Institution: Swansea University
Unit of Assessment: 15 - General Engineering (cross ref 13)
Title of case study: The development of new coatings for Tata Steel Europe through collaborative research
1. Summary of the impact

Collaborative research with Tata Steel has delivered significant **economic impact,** maintaining leading-edge business performance with **new functionally coated metal construction products** carrying 40 year warranties, and research contributing to global competitiveness for Electrical Steels. In addition **partner company performance through skilled people** has been improved through the delivery of **61 highly trained doctoral level coatings leaders and technologists,** the majority of whom are now running their own research groups or are director level technologists.

Public interest and engagement activity has focussed on the application of research techniques and in functional coatings for energy through the '*Buildings as Powerstations*' concept and '*Materials Live'* events.

2. Underpinning research

Swansea University has a track record of almost a century of world-class research leading to new product development. The Corrosion and Coating Group within the Materials Research Centre (MRC) was established with industry support in 1996 built around three consecutive Materials for Better Construction EPSRC grants. During this time, the group leaders, Professor **Dave Worsley** (at Swansea since 1992) and Professor **Neil McMurray** (at Swansea since 1994) were able to leverage further support for research through the EPSRC EngD programme in steel technology that still runs today. The national significance of the research cluster was recognised in 2006 with the award of a Coatings Platform Grant that provided underpinning science to further the understanding of new coated metal systems used in construction. The key enabling technology was the development of scanning electrochemical methods for examining corrosion mechanisms designed and manufactured at Swansea (R1) which led to a full understanding of new galvanising alloys electrochemistry (R2), the influence of processing conditions (R3), chromium free corrosion resistance (R4) and photo-degradation mechanisms (R5). The work initiated in the late 1990s has directly led to impact with the lead industry partner Tata (the UK's largest manufacturer) now offering 40 year full warranties on coated steels for construction. Without this underpinning science it would not have been possible for the industrial partners to implement and optimise new coatings with confidence.

In 2007 the research group was expanded to include new lecturing staff (**Geraint Williams** (at Swansea since 1993, first as Research Officer, academic staff since 2007, now Associate Professor) and **James Sullivan** (at Swansea since 2004, first as Research Officer, academic staff since 2007, now Associate Professor)). A series of industry-led workshops identified that building functionality will be a major feature of architecture of the future. As such in 2007 a new initiative lead by Swansea to examine low cost photovoltaics on steel was started with Imperial College and Bath. This work has led to a number of enabling research outputs (e.g. R6) and the industry partners are now (2013) commencing the next phase of industrial scale up through the Innovation and Knowledge Centre. This is supported by additional 3 academic staff appointments to the MRC and a substantial increase in the research group and substantial collaboration with Imperial College London and Oxford University through the £7m Welsh Government sponsored Sêr Solar Programme.

The importance of the scale up of functional coating manufacturing in Wales is recognised through the creation of the new Innovation and Knowledge Centre established in 2011 with a £10m EPSRC/TSB grant and over £4m (to date) from Welsh Government and £6m industrial investment. The ***SPECIFIC IKC*** is working with multiple partners to bring forward both existing anti corrosion and new photovoltaic coatings together with new functional coatings that are at this stage only at the laboratory bench scale.

Critical to the impact of the programme have been the teams of research associates, fellows and students and the active involvement of partner industries and universities. The majority of the team have come through the EPSRC funded EngD programme working on coatings development with industry partners and have subsequently maintained that as a career path. 26 Research Leaders have their roots in the corrosion mechanisms on steel detailed below (R1 to R5). The four key related impacts all build on key scientific and mechanistic understanding developed from the enabling work conducted in the early part of the new millennium and published after full commercialisation.

3. References to the research

The research outputs described are in leading journals and have been instrumental in creating both further research and development and are leading contributors to the impacts described in section 4. Papers prior to 2008 included in the last RAE. The outputs R2, R4 and R6 are those that best cover the spread of the impact.

[R1] Determination of localised corrosion mechanisms using a scanning vibrating electrode technique, D.A. Worsley, A. Belghazi and H.N. McMurray, Chemical Communications, 1997, 2369-70 (IF 6.4, citations 20)

[R2] The kinetics and mechanism of cathodic oxygen reduction on zinc and zinc aluminium galvanised alloy coatings. H. Dafydd, H.N. McMurray and D.A. Worsley, Corrosion Science, **47, 2005, 3006-18 (**DOI: 10.1016/j.corsci.2005.05.036**)** (IF 4.0, citations 38)

[R3] Microstructural changes in zinc aluminium alloy galvanising as a function of processing parameters and their influence on corrosion J. Elvins, J.A. Spittle and D.A. Worsley, Corrosion Science, 47, 2005, 2740-2759.(DOI 10.1016/j.corsci.2004.11.011) (IF 4.0, citations 26)

[R4] Cerium (III) inhibition of corrosion driven organic coating delamination studied using a scanning Kelvin microprobe, *Journal of the Electrochemistry Society*, H.N. McMurray, G. Williams and D.A. Worsley, 149, 2002, 154-162 (DOI 10.1149/1.1457983) (IF 2.6, citations 40)

[R5] A novel flat panel reactor for monitoring photodegradation A.J. Robinson, J.R. Searle and D.A. Worsley, Materials Science and Technology, 20, 1041-1048, 2004. (DOI 10.1179/026708304225019885) (IF 0.8, citations 18)

[R6] Ultrafast near infrared sintering of TiO_2 layers on metal substrates for dye sensitised solar cells, T.M. Watson, I. Mabbett, H Wang, L.M. Peter and D.A Worsley, Progress in Photovoltaics, 2010, 19(4), 482. (DOI: 10.1002/pip.1041) (IF 7.7, citations 7)

