

## Impact case study (REF3)

<b>Institution:</b> University of Hull		
<b>Unit of Assessment:</b> 08 Chemistry		
<b>Title of case study:</b> Novel Magnetic Inks – Design, Formulation, Manufacture & Printing		
<b>Period when the underpinning research was undertaken:</b> 01/10/2012 - present		
<b>Details of staff conducting the underpinning research from the submitting unit:</b>		
<b>Name(s):</b>	<b>Role(s) (e.g. job title):</b>	<b>Period(s) employed by submitting HEI:</b>
Professor JD Wadhawan Professor SM Kelly	Professor Special Projects Officer (R&E)	2005 – present 1995 - present
<b>Period when the claimed impact occurred:</b> 01/10/2014 – present		
<b>Is this case study continued from a case study submitted in 2014?</b> No		
<p><b>1. Summary of the impact</b></p> <p>The impact is multifaceted and complex as Benrose Booth Paragon (BBP), a struggling supplier of parking and mass transit tickets, was transformed through collaboration with Hull University to become a world leader, allowing it to achieve financial sustainability (4.1), to give back to the community (4.2) and to develop in-house R&amp;D and manufacturing capabilities, which will sustain these impacts into the future (4.3). BBP increased its workforce (139 to 174) and turnover (£8.7M to £22.8M) between 2014-2016 and, pre-Covid-19, supplied its parent companies with 20 magnetic inks for customers, including UK railways at ca. one billion tickets annually, and the London and Paris mass-transport systems.</p>		
<p><b>2. Underpinning research</b></p> <p>The research underpinning this impact was carried out within a series of externally-funded research projects. These involved the synthesis, purification, characterisation and deposition from stable, aqueous colloidal solutions of inorganic nanoparticles, with a defined physical property spectrum, such as magnetic properties, to thin, stable and uniform films of a defined thickness and resolution on planar substrates, such as paper [R-1-3] and advanced printing techniques [R-4, R-5]. A chemical engineer (Wadhawan) and a chemist (Kelly) created an in-house manufacturing &amp; QA/QC facility at BBP for new, printable magnetic inks for paper tickets with sector-leading performance for information density, complexity, readability over distance (for passive and active tickets) and long-term stability (of data storage).</p> <p><b>Research theme 2.1: Smart tickets for mass transport systems</b></p> <p>This capability is based on research led by Wadhawan and Kelly in the synthesis, characterisation and deposition from aqueous colloidal solutions of nanoparticles from 2012-2020 [R1-3]. Wadhawan's understanding of printing processes for redox-active inks from 2015 [R-4] provided the expertise to fine-tune these parameters for magnetic inks for commercially-viable, high-resolution, volume printing of magnetic inks at the high speeds (60 m/min) required for commercial ticket applications. These specifications include much-improved values for the viscosity, solid content, colour, and minimal coagulation/phase separation of magnetic inks over time in storage. From 2014-2020 Wadhawan, Kelly and the BBP R&amp;D team used this underlying research to optimise a range of magnetic inks with the required values of surface wettability, quick drying, shape-retention and magnetic properties needed to meet different technical specifications and customer requirements over the lifetime of smart, digital tickets [R-5]. The Hull academics created an R&amp;D and production capability at BBP (ParagonID from 2017) that designed, formulated, tested and manufactured new print inks as stable colloidal solutions of magnetic ferrite nanoparticles for smart paper tickets for the mass-transport and carparking markets, for example.</p> <p><b>Research theme 2.2: Radio Frequency Identification (RFID) tags</b></p> <p>Building upon the successful underpinning research on formulating magnetic inks from 2014-2018, the Hull University/ ParagonID R&amp;D team [R-1-5] produced a new ink developed from 2018-2020 that was based on novel stable colloidal solutions of electrically conducting silver nanoparticles. This novel ink will be used to manufacture RFID tags that can be printed on paper and plastic substrates, such as PET, for recyclable identification and device-location-tracking products. Such tags allow the NHS, for example, to manage the allocation of medical equipment, moveable beds, trolleys, etc. These inhouse RFID tags will be qualified for more environmentally-friendly production in 2021 to replace those currently sourced from China. This will shorten the supply chain and re-shore jobs to the UK (Hull).</p>		

