Institution: Coventry University		
Unit of Assessment: 12		
Title of case study: Using wettability science to enhance industrial processes		
Period when the underpinning research was undertaken: 01/01/2018 – 30/08/2019		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
David Waugh	Associate Professor	06/01/2017 – present
Jonathan Lawrence	Professor	01/03/2017 – present
Period when the claimed impact occurred: 01/02/2019 – 01/04/2020		
Is this case study continued from a case study submitted in 2014? No		

1. Summary of the impact (indicative maximum 100 words)

Research conducted at Coventry University determined the importance of droplet volume on analysing wettability and adhesion properties of liquids on porous media and demonstrated the importance of wetting transitions and mixed state wetting regimes for adhesion applications. Global manufacturers and distributors of surface and interfacial science measurement equipment used this research to increase their commercial offerings to clients in the ink-jet printing industry and to change their marketing strategy. In addition, the research has enhanced the research and development of inks and substrates, and wettability analysis techniques have been implemented by these clients to enhance product development and manufacturing processes.

2. Underpinning research (indicative maximum 500 words)

Dr David G. Waugh (Associate Professor) and Professor Jonathan Lawrence at the Coventry University Institute for Advanced Manufacturing and Engineering conduct fundamental and applied research in wettability science and adhesion science. Dr Waugh and Professor Lawrence were invited to collaborate with DataPhysics Instruments GmbH to provide wettability expertise to optimise their ink development process for the ink-jet industry. Their research showed the importance of liquid droplet size for applying wettability science to the development of inks and substrates using the DataPhysics Instruments picolitre droplet dispensing system (PDDS) [R1]. This research determined the variation in contact angle on porous media using microlitre, µL (0.2-5 µL), and picolitre, pL (15-380 pL), droplets for wettability analysis. By successfully applying picolitre droplet volume wettability analysis to develop wetting envelopes, this approach was shown to predict ink-jet printing quality accurately and highlighted how the PDDS can be used to emulate ink-jet printing for ink and substrate development. The impact of absorption and evaporation on different droplet volume sizes used, also demonstrated that both absorption and droplet volume are key when analysing inks on porous printing substrates [R1].

Dr Waugh and Professor Lawrence have carried out an extensive study into the effects of surface engineering on wetting surface parameters, such as wetting transitions and mixed state wetting regimes [R2]. It was found that the contact angle and determination of associated surface-free energies (the combined surface properties determining adhesion) can be used to provide important information on the adhesion properties of materials for different applications [R2, R3]. This key knowledge is having significant impact in those industries which rely heavily on adhesion science. The research has also been effective in highlighting how surface properties of materials can be modified, optimizing a material for specific applications such as bioengineering and developing bio-implant materials [R3].

The research on PDDS and wetting surface parameters has enabled DataPhysics Instruments to enhance their own research and development processes optimising the approach to applying wettability and adhesion science to not only the ink-jet industry, but more widely to other industrial applications. This has also led to the industry to achieving a better understanding of state-of-the-art knowledge in wetting.

3. References to the research (indicative maximum of six references)

(R1) Gruber M., Waugh D.G., Lawrence J., Langer N., Scholz D. (2019) 'On the droplet size and application of wettability analysis for the development of ink and printing substrates', *Langmuir*, 35, 12356-12365. https://doi.org/10.1021/acs.langmuir.9b01674

(R2) Waugh D.G., Lawrence J., Langer N. and Bidault S. (2018) 'Mixed-State Wetting and Wetting Transitions on Laser Surface Engineered Polymeric Materials', International Journal of Wettability Science and Technology (IJWST), 1, 63-84.

