**Institution:** University of Manchester

**Unit of Assessment:** UoA13a Metallurgy and Materials

## a. Overview

Research in Metallurgy and Materials Science at the University of Manchester (UoM) is centred on the School of Materials in the Engineering and Physical Sciences (EPS) Faculty. The School is the largest Materials department in any European University with an unrivalled breadth and depth of expertise, together with state-of-the-art facilities, the combination of which provides a platform for world-class research.

Research in the UoA is organised into five groups:

- Biomaterials
- Ceramics and Inorganics
- Corrosion and Protection
- Engineering and Process Metallurgy
- Polymers, Composites and Carbon

The interdisciplinary nature of our research is exemplified by 2 members of staff of the School of Computer Science being returned in this UoA along with 1 member of the Faculty of Medical and Human Sciences. A reflection of our strong research collaborations with life sciences is the joint appointment of *Tirelli* with the Faculty of Medical and Human Sciences and *Blanford* and *Saiani* having their principal offices and laboratories in the Manchester Institute of Biotechnology.

Highlights of the research achievements of staff in the UoA include:

- A major role in the discovery and isolation of graphene that led to the 2010 Nobel Prize in Physics
- The development of polymer microgels for the treatment of lower back pain, and of new biomedical implants for tendon repair and nerve regeneration
- A new environmentally-friendly anodising treatment for aluminium aerospace alloys
- Election to Fellowships: Royal Society (*Young*), Royal Academy of Engineering (*Sherry*)
- Queen's Anniversary Prizes: Dalton Institute (*Sherry*), New Imaging Techniques (*Withers*)
- Establishment of the Manchester X-ray Imaging Facility (MXIF)
- Establishment of the National Composites Certification and Evaluation Facility (NCCEF)

## b. Research strategy

The over-arching vision of the UoA is to sustain its position set out in the RAE2008 submission as "*An Integrated World-leading Research Provider of First Choice in Materials Science, Engineering and Technology*". The exceptional range of subject coverage in the UoA includes: *structural materials* (metallics, polymers, ceramics, composites, etc.); *functional materials* (biomaterials, nanomaterials, electronic materials, etc.); *materials performance* (corrosion and corrosion protection, structural integrity, stress and damage characterisation, etc.); *materials processing* (thermo-mechanical processing, composites, etc.). Whilst performing world-leading research in these areas, we aim to employ our skills and expertise to solve important multidisciplinary challenges. We also aspire to develop an exemplary record of knowledge transfer, to continue to perform significant public-engagement activities and to harness high-quality research capability to produce the best environment for postgraduate training. This vision is closely aligned with the research elements of UoM Manchester 2020 strategic plan, with progress assessed annually.

A key aspect of our research strategy has been to increase the quality and impact of our published outputs. We consider that research excellence should be reflected in an ability to publish in the best places, and for these publications to have impact on the discipline, as reflected in citations:

- To achieve this, the strategy has been to encourage staff to publish their best work in internationally-rated Journals, with the highest impact factors. This has resulted in staff in the UoA publishing in the assessment period papers in *Science* (3), *Nature Nanotechology* (4), *Nature Materials* (3), *Nature Communications* (3) and *Nature Physics* (2).
- Over the assessment period staff in the UoA have published in excess of 1,350 outputs (5/fte/year) that have received more than 13,600 citations with 15 of these papers already having >100 citations in the assessment period. A similar number of outputs received a total of ~7,200 citations in the equivalent period for RAE 2008.

**Research Groups**

In order to manage and promote research excellence, our strategy has been to organise our research activities into 5 overlapping research groups that give a comprehensive coverage of the subject area. Each research group is led by a senior academic (*indicated*) and all groups have sufficient 'critical mass' to impact upon their international research communities. Cross-fertilisation of ideas and collaboration are ensured by staff being associated with more than one group.

*Biomaterials (Tirelli)*

The strategy of this group is to cover the development of new materials extending right from their chemical synthesis to their medical use. A particular strength of the activity is our use of biological concepts to design artificial constructs and orient the behaviour of cells. The group has the following principal themes: *Cell and Tissue Engineering*; *Biomolecular Materials*; *Bioengineering*. Significant progress has been made since RAE2008 in the development of polymer microgels for the treatment of lower back pain, and of new biomedical implants for tendon repair and nerve regeneration that are now undergoing clinical trials.

*Ceramics and Inorganics (Freer)*

The strategy of the Ceramics and Inorganics group is to undertake research upon the processing, characterisation and applications of structural and functional ceramic materials, both in 'bulk' form and as thin/thick film coatings with the following principal themes: *Advanced Processing Techniques*; *Ceramics Advanced Characterisation Techniques*; *Electroceramics*; *Coatings*. There have been significant developments in the assessment period in the understanding the importance of dopants in multiferroic materials and in the fabrication of yttria-stabilized zirconia thermal barrier coatings for turbine blades.