**Research theme 2.3: e-Passports and RFID security solutions**

These new RFID tags have also facilitated the development of new generations of smart cards, passports, e-identity cards, etc., with enhanced levels of security and information-content. These developments and capability allowed ParagonID to tender for the printing of passports for Mexico and the USA (October 2020, decisions pending). Wadhawan's research into the electrochemistry of explosive residues (commercially sensitive), coupled with knowledge of electrochemistry of ink dopants [R-4], has also produced a novel ink capable of the detection of explosive residues on tickets (Hull patent invention record 2019), with clear impact potential for security and safety applications.

**3. References to the research**

R-1 RW Bourne, SM Kelly, JD Wadhawan. 2012. Synthesis and characterisation of organic-modified inorganic nanorods, *J. Expt. Nanosci.*, 7, 673.

R-2 NS Alahmadi, JW Betts, F Cheng, MG Francesconi, SM Kelly, A Kornherr, TJ Prior, JD Wadhawan. 2017. Synthesis and antibacterial effects of cobalt-cellulose magnetic nanocomposites, *RSC Advances*, 7, 2020.

R-3 E Halls, KJ Wright, JE Pickersgill, JP Smith, AA Altalhi, RW Bourne, P Alaei, T Ramakrishnapa, SM Kelly, JD Wadhawan. 2012. Voltammetry within structured liquid nanosystems: towards the design of a flexible, three-dimensional framework for artificial photosystems. *Electrochim. Acta*, 70, 215.

R-4 CC Dai, P Song, JD Wadhawan, AC Fisher, NS Lawrence. 2015. Screen-printed Alizarin-based carbon electrodes: monitoring pH in unbuffered media, *Electroanalysis*, 27, 917.

R-5 JD Wadhawan, HJ Ward, TA Armstrong-Telfer, SM Kelly, NS Lawrence. 2020. Evaporation rate measurement as a quality control tool for quality assurance in the manufacture of inks suitable for high speed ( $\geq 60$  m/min) printing. *J. Electroanalytical Chem.*, 872, 114328, 2020.

**Research Grants**

- Innovate UK: *The design, formulation, characterisation and production, on a commercial scale, of colloidal solutions of surfactant-stabilised magnetic micro-particles for deposition*, 01/06/2014 - 30/05/2016 (KTP 009576), £121,942;
- Innovate UK: *The development of innovative and enabling technologies for the detection of dangerous substances in a high-throughput environment: the development of a prototype sensor for an emerging threat, suitable for commercialisation*, 02/04/2018-31/03/2020 (KTP 010844), £122,696.
- EU: SURFUNCELL, 01/12/2008-30/11/2012 (FP7 THEME NMP-2007-2.1-1; Grant Agreement No.: 214653), £415,260.
- EPSRC: *Study of nanocrystal-polymer composites for blue light-emitting diodes*, 01/10/1999-30/09/2002 (GR/M769982), £173,020; *Anisotropic photovoltaic nanotubes*, 31/03/2012-30/03/2015 (GR/N65943), £293,624; *Liquid crystalline hybrid dielectrics for monodomain organic semiconductors*, 31/03/2012-30/03/2015 (EP/J001597/1), £517,190.

**4. Details of the impact**

The impact of this research is significant and its 'reach' is truly large with the result of the work already used millions of times per day in many countries around the world. It has transformed a previously-failing local company (BBP) into a world-leader in magnetic ink production for mass transit and other ticketing and security applications, providing substantial financial and reputational benefits to the company [4.1], as well as significant local economic and societal benefits [4.2]. The introduction of new in-house R&D and manufacturing capabilities within BBP [4.1] has also secured the company's long-term future with a number of new product developments already poised to transform the industry further [4.3].