Four major research grants have supported this work within the REF period:

[G1] **2006-11**: EPSRC Platform Award, *Understanding and Improving Corrosion-Resistance in Structural Coated Steels*, HN McMurray (PI), V Randle and DA Worsley. EPD05284X (£426,685)

[G2] **2007-10:** EPSRC consortium bid on Photovoltaics with Swansea the lead RO, *Metal substrate mounted flexible dye sensitised semiconductor solar cells*, DA Worsley (PI) and J.C. Arnold, EPE035205/1 Total bid value £1.52 million

[G3] **2009-2015*:** D Worsley PI, J H Sullivan Steel Training Research and Innovation Partnership (STRIP) ESF/Industry funding £7 million

[G4] **2011-present** D Worsley (PI) HN McMurray, G Williams, JH Sullivan, T Claypole, SPECIFIC: £9.6M EPSRC and TSB (EP/L010372, K000292 and I019278)

4. Details of the impact

- **Impact 1: Economic impact new products: high durability construction products** (Outputs R1-4): Tata Steels Shotton Steel works **(employing 690 staff)** premium product for construction is now a 5% Aluminium containing galvanised steel for construction (18,000 tonnes per week) with a high-performance UV stable organic coating underwritten by a full consequential loss warranty of up to 40 years. These high performance products are only possible through understanding of the critical links between microstructure and corrosion resistance from underpinning mechanistic studies (R1-R3) and photodegradation stability measurement (R5). The new techniques to visualise and quantify corrosion (R1 and R4) are now sold commercially by Swansea with customers including General Electric, Tata and Tokyo Electric Power. ***Partner comment: "Our 40 year corrosion warranties are at the heart of or premium products success.... this comes directly from an understanding of corrosion and photodegradation led by Swansea"*** *(Technology and Innovation Director Tata)*

- **Impact 2: Economic impact new products: chromium free corrosion treatments** Cogent Power manufacture 75,000 tonnes per annum of a high quality grain oriented electrical steel used for devices such as transformers, motors and other electrical devices. Traditionally a chromate wash was used to prevent corrosion; hexavalent chromium is now banned from electrical goods in the European Union Waste Electrical and Electronic Equipment Directive, which became European law in 2003, and as such has to be removed. After two years research with their suppliers Cogent Power had not succeeded and prime production had dropped to 10%. Using the techniques developed (R4) a method was developed to look at the chemical species during the treatment (the research being carried out by authors of refs R1 to R5). In 2012, a £250,000 investment in a new coater resulted in an increase to 60% prime output (consistent with the chromate performance). This translates to a 37,500 tonne increase in prime product annually which retails for £1300 per tonne giving the plant world leading productivity essential for business competitiveness. ***Partner comment: "We had been unable to solve the chromium free treatment of our electrical steels. We invested £250k on a new coater solution and we are now producing ~60% grade 1 appearance standard compared to ~10% prior to the work with SPECIFIC"*** *(Technical Manager, Cogent Power)*

- **Impact 3: Economic impact Investment Induced from UK; the creation of a national innovation centre** The underpinning understanding of coatings behaviour initiated by R1 directly led to the cluster of research excellence at Swansea growing and the SPECIFIC Innovation and Knowledge Centre has continued a successful partnership with Tata, NSG and BASF to develop functional coatings. New process technologies (e.g. R6) have converted what was a batch process to a continuous process and has resulted in a £2.2m investment in production line capability in Wales in 2013. Typical lab methods are all based on typically 30 minute oven heating that is inconsistent with line speeds of 100 m min^{-1}. The near infrared heating methods have solved the three main bottlenecks in cell manufacture. In 2013 an additional £7m has been invested to create a strategic project with Imperial College leading to a national centre for scaling solar energy advanced manufacturing. ***Partner Comment: "New products in the construction require lifetime and function; already work on pigmentation at Swansea has improved the efficiency of our transpired solar collectors being fitted to buildings in the UK. This basic function is driving development work of our next generation of coatings at the SPECIFIC IKC"*** *(Innovation Manager Tata Colors)*

- **Impact 4: Economic Activity Jobs Created**. Continued support from EPSRC and WG for the Engineering Doctorate programme has allowed for both technical impacts detailed above but also critically provided a talent flow from the university to industry. The Swansea led EngD has now produced 204 EngD graduates of whom 90% are working with or for industry and two thirds with the metals sector in which their research activity was initiated. Specifically 26 of the doctorates work directly on coatings development. This provides a sustainable positive impact on industrial partners as well as supporting a more diverse set of research interactions. Seven

of the co-authors of the six outputs are EngD graduates who took leading roles upon graduation and all remain working closely with the industry sponsors to-date. ***Partner comment: "The graduates that come from our EngD partnership are the life blood of our technical and management sections. Their research outputs directly affect our business competitiveness and the large number that work in our supply chain continue to add value after they have left the University. I should know as I was one of the first batch of graduates in 1996!"*** *(Technical Director Tata Steel Strip Products)*

5. Sources to corroborate the impact (indicative maximum of 10 references)

Impact 1: Technology and Innovation Director, Tata Steel Colors, Shotton, Deeside, CH2 4NL.

Senior Projects Officer, Major Projects, BASF Industrial Coatings, Deeside Industrial Park, Chester, CH2 4NH.

Impact 2: Technical Manager, Orb Electrical Steels, Cogent Power, Newport, NP19 0RB.

Impact 3: Innovation Manager, Tata Steel Colors, Baglan Bay Innovation Centre, Central Avenue, SA12 7AX.

Impact 4: Technical Director, Tata Steel Europe, Port Talbot Works, SA13 2NG.