*Corrosion and Protection (Akid)*

Research activities in corrosion and protection are diverse and range from development of new experimental approaches for material characterization, through mechanistic understanding of corrosion and inhibition processes, to advancement of sustainable protective surface treatments and coatings. The strategy has been to develop this expertise in collaboration with industrial partners and principal themes of this group are: *Corrosion Inhibition*; *Nuclear Materials*; *Oilfield Materials*; *Paints and Coatings*; *Surface Engineering*; *Localised Corrosion and Cracking*. Since RAE2008 there has been major progress in the production of new coatings for corrosion protection, including biomedical applications, along with the development of a completely new environmentally-friendly anodising treatment for aluminium aerospace alloys.

*Engineering and Process Metallurgy (Prangnell)*

There is a large and vibrant research activity in metallic materials within the UoA, encompassing all aspects of metals, alloys and metallic composites. Our strategy is for the research to extend from the very applied to the fundamental underlying principles, and it is supported by the use of simulations, modelling, and novel technologies and techniques. The main themes are: *Airframe, Aeroengine, and Transport Materials*; *Metal Forming*; *Joining and Friction Welding*; *Materials for Chemical, Process and Power Generation Industries*; *Phase Equilibria and Transformations*; *Stress, Damage and Failure Mechanisms*; *Thermomechanical Processing*. Significant progress has been made in the assessment period in the use of synchrotron radiation and neutron diffraction to study a range of phenomena such as the determination of residual stresses and the study of phase transformations in a variety of materials including Ti alloys, Zr alloys and steels. We have also helped to develop the first commercially-available bioresorbable magnesium implants.

*Polymers, Composites and Carbon (Young)*

The UoA has a large multidisciplinary research programme upon polymers, composites and carbon-based materials. Our strategy is for this to take place through fundamental studies of structure-property relationships of these materials, including controlled synthesis and processing, and effects of structure and nano-, meso- and macro-scale morphology on physical properties and engineering applications. The areas covered include: *Graphene and Nanostructured Materials*; *Composite Materials*; *Polymer Science and Engineering*. Since RAE2008 there has been a rapid growth in graphene research in the UoA including the use of high-resolution transmission electron microscopy for the atomic resolution of graphene structures, the fabrication of new graphene-based devices, the micromechanics of graphene-based nanocomposites and a completely new insight into the structure of graphene oxide.

**Future Strategic Aims and Goals**

The overall aim of the strategy for our research in the future will be to maintain our position as a world-leading provider in the field of Materials Science, Engineering and Technology. This will be undertaken through the following mechanisms.

*Investing strategically in research excellence.* Strategic investments will be made in both in people and the research environment. Future appointments will be made at lecturer, reader and professorial levels to reinforce areas of research excellence. The UoM will be undertaking the next phase of campus development over the next 6 years by co-locating all of the Engineering activities on a single site, enabling all of the elements of the School of Materials to be co-located and offering unparalleled opportunities for materials research (see detail in section d).

*Broadening the range of funding sources.* Our strategy will be to increase the income overall from the different research councils, develop new areas for EPSRC programme grants, have wider participation in EU projects and increase the proportion of industrial income further.

*Developing our strategic alliances and research collaborations.* The BP International Centre for Advanced Materials and our alliances with Akzo Nobel and EDF will be developed further and the opportunities that will arise from the National Graphene Institute will be exploited (see detail in section d). Further strategic alliances will be developed with multinational organisations as opportunities arise.

*Providing parity of esteem to translational research.* We will strengthen interdisciplinary research through strategic appointments and increase our involvement in knowledge transfer projects.

*Providing world-leading postgraduate research*. Our strategy will be to ensure that we have a thriving research student community by increasing engagement in Doctoral Training Centres and the further development of our 4-year PhD programmes.

**c. People, including:**

**i. Staffing strategy and staff development**

The UoA has a number of principles that guide its staffing strategy. In all appointment and promotion decisions, we seek: (i) to recognise and reward excellence; (ii) to maintain or develop critical mass in key areas; and (iii) to open up interfaces between existing areas of strength. To illustrate these principles in relation to new appointments: (i) our 9 new academic appointments have 100 publications in high impact factor Journals within the REF assessment period, thus demonstrating that they are already producing substantial research outputs at the highest level; (ii) our new appointments contribute to critical mass in areas of existing excellence for the UoA, in Biomaterials (*Blanford, Cartmell*). Corrosion and Protection (*Akid, Engelberg, Curioni*), Engineering and Process Metallurgy (*Jimenez-Melero, Lee*) and Polymers, Composites and Carbon (*Haigh, Vijayaraghavan*).

