

Impact case study (REF3)

Institution: Durham University		
Unit of Assessment: 8 Chemistry		
Title of case study: Durham Chemistry P&G Strategic Partnership		
Period when the underpinning research was undertaken: Between 2000 & 2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s): Around 20 PIs in Chemistry. Main impacts arising from Profs Colin Bain, Jon Steed, Andrew Beeby	Role(s) (e.g. job title): Professors, Associate Professors, Assistant Professors in Chemistry	Period(s) employed by submitting HEI: 2004, 2003 and 1993 to current, respectively
Period when the claimed impact occurred: 1/8/2013 to 31/1/2020		
Is this case study continued from a case study submitted in 2014? Yes. In part, P&G impacts new for REF2021. Alvetex [®] discussed in 2014 Reinnervate case study.		
<p>1. Summary of the impact</p> <p>Research from the strategic partnership between Procter and Gamble (P&G) and Durham Chemistry has "<i>enabled unique and globally scalable innovation that has improved billions of consumers' lives around the world</i>". We describe direct impact via consumer goods innovation of [REDACTED], research savings to P&G of [REDACTED], support/creation of ~150 jobs in the North East, and inward investment from the USA of [REDACTED]. P&G's preferred platform for skin testing new consumer products is now Durham's Alvetex[®] 3D cell culture technology. Alvetex[®], marketed by ReproCell, has had [REDACTED] sales in period. Outreach activities impacting >6500 members of the public and featured on the BBC show "Inside Out" have arisen from the research.</p>		
<p>2. Underpinning research</p> <p>In 2010 Durham Sciences started to explore new ways of working strategically with industry to help build research impact. We chose to work with P&G, motivated by the fact that they are a global innovation-led company giving us the potential to impact their 5 billion worldwide customers. In the early relationship stages we shared research expertise (including [R1, 2, 3]) and ambitions to confirm that a strategic relationship would be of genuine benefit to both sides and to define early research projects building from Durham University (DU) Chemistry research. At the outset we adopted a "master agreement" covering all IP, exploitation and confidentiality aspects. This has meant that subsequent research programmes can be launched with minimal "activation barriers".</p> <p>We have collaborated in diverse chemistry research areas including photobleaches, soil-surfactant interactions, surface-active polymers and molecules, enzyme stability, chelant design, anti-microbials, small molecular migration by experiment and theory, optical brighteners and hueing dyes, phase diagram prediction and lipid delivery systems.</p> <p>We have also co-created a number of larger more collaborative projects involving Physics, Life Sciences, Computer Sciences and the Business School. Since 2010 the research grant portfolio has totalled around GBP23.6m (GBP7.6m/GBP11.5m/GBP4.5m industry/UK or EU government/University) and has involved around 70 University (25 Chemistry) academics and 50 industry researchers (across P&G sites in the United Kingdom (UK), United States of America (USA), Germany, Brussels and Singapore) working with 36 PDRAs and 44 PhD students. The research has been underpinned by several competitively won large grants including: CEMENT</p>		

Impact case study (REF3)

(GBP14m Regional Growth Fund project); MICSED (EU ITN GBP1m to Durham); and Molecular Migration (EPSRC GBP1m/industry GBP2m, Durham, Sheffield and Birmingham Universities with P&G, Mondelēz and Akzo).

We summarise below specific DU Chemistry research in soft matter, analytical, coordination and polymer chemistry that has led to the impacts described in Section 4.

Surface chemistry & characterisation: Prof. Colin Bain developed ellipsometry and Total Internal Reflectance (TIR) Raman Spectroscopy for measuring the absorption rates and quantity of surface-active species at solid-liquid interfaces (e.g. [R3] and GR/S15778). TIR-Raman spectroscopy offers 1-s time resolution and sub-monolayer sensitivity; Bain's invention has been replicated by labs in Europe, Australia and the USA. These methods were re-applied in contract research funded by P&G to measure the uptake of new polymer additives on model surfaces in order to elucidate their mode of action in laundry applications. Bain also has long-term research interests in the properties of liquid jets and in flow and deposition on surfaces (e.g. [R4] and grants EP/E019323, N025245, H018913). The techniques and knowledge developed in these programmes were applied to the impact of jets on thin films of dishwasher formulations created with a slot-die coater, in further research funded by P&G.

