Institution: Queen Mary University of London (QMUL)

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

a. Context

Materials research at Queen Mary has a wide range of non-academic audiences and beneficiaries, including large multinationals, SMEs developing new materials and products, governmental research institutes such as NPL, Dstl, AWE and Diamond Light Source, and museums. The Materials Research Institute's (MRI's) research strategy focuses on distinctive clusters of research strength and expertise, which also provide the focus for a range of impact activities. Over the REF period, MRI academics returned in UOA13B have filed 35 patents, were awarded eight industrial CASE studentships and generated £3.66m of direct grant income from industrial partners including Bridgetone, Dunlop, Cabot, European Thermodynamics, GlaxoSmithKline, NPL, Dstl, DSM, Sabic, D3O, Sibelco, Sintec, Nanocyl, L'Oreal, Sandvik and Farapack. 23% of our total grant awards came from the private sector, which is well above the UK average of 9% (HESA Financial Statistics). The Unit's main impact activities involve materials formulation and processing for our application areas: energy, lightweighting, sensors, opto-electronics and healthcare. Our research has lead to economic impact through the creation of 21 jobs by our spin-out Nanoforce Technology Ltd (Case Study 1). This spin-out generated further economic impact by supporting and consulting over 100 businesses, many of them SMEs, to improve their products or processes, as in for example, Sugru®. An example of our research that led to both economic and environmental impact is in bio-based materials. Here our research helped to develop Zelfo®, a binder-free panel product made entirely out of cellulose for applications like flooring and construction. Biotex™, a range of high-performance yarns, fabrics and pre-consolidated sheets based entirely on renewable resources such as PLA and natural flax fibres, is another example of a product developed through our expertise in bio-based materials. Research in lightweight materials led to economic and environmental impact through the creation of two new businesses in recyclable self-reinforced plastics (PURE® and Tegris®), for applications in automobiles, sports, luggage and protection (Case Study 2). Through their use in anti-ballistic panels, de-mining masks and bomb baskets these materials have probably already saved lives. Application-driven research in rubber materials led to considerable economic impact through among others Dunlop Aircraft Tyres (Case Study 3). Nanoforce has also hosted three training events each benefiting around 20 professionals.

Materials research takes place across a range of UOAs and the impact cases reported should be seen in the context of a much longer list. QMUL's spin-out ApaTech Ltd. (CS to UOA15) is a prime example of a mature technology that has delivered economic and health impacts. It was acquired by Baxter International Inc. in 2010 for a sum of up to $330m. DegraSense (CS to UOA8) is a QMUL spin-out that has been established to develop a point-of-care dental biosensor that could improve the treatment of periodontal disease and other inflammatory conditions. Dental materials research created new business through the development of a new nanohydroxyapatite-filled toothpaste ultraDEX® (CS to UOA3) that blocks dentinal tubules and promotes re-mineralisation. Dunstan's research has led to innovations for Raman microscopes that have been patented and marketed by Renishaw plc (CS to UOA9). Societal impact is exemplified by QMUL's Centre of the Cell, an award-winning outreach project visited by over 40,000 schoolchildren each year that includes exhibits based on our healthcare materials research.

b. Approach to impact

Queen Mary is an extremely outward-facing organisation as evidenced by the many close links staff have with businesses both in the UK and internationally. In 2011, the College received the maximum HEIF5 funding allocation for specialist services to support academics in a range of impact activities including business engagement, technology transfer, public engagement, and entrepreneurial training. The MRI's impact strategy aims to ensure that training and mechanisms are in place to enable staff (including PDRAs and PGRs) to achieve impact as part of the research process. To achieve this, mechanisms are in place at College level which directly link to the management structure of the MRI. MRI staff are encouraged to develop the commercial aspects of their research through a series of seminars organised by the Business Development Office, and Schools and the MRI account for entrepreneurial activities within the workload allocation model.