*Staff Training*

The UoA provides support targeted at early-career researchers, post-doctoral researchers and established academics, drawing on support from the EPS Faculty Researcher Development team. This includes over 70 training workshops and events each year, a collection of web resources and e-bulletins, and funding for researcher-led initiatives. The programme includes 5 key categories; Research & Enterprise, Communication, Career Management, Leadership and Management, and Teaching and Learning. For example, the 2011/12 researcher development programme included Project Management courses (leading to a Certificate in Applied Project Management), and the 2012/13 programme introduced a course on *Supervising for Researchers*. The EPS Faculty also provides all research staff with a Research Staff Handbook, and an annual Research Staff Conference provides up-to-date information and networking opportunities to research staff. During the REF Period, staff from the UoA participated in more than 500 hours of these training courses, in areas including project management, health & safety, equality and diversity, and leadership.

All new academic staff participate in the New Academics Programme, which involves around 50 contact hours over an 18 month period, and a collection of associated mentoring and development activities. The research elements include grantsmanship, managing a research portfolio, publication strategy, and postgraduate recruitment and supervision. In relation to knowledge transfer and impact, the programme also covers Intellectual Property Rights, collaborating with

industry, regional development and public engagement.

Over the assessment period 6 senior staff from the UoA participated in the HEADSTART Leadership Development Programme (Leadership Foundation for Higher Education) which offers a package of development support for those aspiring to more senior academic and administrative leadership roles in the University.

*Staff Career Development*
All newly-appointed academic staff are assigned a mentor and the mentoring culture is supported through the award-winning Manchester Gold programme, which is available to any staff member at the University. Staff are then mentored carefully through their probation period, usually of 3 years. The "An Academic Career" website, developed by the University of Manchester Careers Service is a comprehensive guide to working in higher education and was the winner of the Times Higher Education 2011 Award for Outstanding Support for Early Career Researchers. To review career development and plans, the University implements a Performance and Development Review (PDR) scheme for all staff, which includes a written preparation document, a one-to-one discussion, and an agreed written conclusion. In 2012/13 70% of research staff and 80% of academic staff from the UoA completed PDRs.

The UoM has developed an Implementation Plan to ensure full support for the Concordat to Support the Career Development of Researchers, and has received the HR Excellence in Research Award from the European Commission in recognition of this work. The University participated in the Careers Research Online Survey 2011 to find out the views of research staff and has incorporated the results into the Implementation Plan, especially through improving research staff representation on University committees. Faculty-specific Research Staff Handbooks have also been distributed, ensuring that all researchers are aware of this support.

The UoA also runs a sabbatical scheme enabling staff to concentrate on research for a semester or a year. During the period 2011-13, 5 staff have been on sabbatical (1 for a semester and 4 for a year), interacting with industry and visiting top international universities. For example, *Saunders* was involved with his spin-out company, Gelexir Healthcare Ltd, and *Bangert* spent a semester at the Ernst Ruska-Centre (ER-C) for Microscopy and Spectroscopy with Electrons in Julich. Academic Promotions Masterclasses are held annually. These sessions provide: an overview of the academic promotion route at the University, the role of School and the Faculty Promotion Committees, CV hints and tips (with the offer of 1:1 guidance), and academic promotions case studies. These have been attended by 9 staff from the UoA during the REF period.

*Research Fellowships*
The UoA strongly encourages early career researchers to take the opportunity to establish their research careers through fellowships, has both encouraged existing staff to pursue fellowships, and made longer term commitments to staff with fellowships. Competitive fellowships won by PDRAs in the UoA in the assessment period include:

- *Dr Riaz Akhtar*, British Heart Foundation Fellowship (2008)
- *Dr Rachel Saunders*, EPSRC Postdoctoral Research Fellowship (2009)
- *Dr Michele Curioni*, ERSRC LATEST2 Programme Grant Fellowship (2012)
- *Dr Christopher Race*, Dalton Nuclear Institute Research Fellowship (2013)

Additionally established academic staff have been successful in winning competitive Fellowships:

- EPSRC Career Acceleration Fellowship – *Blanford* (2008)
- EPSRC Leadership Fellowships – *Preuss* (2011), *Saiani* (2013)
- EPSRC Challenging Engineering Fellowship – *Kinloch* (2011)
- BP/Royal Academy of Engineering Chair in Corrosion & Materials – *Akid* (2012)

For all competitive Fellowships staff are carefully mentored throughout the process by senior members of the UoA and provided mock interviews organised by the EPS Faculty.