Synthetic chemistry: Several of Durham's synthetic chemists have collaborated with P&G. Prof. Jon Steed's expertise in ligand design, coordination chemistry and crystallisation (e.g. EPSRC R013373) has been applied to the design of novel two-component CaCO₃ crystallisation inhibitors for dishwashing applications. The work involved inhibitor design, structure function studies of inhibitor-metal interactions, combinatorial studies of efficacy, and development of rapid deposition test apparatus and is described in publication [R5] and a related patent [EP3456808A1].

3D cell growth and skin models: P&G have adopted DU's novel skin test models as their preferred product development platform. The models derive from collaborative research between Cameron, Cooper and Przyborski (Durham Biosciences) that used emulsion templating to produce porous polystyrene materials [R1] that were developed into 3D cell culture scaffolds under EPSRC grant GR/T24043 and described in (e.g.) [R2]. Materials were subsequently optimised to produce thin membranes, tested for cell growth and the technology optimised for scale up and reproducibility. The product was commercialised as Alvetex®, and its early impact was described in a Chemistry REF2014 case.

Imaging and spectroscopy: Prof. Andrew Beeby's research interests lie in the area of photochemistry, time-resolved spectroscopy and imaging. Research methods in [R6] have been applied to study pigments in ancient manuscripts held in libraries across the UK, feeding an active outreach program. The same techniques have been applied to P&G product imaging challenges and transferred to P&G through purpose-built spectrometers that now form an integral part of their research testing portfolio.

3. References to the research

The references listed [and web of knowledge citations as of November 2020] are those that underpin the specific impacts described in Section 4.

R1. A. Barbetta, N. R. Cameron, and S. J. Cooper, "High internal phase emulsions (HIPEs) containing divinylbenzene and 4-vinylbenzyl chloride and the morphology of the resulting

PolyHIPE materials", *Chemical Communications*, **2000**, 221-222. DOI: 10.1039/A909060F [132 citations]

- R2. M. Bokhari, R. J. Carnachan, S. A. Przyborski, and N. R. Cameron, "Emulsion-templated porous polymers as scaffolds for three dimensional cell culture: effect of synthesis parameters on scaffold formation and homogeneity", *Journal of Materials Chemistry*, **2007**, 17, 4088-4094. DOI: 10.1039/B707499A. [79 citations]
- R3. D. A. Woods, J. Petkov, and C. D. Bain, "Surfactant adsorption by total internal reflection Raman spectroscopy. Part III: Adsorption onto cellulose", *Colloids Surfaces A: Physicochemical Engineering Aspects*, **2011**, 391, 10-18. DOI: 10.1016/j.colsurfa.2011.07.027 [19 citations]
- R4. L. Yang, B. K. Kazmierski, S. D. Hoath, S. Jung, W.-K. Hsiao, Y. Wang, A. Berson, O. Harlen, N. Kapur, and C. D. Bain, "Determination of dynamic surface tension and viscosity of non-Newtonian fluids from drop oscillations", *Physics of Fluids*, **2014**, 26, 113103. DOI: 10.1063/1.4901823 [22 citations]
- R5. Y. Hong, N. Letzelter, J. S. O. Evans, D. S. Yufit, and J. W. Steed, "Phosphate-free inhibition of calcium carbonate dishwasher deposits", *Crystal Growth Design*, **2018**, 18, 1526-1538. DOI: 10.1021/acs.cgd.7b01508 [1 citation]
- R6. A. Beeby, L. Garner, D. Howell, and C. E. Nicholson, "There's more to reflectance spectroscopy than lux", *Journal of the Institute of Conservation*, **2018**, 41, 142-153. DOI: 10.1080/19455224.2018.1463920.

The Durham-P&G team were awarded the Royal Society of Chemistry's 2015 "Teamwork in Innovation" award for "multidisciplinary, collaborative and high-impact research leading to product innovation" [E2], some of which is described in this document.

4. Details of the impact

Laundry formulations: Controlled polymer deposition onto different fabrics underpins the stain release properties of many laundry detergents. This improves efficacy, particularly at environmentally friendly low wash temperatures. In two collaborative projects with P&G scientists Dr Andrew Graydon and Dr Anju Booker, Prof. Bain used ellipsometry and TIR-Raman scattering (method in [R3]) to measure the adsorption of polymeric laundry additives onto mimics of synthetic fabrics and the effect of these additives on the adsorption of proteins and complex polysaccharides. The learning led to the introduction of new patented polymer technologies into single unit dose formulations (Ariel pods), a business with an estimated global value of [REDACTED] pa; in the attached evidence document [E1], P&G estimate the direct impact of this DU research as [REDACTED]. The insight gained into the lack of surface adsorption of some candidate molecules also shut down an industry-based research project which could not have succeeded twelve months ahead of schedule with an estimated saving of [REDACTED] [E1].

