent Scholarships and 21% self-funded. The Department supports student recruitment through two schemes: Materials Research Scholarships (5 per annum), which offer up to £6,000 each year to support overseas students who have won competitive scholarships that do not cover the full cost of study; and competitive Industrial Liaison Scholarships, which support up to 16 scholars, with matched funding from industrial sponsors. In addition, the Department provides a package of financial support (£1000pa) so that all PhD students are able to attend at least one international conference and can freely access departmental facilities irrespective of funding source. Students are also encouraged to organise their own social events, for which departmental funding is also available agreed through the staff-student committees.

Student Development and Progress monitoring

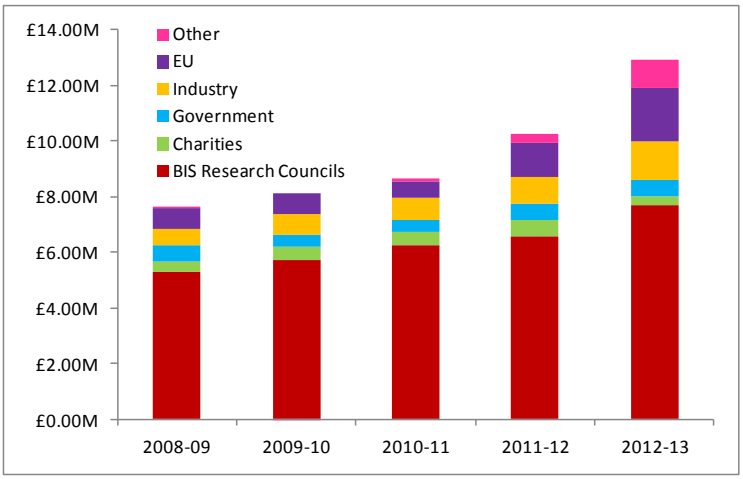
The Director of Postgraduate Studies is responsible for monitoring PhD progress with close cooperation from PhD supervisors, all of whom receive mandatory supervisor training. There are checkpoints at 3 months, 9 months (at which the student presents a report and research plan) and a progress review at the end of the second year. A finalisation report is required at the start of the third year. All students have two supervisors and, if they opt in, a mentor. The Postgraduate Tutor

chairs the Postgraduate Staff-Student Committee, organises the postgraduate research day, which is a full day of poster and oral presentations. PhD students are co-located with the RAs in research themed offices to aid mentoring and cohort building. The HoD meets with the PhD students every 4 months to provide an opportunity to discuss their concerns. In addition, the Graduate School provides an award-winning professional development programme that supports postgraduate students with specific emphasis on their future careers. Imperial is the only university to have won the Times Higher Education Award for Outstanding Support for Early Career Researchers twice: most recently for a course called "Finish Up, Move On", aimed at helping PhD students complete their PhDs and move on to the next stage in their careers. The Department's PhD provision was reviewed by the QAA panel (external membership) in 2011. The panel "were unanimous in praising the high quality of PGR provision in the Department". Data from 2007/8 until 2012/13 show 96% of PhD students completing their degrees within 48 months.

d. Income, infrastructure and facilities

Research Income

The Department's Research spend has grown significantly from £18.4M in RAE2008 to £47.6M in REF, a growth of 159%. A snapshot (Jul 2013) shows that our portfolio of current grants has a total value of £59.3M. The annual growth in expenditure is shown in the bar graph below. The 42 EPSRC grants led by Departmental staff have 25 different PIs. All themes hold major awards (see section b. for further details).



Equipment >£0.5M 08-13	£K
TOF SIMS LEIS	**1,700**
PLD, PVD, Nano Deposition	**1,232**
JEOL 2100F FEGTEM	**1,040**
Ambient Pressure XPS	**900**
Auriga *in-situ* FIB/FEGSEM	**800**
2500^{0}C Press, DSC/TGA	**750**
THz Analyser	**619**
Helios Dual Beam FIB	**600**
TEM, XRD upgrades	**550**
Total	**8,191**

Summary of research income over REF period and major equipment purchased

Equipment Purchases over the REF period

In addition to supporting the 100% increase in the number of RAs, our increased income has enabled us to invest in equipment supporting research in all experimental themes. Since 2008, over £8M of equipment over £500K has been purchased (see table above) in addition to more than £1M in smaller equipment items (over £10K in value). 44% of the total equipment spend has been funded directly by the Department, this includes £350,000 of support for purchases on EPSRC funded projects of equipment costing between £10K and the OJEU limit where a 50% contribution is now required. The proximity of the equipment, high levels of support and a new booking system ensure that all researchers can quickly access the facilities to produce excellent research. To support staff working in Theory and Simulation, the University has invested £5.05M in the REF period on its High Performance Computing facility, of which the Department of Materials is the highest user in the Faculty of Engineering (27% of total CPU time).