*International Appointments and Recruitment*
The UoA is a vibrant international research community, with significant representation from across the globe. For example, 50% of our research students, 60% of our research staff and 35% of our academic staff originate from outside the UK. Reflecting the strong international profile of the UoA, 4 of the 9 academic appointments made during the REF period attracted individuals from outside

the UK. Additionally over 50 of our PhDs and PDRAs have taken up academic positions overseas.

There have been many academic visitors to the UoA, most notably:

- Hokkaido University, Japan - Corrosion and Protection (Habazaki)
- USACH, Chile - Corrosion and Protection (Paez)
- Keio University, Japan - Electron Microscopy (Shimizu)
- Dalian University of Technology, China - Composite Mechanics (Lei)
- Xi'an Technological University, China - Corrosion and Protection (Li)

Staff in the UoA have held a number of visiting professorships abroad, most notably:

- Hong Kong Polytechnic University, Distinguished Chair at ITC (*Young*)
- King Fahd University, Saudi Arabia (*Young & Akid*)
- Ernst Ruska-Centre (ER-C), Julich, Germany (*Bangert*)

*Staff Equality and Diversity*
The University is committed to the advancement of equality in employment and career development for its staff. Equality data monitoring and action planning is therefore embedded into its annual performance reviews. This includes monitoring and identifying actions in relation to recruitment, current staff profile and promotion.

WiSET (Women in Science, Engineering and Technology), formed in 2005, is a network for all female students, technical, research and academic staff in the EPS Faculty. It is funded by the Faculty and aims to encourage more women to enter and develop careers in science, engineering and technology (SET). The Athena SWAN Bronze Award, received in 2008, demonstrates the ongoing commitment of the UoM to women's career progression in STEMM (science, technology, engineering, mathematics and medicine) academia. The School of Materials has also recently made an application for the Athena SWAN Bronze Award.

The University has a dedicated support service for disabled staff. For example a dedicated helper and specially-modified facilities were provided in this UoA for *Prof Porat*, who is visually impaired, until he retired in 2011. The University is one of a small group of institutions that is part of the Equality Challenge Unit's Black and Minority Ethnic (BME) Systemic Change Pilot and is undertaking career development initiatives in relation to recruitment and mentoring.

### ii. Research students

We see the development of the next generation of researchers as central to our mission. In line with the objective of the University to provide abroad-based research training, the UoA has been increasing its engagement in DTCs that provide four year programmes of research and associated activities. As a consequence the number of research students in the UoA has increased from around 180 in 2007/8 to 220 in 2012/13.

*Graduate Student Admissions and Support*
We have an Admissions Office that manages publicity and student recruitment. We seek to attract the highest quality candidates by advertising projects on www.findaphd.com, on our own web site, and in scientific journals. Applications are made online, and to ensure efficient processing of applications, during the REF period the School of Materials developed a web-based platform for distributing applications and collecting feedback to support efficient processing. All research students are interviewed (in person or by phone) and all applicants for the DTC programmes visit the University and are interviewed by a panel. We have thriving taught masters programmes with 5 specialised pathways that align closely with our research strengths (with 200 students in 2011/12), and we have been pleased to recruit an average of 20 students each year from our masters programmes into research degrees during the REF period.

The prestigious UoM President's and Dean's Doctoral Scholarship Award schemes attract highly-talented graduates to undertake leading-edge doctoral research in the University. This source has enabled us to recruit 4 students in the UoA in the period 2011/13. Our commitment to recruiting the strongest students is reflected in the fact that we have also invested over £200k pa of our own funds on research student support, fully or partially supporting more than 20 students, in addition to an average of £750k from Research Council Doctoral Training Accounts, and £560k in 2012/13

from the EPRC Centre for Doctoral Training in Advanced Metallic Systems.

*Research Student Training*
Every research student has a supervisory team consisting of a main supervisor, a co-supervisor and an advisor; the two supervisors are responsible for technical guidance and progress, whereas the advisor is principally responsible for mentoring and pastoral support. We have both traditional 3-year doctoral students and 4-year students on DTCs. The 3 year programme focuses on research excellence within a technical specialism, whereas the 4 year programme provides a broader research training. Over the assessment period the number of 4-year students has increased steadily so that we currently have 50% of the cohort on the 4 year programme. The two programmes share many common aspects: for example, the supervision model, several of the training units, progression mechanisms and a research students' symposium. Additionally DTC students participate in technical modules, impact case studies, science in practice workshops, creativity workshops and secondments. Although we value and will continue to offer 3-year programmes, the 4 year programme has been designed to develop more complete researchers with a broader understanding of research lifecycles and strategies, and we anticipate that by 2014/15, 60% of our students will be following 4-year programmes.