Cleaning and deposition in dishwashers: Automatic dishwashing is a [REDACTED] global business. The need for higher efficiency at lower washing temperatures to help reduce energy consumption drives continuous testing and product innovation in formulations and additives. Prof Bain's expertise in the properties of water jets, droplet splashing, spreading and flow on surfaces (e.g. [R4]) was used in two research projects with P&G scientists: Dr Nathalie Letzelter and Dr Rachel Martin to help understand the dishwashing process. This has led to significant down-scaling of P&G test methods and the development of automated test rigs that reduce the testing time for new materials by a factor of five and allowed direct visualisation of the wash process providing an estimated [REDACTED] pa saving [E1]. P&G state that four new (confidential) technologies have been delivered to market that were qualified by the new methods. Total product sales are estimated at [REDACTED] and P&G have filed multiple patents in the area [E1]. Maximising "shine" by controlling deposition of CaCO₃ and other soils is a second key consideration during dish washing. Work under the CEMENT project led to new combination additives [R5] (and patent EP3456808A1,

Automatic dishwashing cleaning composition) and delivered a new experimental rig to P&G for quantifying soil build up. This has reduced formulation testing times from ~2 weeks to 1 day with consequent R&D savings of [REDACTED] pa [E1]. The scientific learnings continue to impact next-generation formulations.

Skin Models: DU Chemistry research into porous polymer scaffolds [R1, 2] created products for 3D cell growth which formed part of a Chemistry REF2014 impact case. The technology has since been bought by the Japanese Company Reprocell and is being sold as the Alvetex® range [E3]. Manufacture and supply of Alvetex® are led by Reprocell Europe within the UK at sites in Sedgefield and Glasgow. Sales in period are [REDACTED] [E4]. P&G, Reprocell and Durham University have entered a partnership for the full commercialisation of a novel model of human full thickness skin developed on the Alvetex® platform [E4]. This partnership enabled the technology-transfer to ReProCell, ensuring its on-going development. Alvetex® was selected by P&G as its preferred platform for robust and reproducible human skin models and they have invested ca [REDACTED] in Alvetex-reliant projects.

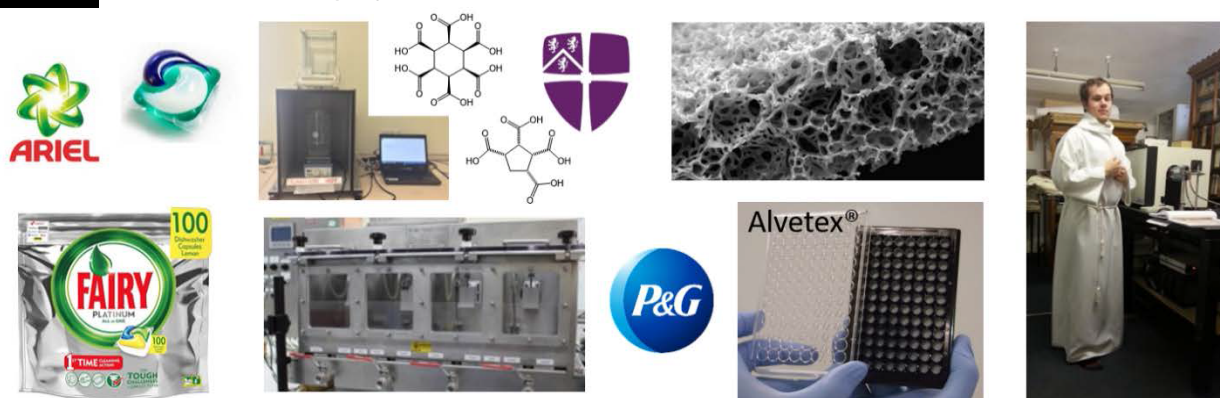


Fig1: (Clockwise) P&G products impacted, new shine ADW test rig and additives, Alvetex® polymers, a P&G/Durham PhD-student "imaging the gospels" and part of the dishwasher test system

Societal and other impacts: While harder to quantify, multiple additional impacts have arisen from the partnership:

- *North East jobs:* Our Regional Growth Fund project *CEMENT* (2011–2016) created + secured 83+195=278 FTE-years (38+91=129 in REF period) in the NE economy within P&G and partner companies such as Peerless Systems [E5]; many of the positions have continued beyond the 2016 formal reporting cut-off. The total salary in-period is ~GBP3.2m. Our *CEMENT* collaboration enabled Peerless to develop then deliver four NE-built 30-pot automated washing systems to P&G sites (total cost GBP1.2m) which has revolutionised formulation testing protocols, saving P&G around [REDACTED] pa per instrument in terms of manpower, water and energy [E6].
- *Policy:* Jeff Weedman (Global Business Development VP at P&G) spoke to US Governors in Washington in 2012 to influence US policy around entrepreneurship. He highlighted how UK universities (citing Durham in particular) were "more competitive, more aggressive, more forward looking, more business friendly" and better set up for interdisciplinary research [E7]. This thinking has helped secure significant subsequent US investment in UK innovation centres in the REF period, which P&G estimate has secured >20 FTE research jobs in the UK [E1]. Durham has received US inward investment of [REDACTED] into research in the period. EPSRC highlighted the partnership in a 2015 case study document [E7].

- *Anti-counterfeit and other devices:* Prof Beeby's spectroscopy expertise [R6] has enabled development of hand-held hyperspectral imaging cameras capable of in-field counterfeit package detection. This has developed into image recognition projects based in computer sciences valued at ██████████. Scanning imaging short wave infrared (SWIR) spectrometers developed at Durham have now being replicated and used in P&G labs (GBP35k ea.) for in-house analysis of garment soil malodour sources, and hand-held devices destined for customer demonstrations of garment cleaning are under development.
- *Outreach spectroscopy and policy:* Soft-matter related outreach activities have reached ~6500 members of the public pa in period via events at Durham Science Festival and Schools Science week staffed by P&G and Durham researchers [E8]. Beeby developed spectroscopic imaging methods to tackle P&G research challenges which have been reapplied in his research with historians [R6]. These have changed UK national policy around acceptable methods of artefact imaging in heritage science [E8]. Associated outreach work on "Imaging the Gospels"; featured on the 9/3/2020 BBC1 Inside/Out show filmed in Durham Chemistry [E8] and has been disseminated in over 20 lectures to groups including the Royal Society, Royal Academy, history groups and libraries.

We summarise with a quote from a P&G Senior Director [E1]: "*...the innovation partnership that Durham has established with P&G has enabled unique and globally scalable innovation that have improved billions of consumers' lives around the world directly supporting the economic, societal and health benefits that our product range enable*".

5. Sources to corroborate the impact

- E1. Letter from an Associate Director at P&G Newcastle to evidence commercially sensitive figures quoted in Section 4. Evidence was derived from a series of interviews held with P&G staff involved in the research described.
- E2. Royal Society of Chemistry Teamwork in Innovation award 2015 citation.
- E3. Alvetex[®] product brochure downloaded from <https://resources.reprocell.com> 29/1/2020 and 2014 REF impact case study.
- E4. Testimonial from CEO of ReProCell evidencing Alvetex[®] sales.
- E5. Summary document of jobs created under RGF funding as submitted to Department of Business Innovation and Skills as part of project audit and CEMENT project output/impact reports D1-D4 April 2014.
- E6. P&G OPTIMAS internal document (confidential).
- E7. Evidence on the impact of partnership on policy: EPSRC 2015 case study: <https://epsrc.ukri.org/newsevents/casestudies/pandgepsrcpartnership/>; The Roberts report; Wilson review, page 26: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/32383/12-610-wilson-review-business-university-collaboration.pdf (2012); Presentation by P&G VP of Global Business Development to US state Governors documenting the importance of industry-academia strategic relationships (<https://www.c-span.org/video/?304528-3/creating-entrepreneurial-culture>, particularly minutes 37 to 45 on the P&G-Durham relationship).
- E8. Examples of Outreach around "Imaging the gospels" includes: <https://eic.rsc.org/feature/the-monks-theses/3007345.article>; <https://www.soci.org/chemistry-and-industry/cni-data/2014/12/illuminating-the-past>. BBC iplayer film broadcast nationally 9/3/2020 (filmed on 30/1/2020). Evidence of change in policy for document illumination safety limits. Evidence for science outreach numbers in annual reports of activities.