Equipment Sustainability

We have a superb track record in maintaining all our facilities and enabling equipment sharing. The College's TRAC committee sets the charge-out rates (directly allocated costs) for the Department's major capital equipment, the total renewal value of which is £12.4M.The facilities are operated on a College-wide basis and are available to users who contribute to maintenance and dedicated technical staff costs. The Department's facilities operating budget enables us to accommodate the servicing of large items of equipment beyond the period of any initial grant, with thorough management mechanisms in place. The cost of maintaining the equipment to the

Department is predominantly offset by income of £1.7M over the REF period (£167K per annum in 2008-09 to £400K in 2012-13) derived through allocated costs on grants, and industrial projects; a small proportion is absorbed by the Department. The Department has a policy that its PhD students can use the facilities free of charge if they lack appropriate external funds. The Departmental Facilities Committee sets priorities for spending on new departmental equipment, publishing an annual "Target Equipment List" of instrumentation required to keep our facilities World-leading. The Department currently budgets up to £400K and £700K per annum for maintenance contracts and instrument purchases respectively. In 2012 our major instruments were on average operational 94% of the time. In accordance with our strategy of providing world-class research facilities, the Department strongly encourages academics to apply for equipment funding and invests its own resources to ensure capabilities are enhanced across all thematic areas.

Infrastructure Spend over the REF period

To accommodate its expansion, the Department refurbished a total of 2700 m^2 of space in the REF period adding 16 new fume hoods at a total cost of £10.4M. 90% was spent on three major projects. First, new space for the Functional Materials experimental facilities (PLD, sputtering, e-beam, nanoparticle deposition, yellow room, nanolithography, MBE, FIB, ion mill) and Thomas Young Centre for Theory and Simulation of Materials was built using £2.5M SRIF funding, creating accommodation for 13 academics and more than 50 PDRAs/PhDs and successfully brings theorists and experimentalists into daily contact. Second, the redevelopment of the old workshop provided four academic offices, study space for 28 PhD students, 70 m^2 of laboratory space for the Centre for Advanced Structural Ceramics and a new machine shop with adjoining offices for technicians. Third, a large under-utilised workshop space was reconfigured to yield five new laboratories at ground level and two large lecture areas for postgraduate activities on a new mezzanine, funded by a Royal Society/Wolfson refurbishment grant and £3.2M of College funds. A second Royal Society/Wolfson award provided funds for the refurbishment of laboratory space for Fuel Cell research and £650K of College funding supported the creation of the Centre for Nuclear Engineering, additional space for the Department in which to co-locate researchers undertaking activity related to Nuclear Engineering.

Safety

The Department ensures that all research is conducted safely and regularly reviews its safety management systems, procedures and risk assessments. Every laboratory has been allocated a person responsible for safety, and monthly inspections of laboratories and facilities are conducted by the Head of Department and Departmental Safety Officer. In March 2012, the Department's safety culture and systems were praised in the College's Health and Safety Audit and over the REF period there were no major accidents or incidents.

Consultancies and Professional Services

The Department runs successful CPD courses in SIMS-LEIS and Structural Ceramics. It also draws upon the expertise of *Imperial Consultants*, a wholly-owned subsidiary of the College: staff completed 93 consultancy projects with a total value of £887K during the REF period. *Imperial Innovations plc* was established to combine the technology transfer, company incubation and an early stage venture-capital fund. During the REF period, the Department's staff have provided Imperial Innovations with 43 new invention disclosures which have resulted in 39 patent applications. Commercial licence agreements and realising shares in spin-outs gave the Department a total income of £1.9M over the REF period and a further $1M in consultancy fees from KAUST.