One of our highlights is the annual Research Student's Conference, which includes presentations from all first and third year students, and a lively poster session with contributions from all second year students. Each conference also includes a keynote speaker (the winner of the second year poster prize) and externally-sponsored (e.g. by Intertek in 2013) prizes for the best posters.

*Progression Monitoring*
The online progression monitoring system, eProg, provides all research students with clear direction on the critical milestones for their research degree. eProg records provide evidence of a student's engagement with training. Prior to progression to a new year of study, each research student provides a short written report summarising their progress and plans (accompanied by a longer continuation report with details of related work and results to date after a full year of research, which is assessed by a technical expert), and both gives a presentation and is interviewed by a panel consisting of two members of staff. Where progress towards a PhD is not considered appropriate, there are exit points to research masters degrees.

**d. Income, infrastructure and facilities**

**Infrastructure and Facilities**
The UoA has excellent facilities available for materials research and during the REF period:

- We developed new 800 $m^2$ laboratory and office space for the National Composites Certification and Evaluation Facility (NCCEF) in 2009, supported by £4.8M from the NWDA (including staffing and equipment).
- The Manchester X-Ray Imaging Facility (MXIF) has been established in over 400 $m^2$ of refurbished space with the support of over £3M in EPSRC instrumentation grants.
- The UoM has invested £4.5M in the Diamond Light Source to build and exploit an imaging beam-line (operational Spring 2012) at the Research Complex at Harwell (RCaH). Having one of the largest hutches, it provides access to high flux 1 µm and 50 nm imaging for a wide range of in-situ and time-resolved experiments.
- A Cumbrian Facility has been established, funded through a £20M UoM investment, as a state-of-the-art research base of the Dalton Institute to provide academia and industry with the opportunity to carry out high-end research in radiation science and nuclear engineering decommissioning. It incorporates academic access to the active research facilities within the National Nuclear Laboratory Central Laboratory on the Sellafield site.
- Four new electron microscopes have been purchased including a Titan™ G2 80-200 scanning transmission electron microscope (S/TEM) with ChemiSTEM technology, the first of its kind in the UK. This is one of the world's most powerful high-resolution microscopes, capable of creating atomic-scale images of the microstructure of materials. Its procurement was funded as part of an £8M Government investment to strengthen the existing research capability within the Dalton Nuclear Institute.

*Future Plans*

- *UoM* has invested £750M in its estate since 2004. The next phase is the Manchester Engineering Campus development. At around £250M this project will be the single largest construction project investment ever delivered in the University. It will see all Engineering activities of the UoM co-located on the main campus and enable all the elements of the School of Materials to be co-located. This will provide unparalleled opportunities in materials research and even closer interdisciplinary collaboration in EPS. Construction is planned to begin in 2015 and the new Campus is expected to be opened by 2018/19.
- *National Graphene Institute*. The 7,600 $m^2$ NGI building, funded by both the EPSRC (£38M) and ERDF (£23M), is due for completion in early 2015. The NGI will operate as a 'hub and spoke' model, working with other UK institutions involved in graphene research. Some of the world's leading companies are also signing up to work at the Institute, where they have the chance to work on cutting edge projects, across various sectors.
- *Multidisciplinary Characterisation Facility.* £18M funding from the UK Research Partnership Investment Fund was secured in 2013 to set up the new facility which will focus on the UK's strategic development in advanced materials and manufacturing and will provide the necessary expertise to accelerate innovation from the laboratory to market. This will be supported by an additional inward 10-year investment of more than £100M from founding partners BP plc; Rolls-Royce; AMEC; Sellafield; NNL; FEI Company; Xradia; Rapiscan Systems; AREVA; Westinghouse; EDF; and TISICS. The facility will support research and development into advanced materials, which underpins all manufacturing sectors.

**Research Funding Portfolio**

*External Research income.* This has grown throughout the REF period with an average of more than £250k/fte/year, up from £150k/fte/year for RAE 2008, through a combination of industrial grants and EPSRC responsive mode awards, programme grants and competitive fellowships. The research council funding base has also been broadened with >£5M of MRC and BBSRC grants.

*Participation in EU projects*. We have appointed an EU Coordinator, increased engagement in EU events, and run training on EU funding. Evidence of progress: annual expenditure on EU projects tripled from £216k in 2008/09 to £694k in 2012/13.