**Dimension 4.1: Economic and end-user benefits**

The high reputation of the University of Hull's research in colloid-stabilised nanoparticles, printing and magnetic materials led to a collaboration between BBP and the university in 2012 to create an R&D team and an in-house production and QA/QC facility at BBP for the formulation, testing and manufacture of novel printable magnetic inks for the magnetic stripe on the *verso* side of a

ticket to enable automatic reading and ticket validation. The strategic intent behind this collaboration was not only to eliminate a business-critical, single source of failure (as BBP's suppliers of magnetic inks were due to cease trading), but also to create a portfolio of novel magnetic inks with sector-leading performance for each of BBP's market sectors. By 2014 an in-house R&D team and production and QC/QA facility had been created at BBP, alongside optimised printing processes. This capacity was enhanced further via two Knowledge Transfer Partnerships (KTPs) with the University of Hull (ranked 'outstanding' by Innovate UK) [IM-1&2]. The success of this collaboration allowed BBP to acquire its main UK competitor from administration in 2015. Underpinned by its new business model of innovative magnetic ink design, manufacture and optimised printing at its Hull site [IM-3], this market consolidation enabled BBP (named ParagonID from 2017) to develop a larger customer base.

In addition, BBP's (ParagonID's) tickets also developed sector-leading performance that used product-specific low- and high-coercivity magnetic inks from its new production and QA/QC facility [IM-4]. This integrated in-house capability also allowed the company to increase its UK market share, its workforce (from 139 to 174) and its turnover (from £8.7M to £22.8M) between 2014-2016 [IM-3, 4, 5 & 6]. Paragon (ParagonID's parent company) is now the world's largest provider of paper tickets for the transport and car-parking markets using ca. 20 different magnetic inks manufactured @ ca. 200 tons per annum exclusively in Hull. For example, its low-coercivity inks are used for London Underground tickets and its high-coercivity inks are used in Nice Tramway tickets [IM-3, 4, 5 & 6]. Other markets include the UK railway network, at ca. one billion tickets per year, and mass-transport systems in Paris (RATP), New York, Phoenix, Nice, Cairo, Caracas, Tyne & Wear and Canada.

#### **Impact Dimension 4.2: Enriching the ticket-printing sector and local communities**

This highly profitable business allows ParagonID to sponsor business exhibitions, e.g., the Transport Ticket Global conference, January 2021 [IM-7], to encourage other innovators within their sector as well as provide support for local ventures [IM-8]. There have been significant social impacts from the Hull University/ParagonID collaboration, including the creation of a significant number of well-paid, high-tech jobs [IM-3, 5 & 6] in Hull, which is one of the twenty most deprived socio-economic regions in the UK (4.1). Finally, this university-industry collaboration also contributed to BBP's (ParagonID's) growth and development, which provides significant tax revenue and local pride [IM-8].

#### **Impact Dimension 4.3: Increased R&D capability for sustainable market leadership**

ParagonID's collaborations with Hull University have created an outstanding research and innovation capability that drove its rapidly expanding business portfolio. This ongoing relationship will ensure that these developments are sustained into the future. For example, a new ink formulation has been successfully trialled for large-scale printing of Radio-Frequency Identification (RFID) tags at high speeds [IM-9]. These successful large-scale trials demonstrate that these printed RFID tags are cost competitive and more sustainable logistically and environmentally than ParagonID's current RFID tags (produced in China using a costly and environmentally unsustainable etching process). Thanks to these developments, ParagonID recently tendered (October 2020) for several national passport contracts based on these prototype RFID tags that are printed with the new Hull inks.

In the longer term, the new RFID tags will impact across the travel sector as customers' baggage identification is upgraded from simple barcodes to smart RFID tags [IM-9]. Hence, despite Covid-related challenges in the global printed ticket market, the future of this R&D and magnetic ink production facility has been secured by exploiting the research from the two KTPs with the University of Hull (as confirmed by the testimonial/supporting letter from ParagonID's General Manager [IM-10]). These KTPs and their impact also earned a high degree of significant esteem. For example, KTP1 (2014-16) received the Best Business Impact Award at the 2019 'KTP Best of the Best' Awards [IM-11]. KTP1 also won, or was shortlisted for, the following awards:

- 2017 Yorkshire Post Excellence in Business Turnaround Award  
<https://www.businessupnorth.co.uk/bemrosebooth-paragon-celebrates-awards-success/>
- 2018 Yorkshire Business Masters Investment Award  
<https://www.thebusinessdesk.com/yorkshire/news/2017462-shortlist-revealed-for-yorkshire-business-masters-awards-2018>

- 2016 Educate North Awards
- <https://www.prolificnorth.co.uk/awardsevents/featured/2016/03/educate-north-awards-2016-shortlist-announced#table>
- 2016 Times Higher Education Leadership and Management Awards in the Knowledge Transfer Partnership of the Year category  
<https://www.timeshighereducation.com/news/times-higher-education-leadership-and-management-awards-thelmas-2016-shortlist-announced>
- 2017 Yorkshire Business Masters in both the Innovation and International categories  
[https://www.thebusinessdesk.com/yorkshire/news/746269-yorkshire-business-masters-shortlist-revealed?news\\_section=5%29](https://www.thebusinessdesk.com/yorkshire/news/746269-yorkshire-business-masters-shortlist-revealed?news_section=5%29)
- 2017 Made in Yorkshire Awards (in both the Advanced Manufacturer and Manufacturer of the Year categories) <https://www.insidermedia.com/event/made-in-yorkshire/coverage>

Mr HJ Ward, former KTP Associate at BBP; then BBP R&D Project Leader (06/2014-06/2018), and now ParagonID's Technical Development Manager, was also nominated for, or won:

- 2018 Top 30 Under 30 award for the Humber region: <https://www.top30under30.co.uk/alumni>
- shortlisted as 2018 Young Manufacturer of the Year by The Manufacturer magazine: <https://www.themanufacturer.com/articles/the-manufacturer-mx-awards-2018-shortlist-revealed/>

### 5. Sources to corroborate the impact

IM 1a) Knowledge Transfer Partnership 009576 details, between BBP and UoA, available at: <https://info.ktponline.org.uk/action/details/partnership.aspx?id=9576>

IM 1b) KTP 009576 Certificate of Excellence

IM 2a) Knowledge Transfer Partnership 010844 details, between BBP and UoA, available at <https://info.ktponline.org.uk/action/details/partnership.aspx?id=10844>

IM 2b) KTP 010844 Certificate of Excellence

IM 3) Bemrose Booth Paragon Limited. Filing history, available at:

<https://beta.companieshouse.gov.uk/company/04891375/filing-history>

IM 4) Journal paper exemplifying the methodologies developed by the University to support the QA/QC activities of ParagonID:

<https://www.sciencedirect.com/science/article/abs/pii/S1572665720305555>

IM 5) KTP between BBP and UoH, used as a success story by Innovate UK, available at:

<https://innovateuk.blog.gov.uk/2019/05/03/research-post-graduates-cant-help-my-business-or-can-they/>

IM 6a) Impact case study in Kingston upon Hull at: <https://www.hull.ac.uk/work-with-us/business/case-study/paragon-id/>

IM 6b) Impact case study in Kingston upon Hull at:

<https://bdaily.co.uk/articles/2016/05/26/bemrosebooth-paragon-creates-20-new-jobs-after-investing-in-its-hull-facility/>

IM 7) Evidence of ParagonID's wider contribution to the ticket printing sector:

<https://www.transport-ticketing.com/meet-our-sponsors-and-exhibitors> & <https://www.transport-ticketing.com/>

IM 8) Evidence of ParagonID's community engagement, available at:

<https://www.hulldailymail.co.uk/news/business/paragon-id-backing-teenagers-bizarre-1629264>

IM 9) Promotional page for RFID tags developed by ParagonID

<https://www.rfiddiscovery.com/inspiration/rfid-vs-barcode>

IM 10) Testimonial letter from ParagonID's General Manager confirming the invaluable impact that Hull's research and collaboration has had on ParagonID's business

IM 11) Business Impact Award 2019 for the KTP between BBP and UoH, available at:

<https://www.gov.uk/government/news/ktp-best-of-the-best-2019-winners-announced>