Future Investment Plans

The Department intends to continue its growth with a planned increase in research volume of £13.9M in 2013-2014 with 89% of the funding already secured. As in the REF period, funds will be sought to support research projects and the purchase of new equipment, with a focus on instruments that will permit *in-situ* and *in-operando* characterisation. Plans have been submitted to the College's project committee for the refurbishment of another 323m^2 of new space for research including the conversion of 100m^2 of existing space to a new lab. The Department plans to further diversify its research portfolio with a greater outreach to industry and to this end we have employed a Marketing Officer who is already designing a new Materials Gateway to showcase the best of our activities.

e. Collaboration and contribution to the discipline or research base

The contribution of the Department to the discipline of Materials Science and Engineering through the quality of its research output is outlined in the table. The 1038 papers written in the REF period by the returned staff have, to date, been cited **13,764** times.

	Total
Plenary, keynote and invited talks	657
Refereed journal papers	1038
Proceedings papers	139
Patent applications	39
Books and other publications	60
Prizes	38
Fellowships of Societies	54

External Research Collaborations

53% of papers published in the REF period had an international co-author and 37% had a national (non-Imperial) co-author. We have substantial collaborative research activity with European (324 papers) and US institutions (229 papers) but have also considerable joint activity with institutions in Australia, Japan, China, Saudi Arabia, South Korea, Canada, Brazil and Singapore. The institutions with which we jointly publish most include Cambridge (96), UCL (71), Oxford (63), LBNL (53), UC Berkeley (47), Warwick (39), QMUL (32), STFC facilities (30), Sheffield (28), UC Santa Barbara (24), LANL (23), ETH Zurich (22), and NPL (18). The joint publications with large scale facilities reflects the Department's substantial activities in materials characterisation, with £2.4M support for research at UK facilities in the REF period, £0.45M funding for experiments at European facilities and 131 days of access to non-European facilities. We receive International funding from the EU, NSF, NIH, US Army, USAF, Australia, Singapore and China. The Department is the Imperial Hub for the London Centre for Nanotechnology (LCN) and the Thomas Young Centre (TYC). The LCN is a joint activity with UCL. The TYC provides a hub for researchers in Theory and Simulation of Materials and includes Imperial College, UCL, Kings College London, Queen Mary University London and the Royal Institution. To support collaborative research the Department has hosted a total of 100 Visiting Academics over the REF period. TSM-CDT has supported placement/exchange students at MIT, EPFL, Paul Scherrer Inst, MPIE Düsseldorf, LLNL, UPenn. We have a Marie Curie IRSES network with the Department of Chemistry at Imperial and partners at Stanford, University of Montreal, Polytechnique Montreal, and Ecole Superieur in Aix-en-Provence. We are partners in CIMLAE (Centre for Innovative Manufacturing) with the Department of Physics at Imperial, Cambridge, Manchester and Swansea.

Research Collaborations within Imperial College London

Materials research at Imperial is enriched by strong interdepartmental collaboration, with the Department of Materials hosting joint appointments with Bioengineering (Stevens), Physics (Haynes, Mostofi, Finnis, Tangney) and Mechanical Engineering (Giuliani). Research activity across College is facilitated through its Research Institutes, and members of the Department have been able to expand their research activities through links with the Energy Futures Lab, the Institute of Biomedical Engineering, the Grantham Institute for Climate Change, the Institute for Shock Physics and the Manufacturing Futures Lab. The Department has also led in the development of the new Centres for Terahertz Science & Engineering, Advanced Structural Ceramics (CASC) and for Nuclear Engineering. The research centres and institutes provide a focal point for multidisciplinary activity - enabling training, funding and global partnerships for researchers and students.

Industrial Collaborations

The Department has relationships with many companies in the materials sector, which are renewed and reinforced through regular staff exchanges and recruitment of our students. We play key roles in the College-level strategic partnerships, e.g. with AWE, BP, EDF, Shell, British Energy, Rolls-Royce and BAE Systems. Amongst the organisations with whom we collaborated over the REF period are: CEA, ITU, SCK, ANSTO, Culham, CASL (Oak Ridge), BARC Nuclear Decommissioning Authority (NDA), EdF Energy, DSTL, Westinghouse, EPRI, AMEC, MoD, Ericsson, Morgan, Murata Manufacturing and Rio Tinto. Continued funding for the Corus/Tata RAEng Chair demonstrates their long-term commitment to the Department and the appointment of Prof Bill Lee as a William Penney Fellow with AWE is further demonstration of commitment. The Faculty's Corporate Research and Strategy team aids this and other interactions with industry and government agencies. Our External Advisory Panel meets annually with senior departmental academics. Its members are predominantly from UK and EC industry (Corus/Tata, Caparo

Industries plc, Rolls-Royce, Morgan Crucible Company plc, DSTL, NDA, Smith and Nephew, Shell) relevant to our research portfolio but with some EU (TU Delft), US (MIT) and UK (Oxford and Cambridge) university members; its remit is to advise us on teaching and research strategy. CASC and the Centre for Nuclear Engineering have active industry consortia and the TSM-CDT project partners are Rolls-Royce, DSTL, Culham Centre for Fusion Energy, BP, Baker- Hughes, Materials Design, Johnson Matthey, Argonne National Lab, US Air Force Research Lab, Element Six.