*Industrial income*: Evidence of progress: annual expenditure on UK, EU and non-EU industrial projects increased from £1.7M in 2008/09 to more than £2.6M in 2012/13.

*Income in kind:* This totals >£7M mainly as a result of greatly increased usage of central facilities such as the Diamond synchrotron. It compares with income in kind of £1M reported for RAE2008.

*Involvement in knowledge transfer projects.* Evidence of progress: we have been involved in 28 knowledge transfer projects with a total value of £1.6M (e.g. EPSRC IAAs and KTAs, Knowledge Transfer Partnerships and KT Challenge Awards) with 27 commercial or industrial partners (contributing over £2M). This activity has more than doubled in size and value since RAE2008.

*Major Strategic Alliances* have been established with several multinational companies:

- *BP International Centre for Advanced Materials (BP-ICAM)*. This centre, established in 2012 with the support $100M from BP over the next 10 years, leads research aimed at advancing the fundamental understanding and use of materials in the oil and gas industry.
- *EDF*. The University has a global framework agreement with EDF, worth over £2M during the assessment period providing a framework for strengthening and extending the existing research collaborations between EDF R&D, EDF Energy and the Dalton Nuclear Institute.
- *Akzo Nobel.* The Akzo Nobel Laboratory of Corrosion Protection was established in 2012 as the result of a five-year strategic partnership between the largest global paints and coatings company and School of Materials with support of £0.5M/year.

*Major Research Programmes* are undertaken in close collaboration with end users:

- *Light Alloys Towards Environmentally Sustainable Transport 2 (LATEST2).* This £5.6M EPSRC programme is overcoming challenges to achieve reductions in the environmental impact of transport working closely with Jaguar Land Rover, Constellium and Airbus.
- *Materials Performance Centre.* This national centre of excellence in nuclear materials research and training, sustains strategic research partnerships with EDF, EDF Energy, National Nuclear Laboratory, Rolls Royce, Serco and Westinghouse. Its research income

includes a £4.1M EPSRC programme grant in New Nuclear Manufacturing. The impact of the MPC is through collaborative work within the UK and internationally, enhanced through links with, amongst others, Areva, Corus, HSE (Nuclear Division), NDA, TWI, US National Laboratories and the US Nuclear Regulatory Commission.

**Future Plans for the Funding Portfolio**

- The BP-ICAM and Akzo Nobel alliances established in 2012 and the Rolls-Royce UTC in Nuclear Technology will be developed into full-fledged joint research programmes with gearing though winning matching funds from the EPSRC and other funding bodies.
- The first 30-month phase of the 10-year €1Bn EU Graphene Flagship was launched in 2013 and members of the UoA play an important role in delivering graphene composites in the programme. It is envisaged that this will develop into a major component of the Flagship.
- The LATEST2 EPSRC programme grant will continue until 2015 but plans are already being made for a "LATEST3" programme which may expand beyond light alloys into composites, with close involvement with industry.
- The recently-established Dalton Cumbrian Facility, the new state-of-art complex for the Dalton Nuclear Institute, will enable staff in the UoA and industry to jointly carry out world-leading research and deliver dedicated skills development programmes.
- The newly-funded Graphene NOWNANO, Regenerative Medicine and Advanced Metallic Systems EPSRC Centres for Doctoral Training will facilitate further support for PhDs.

**Professional Services and Consultancies**

*Professional Services*

- *The Manchester X-Ray Imaging Facility*. This is a unique facility that provides both academic and industrial researchers with access to a unique suite of world-class equipment for non-destructive 3D imaging. The facility provides openly available access to the widest range of differently configured laboratory CT systems in the UK. This capability is further augmented by the Materials Testing & Analysis Unit and access to Manchester-Diamond nano-tomography synchrotron X-ray beam line at the Diamond light Source, Oxfordshire.
- *National Composites Certification and Evaluation Facility* This supports the supply chain across all sectors in the transition from metallic to advanced composite manufacturing and reduces the development time of a product, through the certification of new processes and materials. The centre, established with £4.9M funding from the NWDA, operates to the procedures which are compliant with UKAS (to ISO 17025).

*Consultancies (2008-13)*

*Freer* - Ricardo Engineering; *Lee* - Shell, Deput, Orteq, GE, Montupet, Doncasters
*Lyon* - Network Rail; *Prangnell* - BAE Systems: Global Combat Systems
*Sherry* - Government Office for Science, MoD, NDA, Rolls-Royce, NNL, EDF.
*Wortmann* - PZ Cussons, UK; Philips, NL; Henkel, GER; Alberto Culver, USA; Unilever, UK; Dyson, UK; Renault, F; Designer Yarns, UK; Procter & Gamble, UK & USA
*Wilkinson* - Intertek; *Young* - Mars Drinks, Dow Chemicals, USA.