(R3) J., Previtali B. (2019 Menci G., Demir A.G., Waugh D.G., Lawrence) 'Laser surface texturing of β-Ti alloy for orthopaedics: Effect of different wavelengths and pulse durations', *Applied Surface Science*, 489, 175-186. https://doi.org/10.1016/j.apsusc.2019.05.111

4. Details of the impact (indicative maximum 750 words)

The major impact of this research has been its use by DataPhysics Instruments GmbH, C. Gerhardt UK Ltd, and their clients who operate in a number of industries. The collaboration between Dr Waugh, Professor Lawrence and DataPhysics Instruments has enabled a shift in research and development practice in the ink-jet and textile printing industries. As a result of the Coventry University research, there has been Impact on Research and Development strategies, as well as changes in Marketing strategies with Commercial benefit to DataPhysics Instruments and Gerhardt Ltd. New sales have been generated as a direct result of the implementation of the research findings.

Impact on Research and Development strategies

As a result of the Coventry research, a new best-practice approach has been made available by DataPhysics Instruments, offering an optimised picolitre wettability science analysis to ink and substrate research and development. This has provided new industrial capability in the form of an application to ink jet research and development, utilising picolitre volume droplets and their newly developed picolitre droplet dispensing system (PDDS). Identifying and developing this new application for the PDDS has had direct impact on the speed and quality of research and development output for a number of industry consumers. Not only can industry now use wettability science and the wetting envelope model to ascertain whether a developed ink is optimised more quickly, they can also make use of this knowledge to determine optimum liquid and substrate parameters needed, based on the printing application. Ultimately, this provides a faster and more efficient means to determine the optimised parameters for inks and substrates. The Managing Director of DataPhysics Instruments writes:

"Increased understanding of the importance of droplet volume provided by this research, has enabled us to increase our commercial offering to ink jet industry companies and textile printing companies, who require a more efficient and enhanced way to carry out their research and development, allowing them to accelerate the development of new inks and printing substrates, ready for market." [S1]

Impact on Marketing Strategy and Commercial sales

Dataphysics Instruments equipment can be applied to any and all areas of wettability and adhesion. These include, but are not limited to, ink jet printing, non-stick technologies, anti-icing

and de-icing technologies, water harvesting, electrical engineering and electronics and resin preservative treatments. The research on the PDDS system has enabled DataPhysics Instruments to reinvigorate their marketing strategy for this ink dispensing system. The DataPhysics Instruments Sales and Applications Teams have been able to inform their clients of the benefits of using picolitre droplet technologies, within their research and development departments. Direct commercial impact has been achieved through additional sales generation and increased revenue. The Managing Director of DataPhysics Instruments adds:

"In particular, we have been able to exploit the research to demonstrate a new application for our picolitre droplet dispensing system (PDDS) and how that can be used to enhance the development of inks and printing substrates." [S1]

In relation to sales and sales strategy, he states:

"This has informed our new marketing strategy for the PDDS systems, which includes this capability. On the strength of this, we have secured an additional 195,000 Euro (approximately £170,000) sales and generated a notable and promising increase in sales enquiries." [S1]

Similar commercial impact has been achieved for one of DataPhysics Instruments' distributors. The Product Manager at Gerhardt Ltd writes:

"By using and showcasing the research works listed to different industries, such as polymer/metallic component manufacture and adhesive manufacture and use, we have been able to achieve an increase in sales enquiries of 25%." [S2]

A renewed marketing strategy, underpinned by the Coventry University research, has garnered both increased sales enquiries and actual sales for Gerhardt Ltd. The Product Manager at Gerhardt Ltd states:

"I would immediately identify two significant sales, one to a speciality chemical manufacturer and one to a carbon fibre recovery/reuse company, where we gained tangible benefit from being able to reference the adhesion/wettability work featured in the above IJWST paper. Each of these sales represented investments of over £30k, for the companies involved and I am confident that the commercial advantage that they have gained, within their fields of operation, have returned that investment many times over." [S2]

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

(S1) Testimonial letter from Managing Director, DataPhysics Instruments GmbH, Raiffenstrasse 34, 70794 Filderstadt, Germany

(S2) Testimonial letter from DataPhysics Product Manager, C. Gerhardt UK Ltd, 5 Avonbury Court, County Road, Brackley, Northamptonshire, NN13 7AX, United Kingdom