Advisory Roles

Highlights include: the appointment of Professor Grimes FREng as the Chief Scientific Officer at the Foreign and Commonwealth Office; the contribution of staff to government committees particularly in the nuclear sector where Grimes has given evidence to HMG Trade and Industry Select Committee on new nuclear build and advised the All Parliamentary Sub-committee on nuclear energy issues and Professor Bill Lee FREng is a member of DECC's Committee on Radioactive Waste Management; the selection of 15 staff for the EPSRC College; the appointment of Professor Alford FREng to the EPSRC Physical Sciences Advisory Team (SAT); selection of Dr Payne as adviser to the House of Lords select committee on scientific equipment; requests for our staff to review research proposals from UK funding bodies, EU programmes and national funding bodies from across the world including Australia, Singapore, and the USA. Dr Heutz is a member of MatSEEC (Alford was previously Chair), the Materials Science and Engineering Expert Committee of the European Science Foundation which had a role in formulating Horizon2020.

Contribution to Science and Engineering

In the past six years Professors Dunne, Alford, Lee, Grimes and Stevens have been elected FREng. Staff from the department hold a total of 54 fellowships of learned societies including IoM^3, RSC, IET and IoP. Many staff contribute to the activities of the learned societies, for example, Dr McPhail sits on the Council of IoP and Professor John Kilner received the 2012 Platinum Medal of the IoM^3 for his outstanding service to the institute. Professor John Kilner is also the European Editor of the *Journal of Solid State Ionics*, Professor Molly Stevens is an editor of *ACS Nano*, Dr Natalie Stingelin is editor of *JMatChemC*, Professor Neil Alford is an Associate Editor of the *Journal of the American Ceramics Society* and was awarded an MBE for services to Engineering. 16 staff serve on the editorial boards of journals. Professors Grimes and Stevens have acted as conference Chairs at the MRS (Boston 2011 and 2013) and 19 staff from the Department have acted as conference organisers at 87 national and international meetings.

Awards and Prizes

Academic leadership is also recognised through the awards and prizes won over the REF period including the Royal Society Clifford Patterson Prize (Stevens 2013), IoM^3 Griffith Medal and Prize (Alford 2008, Grimes 2010, Stevens 2012), Royal Society of Chemistry Norman Heatley Prize (Stevens 2010), IoM^3 Rosenhain Medal and Prize (Stevens 2010, Ryan 2011), the American Ceramics Society W. David Kingery Award (Lee, 2012), European Materials Society EU-40 Prize (Stevens 2012) and IoM^3 Harvey Flower Titanium Prize (Dye 2010). The potential of our new staff to develop as leaders is demonstrated by the award of IoM^3 Silver Medal (Heutz 2008, Gourlay 2010, Giuliani 2011, Moram 2012) and the American Ceramics Society Robert L. Coble Award for Young Scholars (Jones 2010). The Department's staff have also given prestigious lectures including the IoM^3 Finniston (Kilner 2008) and Ceramics Society Mellor Memorial Lecture (Lee, 2012), Clifford Patterson Prize Lecture (Stevens 2012), Wain Medal Lecture (Stevens 2011). Kilner and colleagues were the 2012 recipients of the International Union of Materials Research Societies Somiya Award for International Collaboration. In total over the REF period the Department's staff have given 83 Plenary and Keynote lectures at national and international conferences.

In Summary, over this REF period we have increased:

- Research income by 159% from £18.4M to £47.6M
- Staff numbers by 37% from 27 to 37 FTE
- PhD numbers by 109% from 75 to 157
- Journal impact factor from 6.2 to 8.2.
- REF publications in the upper quartile from 77% 2008 to 95% in 2013
- PDRA numbers by 110% from 40 to 84
- Research income per FTE per annum by 126% from £154K to £349K
- QS World ranking from 14th to 5th in 2013