**e. Collaboration or contribution to the discipline or research base**

**Collaborations**

Research collaboration takes place widely between members of this UoA and other researchers in industry and academia across the world. This is actively supported by a number of mechanisms in the School of Materials that include our sabbatical programme (5 in the assessment period), visitor/secondment programme (25 in the assessment period) and Industrial Advisory Board.

*Within the University of Manchester*

This is reflected in staff of two other Schools being included in the UoA. Additionally the Head of the School of Materials, *Paul O' Brien FRS* holds a joint appointment between the Schools of Chemistry and Materials and is returned by UoA8 since his research is in Materials Chemistry. Collaboration is also facilitated by the University of Manchester Research Institute (UMRI) that has been created to take forward the Manchester Strategic Vision 2020 goal of establishing the University as a major centre for interdisciplinary research. UMRI has two principal aims:

1. To foster interdisciplinary research by ensuring that the necessary structures, resources

(including funding) and incentives are in place; and
2. To provide a governance framework for Research Institutes and other interdisciplinary structures in the University to assist in maximising their performance.

Members of the UoA play a leading role in a number of the cross-faculty Research Institutes:

- *Dalton Nuclear Institute* (Director *Sherry*; *Engelberg*, *Jimenez-Melero*, *Lyon*, *Preuss*, *Quinta da Fonseca*, *Withers*, *Xiao*) has established the most advanced academic nuclear research capability in the UK and is a leading centre in nuclear science and engineering.
- *University of Manchester Aerospace Research Institute* (Director to 2012 *Withers*; *Cernik*, *Derby*, *Kinloch*, *Liu*, *Potluri*, *Prangnell*, *Preuss*, *Sampson*, *Skeldon*, *Thompson*, *Young*) plays a vital role in positioning the University of Manchester at the forefront of international aerospace research and nurturing a broad-based research portfolio.
- *Manchester Interdisciplinary Biocentre* (*Blanford*, *Saiani*). Focusing on advanced quantitative approaches to specific biotechnology challenges at the interface between medicine and biology and the physical sciences and engineering, the MIB is supported by world-class infrastructure. Dr Blanford is group leader in the Institute upon sensitive measurements of protein–surface interactions in electrocatalytic enzymes.
- *National Graphene Institute* (*Bangert*, *Haigh*, *Hill*, *Kinloch*, *Thomson*, *Vijayaraghavan*, *Young*). Members of the UoA have been intimately involved in graphene research since its inception in 2004 and are founder members of the NGI. Strong interdisciplinary collaboration on graphene research has taken place throughout the assessment period.

*With other UK Universities*

Members of the UoA have collaborations with academics in 15 other UK Universities, most notably:

- Joint £6.3M EPSRC Centre for Doctoral Training in Advanced Metallic Systems with the University of Sheffield
- EPSRC Graphene Science and Innovation Award (£5M) with the University of Lancaster.
- Nuclear Advanced Manufacturing Research Centre led by the University of Sheffield and The University of Manchester, with Rolls-Royce as lead industrial partner. Other founding partners were Areva, Westinghouse, Sheffield Forgemasters and Tata Steel.

*With International Industry and other Organisations*

Collaboration with industry and other organisations is overseen by our Industrial Advisory Board, We have established number of major strategic alliances with industrial organisations that helps to inform our research agenda as described in detail in REF3a. They are summarised briefly below:

- *BP.* A major alliance was established in 2012 with BP involving a number of strands. The *International Centre for Advanced Materials (BP-ICAM)*, leads research aimed at advancing the fundamental understanding and use of materials across the oil and gas industry.
- *EDF*. The University has a global framework agreement with EDF, the leading electricity producer in Europe, worth over £2M during the assessment period. It provides a framework for strengthening and extending the existing research collaborations between EDF R&D, EDF Energy and the Dalton Nuclear Institute.
- *Akzo Nobel.* The Akzo Nobel Laboratory of Corrosion Protection was established in 2012 as the result of a five-year strategic partnership between the largest global paints and coatings company and School of Materials with support of £0.5M/year.

We also have a number of sector-based research programmes described in detail in REF3a:

- LATEST2 EPSRC Grant, industrial partners – Jaguar Land Rover, Constellium and Airbus
- EPSRC Centre for Doctoral Training in Advanced Metallic Systems. All 30 PhD projects are undertaken in collaboration with UK industrial organisations that include Rolls Royce, Magnesium Elektron, Westinghouse, TWI, DSTL, Alcoa, Airbus and BP.
- Materials Performance Centre - strategic research partnerships with EDF, EDF Energy, National Nuclear Laboratory, Rolls-Royce, Serco and Westinghouse.