College support structures

Queen Mary Innovation (QMI) negotiates agreements with industry to commercialise innovations arising from our research base, including licensing and other royalty-bearing agreements. QMI hold regular seminars for MRI staff to explain their role in IP protection and accessing Proof-of-Concept (PoC) funding, etc. During the REF period QMI have facilitated 6 PoC grants for academics in this UOA (total £363k), including an externally funded PoC (Krause, £222k) with BLTC, in areas as diverse as composites (Barber), biosensors (Krause), optical amplifiers (Gillin), metallic components (Bushby) and photocatalysis (Dunn). In addition they facilitated patent applications and established in 2006 a formal partnership with IP Group Ltd, an early-stage venture capitalist (VC) with a proven track record of investing in university spin-outs.

Queen Mary's Business Development Office (BDO) links business with academic researchers and facilities at QMUL. The Business Development Managers identify relevant expertise to meet commercial requirements through collaborative research, contract research and consultancy. The BDO is intimately linked with the MRI management structure with our Senior Business Development manager on the Management Committee. This approach has led the BDO to organise a series of meetings for the MRI with industry and Knowledge Transfer Network (KTN) representatives to launch an industry initiative which is designed to develop collaborations which will lead directly to impact from our portfolio of facilities and expertise.

QMUL Public Relations (PR) provides expert advice to academics to maximise their communication skills, and builds strategies focused on impact and connecting research with the right audience via press releases to improve the visibility of our research. A recent example is Dunn's work on acoustic enhancement of organic solar cell performance, which with the help of our PR office generated significant press interest, ranging from New Scientist to the Daily Mail.

The MRI aims to encourage an entrepreneurial culture by embedding enterprise and innovation across the breadth of academic endeavour by providing entrepreneurship training activities such as workshops, alongside a number of funded College-wide initiatives such as the QM Innovation Fund. Launched in 2012, this highly flexible internal fund encourages industry collaboration to realise the impact of research. Three Innovation Funds, each with the maximum value of £10k, have been awarded so far to MRI academics for projects on dental materials (Krause), thermochromic glazing (Binions) and self-reinforced plastics (Peijs). The close link between the MRI and Schools structures allows us to respond rapidly to opportunities. For example the EPSRC Global Engagement project provided funds at very short notice to develop a Joint Institute at Sichuan University (SCU). This was an MRI led initiative but SPA provided the project lead (Gillin) with 2 years release from teaching to travel to China to establish it. This has now led to a £0.7m start-up grant from SCU to support it and the appointment of 3 full time and 3 part time staff.

Institute and School support structures

The MRI and Schools supports a range of mechanisms aimed at ensuring impact is realised that complements College structures and services.

Director of Industrial Engagement: Prof. James Busfield was appointed to a new role as Director of Industrial Engagement in the School of Engineering and Materials Science (SEMS) in 2010 to identify and promote new collaborative opportunities with industry that often lead to impact-generating research. Since 2013, this was expanded to include external relations within the MRI. The MRI has a full-time member of support staff who coordinates our wide range of industrial partnerships. A large industrial liaison forum (ILF) event is held each semester attracting industrial partners to QMUL and providing networking opportunities for both staff and students. The research-focused autumn ILF is typically attended by more than 60 external visitors from industry reviewing in excess of 100 posters, and includes networking activities providing a focal point for securing contract research or PGR project funding.

Nanoforce – bridging the gap between academia and industry: Nanoforce Technology Ltd. was set up as a spin-out from QMUL in 2005 with £3.1m of funding from the Micro- and Nano Technology competition, specifically to bridge the gap between academic and industry-led research. As our *'Portal to Industry'* Nanoforce enables MRI academics to be involved in applied research at industrial time scales (months) and gives MRI academics greater flexibility to conduct R&D projects with industry that have great potential to generate impact. Nanoforce has also hosted a number of KTN events in areas such as smart textiles, self-reinforced plastics and rubber.