*National and International Secondments*

There has been a number of industrial secondments to the UoA in Manchester, most notably:

- DSTL,UK - Visiting Professor in Composite Materials (Wells)
- Toray, Japan – 2 visiting staff for 2 years each working upon carbon fibres (*Young*)

- Hitachi Metals, Japan – 1 visitor for 1 year working on functional ceramics (*Freer*)

**Leadership within the Academic Community**

*Election to Membership or Fellowship of Learned Societies*

- Fellowship of the Royal Society: *Young* (2013), *O'Brien* UoA8 (2013)
- Fellowship of the Royal Academy of Engineering: *Sherry* (2011); *Thompson*, *Withers*, *Young*

*Major Awards and Prizes*

- Queen's Anniversary Prizes – Dalton Institute (*Sherry*, 2012), New Imaging Techniques to Support Advanced Materials and Manufacturing (*Withers*, 2013)
- Royal Society Armourers & Brasiers' Company Prize – *Withers* (2010)
- Institute of Materials, Mining and Minerals Prizes
  - Platinum Medal – *Thompson* (2010)
  - Holliday Prize - *Young* (2011)
  - Swinburne Medal and Prize – *Young* (2012)
  - Rosenhain Medal and Prize – *Kinloch* (2013)
  - Silver Medal – *Haigh* (2013)
  - Grunfeld Memorial Award and Medal – *Robson* (2011), *Preuss* (2013)
- Saatchi & Saatchi Award for World Changing Ideas, Edward de Bono Medal – *Derby* (2008)
- RSC Corrosion Science Award (Chemetall sponsored) – *Thompson* (2008)
- RSC Macro Group, Young Researchers Medal – *Kinloch* (2011)
- Kilburn and Williams Medal, UoM *Thompson* (2009), *Withers* (2013)
- Plueddemann International Award, Dow-Corning, USA – *Young* (2010)
- Ottewill Award, UK Polymer Colloids Forum – *Lovell* (2011)
- Grande Medallion, Cefracor (Corrosion Society, France) - *Lyon* (2012)
- Oliver Stubbs Award, Institute of Metal Casting Engineers - *Lee* (2009)
- Kape Memorial Award, Institute of Materials Finishing - *Thompson*, *Skeldon*, *Curioni* (2013)

*Service on National/International Advisory Boards*

UoA staff have served on important national and international advisory boards. *Sherry* has served upon a number that include: UK Ad Hoc Nuclear R&D Advisory Board; Nuclear Energy Skills Alliance; MoD Structural Integrity Technical Working Group; MoD Materials & Chemistry Technical Working Group; UK Forum for Engineering Structural Integrity; US Idaho National Laboratory Advanced Test Reactor, Scientific Review Board; NDA Radioactive Waste Management Directorate R&D Advisory Panel. *Thompson* was also a member of the BP Inherently Reliable Facilities Technology Panel (2009).

*Leadership in Industry, Research Councils, Learned Societies, Professional Bodies*

Members of the UoA have also been active in leadership in the academic community through service that includes: EPSRC (Prioritisation panels – 12, Strategic Advisory Team for Materials – *Freer*, Strategic Advisory Team for Engineering – *Withers*); Royal Society University Research Fellowships Award Committee – *Gough*; RAEng Standing Committee for Engineering Policy – *Sherry*; Learned Society committees, (IOM$^3$ – 3, RSC – 4, RMS - 1), BSI committees (*Wortmann*, *Vijayaraghavan*); UK Society for Biomaterials – *Gough.*

*Conference Organisation and Programme Chairs*

UoA staff have been involved in organising more than 20 major international conferences and conference sessions. Highlights include: Electroceramics XI, Manchester, Organiser - *Freer* (2008); IUPAC World Polymer Congress (Macro2010), Glasgow, Chairman – *Lovell*.

*Invited Plenary and Keynote Lectures*

Staff in the UoA at all levels have delivered more than 150 invited Plenary and Keynote lectures at conferences in the UK and abroad in the REF assessment period.

*Journal Editorships and Editorial Board Membership*

Staff in the UoA are editors of 5 major journals, including the Journal of Materials Science (*Blanford* & *Young*). They are also members of more than 30 journal editorial boards.

*Patents Awarded*

Over 20 patents have been awarded to staff in the UoA in the assessment period: *Akid* 5, *Lovell* 1, *Downes* 5, *Saunders* 1, *Young* 3, *Kinloch* 5, *Freer* 1, *Saiani* 2, *Cernik* 1.