c. Strategy and plans

QMUL has embedded impact within its 2010-15 Strategic Plan, and impact-related indicators are cascaded down to schools and institutes, with a requirement to assess progress on an annual basis as part of the Planning and Accountability Review. Relevant indicators include disclosure of inventions, financial support for commercialisation of research, income-generating technology license agreements and creation of spin-out companies. Over the period, academics returned in UOA13B have filed 35 patents in areas such as nanomaterial synthesis (e.g. EP2520544/A1; EP/2297283; GB1222781.5), polymer processing and composition (e.g. WO/ 2013072350/A1; WO/2012084200/A1), energy materials (e.g. WO/2011012545/A1), sensors (e.g. WO/2013113877/A1; WO/2012013937), biomaterials (e.g. WO/2011/161422/A1; WO/2012099482 /A8), opto-electronics (IPO/1311862.5) and membranes (e.g. WO/2008121447/A1; WO/ 2009115938/A1). Over the period, 23% of our total grant awards came directly from industrial partners, totalling £3.66m and we are expecting to grow this number through use of co-funded College, EPSRC DTA and China Scholarschip Council (CSC) studentships, as well as through increasing CASE studentships and pump-priming support. We see significant opportunities for generating impact in each of our research clusters.

Energy: Future impact is foreseen from sustainable synthesis routes for materials in energy storage (e.g. electrodes for Li ion batteries or supercapacitors) (Titirici) or fuel cells (e.g. novel catalysts or catalyst supports) (Dunn). In the field of thermoelectric we have a partnership agreement with European Thermodynamics (Reece), while thermochromic films for energy efficient glazing are being developed in collaboration with industrial partner Pilkington Glass (Binions).

***Lightweighting*:** Opportunities to build impact with industrial partners exist in the field of polymers, composites, bio-based materials and self-reinforced plastics (Peijs, Bilotti). Specific areas with strong industrial links are in rubber (Bridgestone, Avon) (Busfield), high-strength fibres and protection (e.g. Dyneema, Dstl) (Peijs, Barber), and structural ceramics (e.g. Kennametal) (Reece).

Sensors: This is a growth activity with strong links to industry, spanning synthesis, processing, characterisation and modelling to device fabrication. Research is focused around new ferroelectric ceramics for high temperature piezoelectric sensors and rapid spark plasma sintering (SPS) to produce novel ceramics (e.g. Meggitt Ltd.) (Reece, Yan). Disposable biosensors are also developed and led to spin-out DegraSense Ltd. (Krause) and links with Philips (Bastiaansen).

Opto-electronics: Research on depositing conducting oxides onto substrates has potential future impact in touch-screens (Gillin) in collaboration with M-Solv Ltd., while the development of conductive polymer composites (Peijs, Bilotti) has potential for future impact in multi-functional devices and smart textiles (in partnership with global CNT producer Nanocyl S.A.). The discovery of magnetic carbon nanotubes (Baxendale) has potential future impact in energy generation and magnetic hyperthermia particles for cancer therapy. Gillin's research on erbium organic materials, with application to integrated optical circuits, is supported by a PoC grant (£50k) in preparation for spinning-out a company in partnership with IP Group Ltd.

Healthcare: Biomedical materials research extends to several academic units including the new 'Institute of Bioengineering' (UOA15), MRI researchers provide significant impact in areas such as new functional fibres for tissue engineering scaffolds (Peijs, Bastiaansen), biosensors (Krause) and drug delivery (Becer, Azevedo).

d. Relationship to case studies

Case Study 1: Nanoforce is a wholly owned spin-out from QMUL, which was directly supported by QMI for areas such as NDA's and IP. Case Study 2: The development of PURE is the prime example of the strong industrial-focused research in polymers and composites. Underpinning research started around 1998/99 and predates many of the support structures described above. However, the work led to a large number of bilateral industrial contracts, which were supported by QMI. Case Study 3: Our work on rubber is another example of strong industrial links with a large number of bilateral industrial contracts formed through networking at among others our ILF and KTN events, and through the use of co-funded PhD studentships supported by CASE, KTA, College DTA, CSC and QMI.