Institution: London South Bank University

Unit of Assessment: General Engineering

Title of case study: Commercialisation of a novel close-chamber technology for water vapour flux density measurements in skin.

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

This case study relates to research that has had an economic and application impact through the continued operation of a University spin out company, Biox Systems Ltd. The success of the Company's AquaFlux device for measuring aspects of skin barrier performance has, since 2008, resulted in:

- Sales of 148 instruments producing revenues of £1.37million and net profits of £190k;
- Exports into 15 countries accounting for 82% of revenues;
- Significant reinvestment (£200k) in new product development;
- 3 new full time technical level jobs.

Access to AquaFlux has enabled commercial and R&D organisations, including health care, household product and cosmetic industries, to gain better insights into the performance of their products. AquaFlux has been cited as the "gold standard" for Trans-Epidermal Water Loss (TEWL) measurement.

2. Underpinning research (indicative maximum 500 words)

The research underpinning this impact case study was carried out by the Photo-physics Research Group at London South Bank University (LSBU) between 1994 and 2007 led by Prof Robert Imhof (Professor of Photo-physics, retired 2010 and now Emeritus Professor at LSBU) and Dr Perry Xiao (Research Fellow (1998-2000) and Lecturer at LSBU from 2000).

Opto-thermal transient emission radiometry (OTTER) is a relatively recent infrared remote sensing technology [1]. Research into the uses of OTTER in a range of applications, including skin characterisation, was funded through grants from the BBSRC (95/A3/E/00440, 1995-1998, £30k). EPSRC (GR/K65027/01, 1996-1998, £120k; GR/L25325/01, 1997-1999, £60k; GR/L96233/01, 1998-2001, £183k; and GR/M56722/0, 1999-2002, £54k) and the Royal Society (2000-2001; £10k).

In collaboration with industrial partners, e.g. Unilever, L'Oreal and GSK, research has led to OTTER being developed for skin water content, skin pigment profiles, and trans-dermal drug delivery measurements. As TEWL provides an important index for skin barrier function, and is related to skin water content, TEWL measurements were often performed along with OTTER measurements. It was found that existing open-chamber based TEWL measurement instruments were difficult to use, measurement results were noisy, unreliable and subject to external influences e.g. ambient temperature, relative humidity and air movement.

As a consequence, a novel condenser based close-chamber technology for TEWL measurement was conceived and developed (1998-2000) based upon a cylindrical measurement chamber, with one end closed with a cold plate, frozen to below zero degrees, and with the other end in contact with the surface of interest. Water vapour from this surface enters the measurement chamber and diffuses towards the opposite end, where it is removed by freezing onto an electronically cooled condensing surface. The condenser creates a diffusion vapour density gradient, and according to Fick's first law of diffusion, the flux density can be determined from the gradient of vapour density [2].

Compared to other conventional TEWL technologies, the new condenser design was found to be easy to calibrate and its measurements were independent of external environments, resulting in low measurement noise, increased sensitivity and reliability, as well as good repeatability and comparability. LSBU was granted a US Patent for the technology in 2000 [3].

In 2002, the research resulted in the development of new data analysis techniques to allow the

instrument to perform not only TEWL measurements, but also skin surface water loss (SSWL) measurements. The research has also led to the development of new mathematical models and algorithms, hardware adaptors for material desorption and membrane permeability measurements, as well as for the measurement of water loss through fingernails, and in-vitro Franz cell membrane integrity testing.

In 2003, research resulted in a new sensor technology being designed and developed which further improved the sensor's response to water vapour**,** and protected the sensor from potential physical damage and contamination [4]. In 2007, a new methodology for studying skin water holding capabilities and skin water diffusion coefficients by combining OTTER measurements with TEWL measurements [5] was developed.

There continues to be a close relationship between Biox and the University, from which the Company benefits. For example, in 2008, the Group's research resulted in new software that was subsequently acquired and used by Biox to improve the speed, reliability and ease of use of its AquaFlux device; in 2010, new protocol control and fast algorithms were deployed, allowing the instrument to manage data in large clinical trials and reduce the measurement time.

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

[1] Imhof, R.E. McKendrick, A. D. and Xiao, P. "Thermal emission decay Fourier transform infrared spectroscopy", Rev. Sci. Instrum., Vol. 66, No. 11, 5203-5213, 1995. Doi: 10.1063/1.1146151

[2] Imhof, R.E., O'Driscoll, D., Xiao, P. and Berg, E.P."New sensor for water vapour flux. In: Sensors and Their Applications" (Augousti, A. T. and White, N. M., eds), pp. 173–177. Taylor and Francis, London (1999).

[3] US Patent 6439028 (2000). Method and Equipment for Measuring Water Vapor Flux from Surfaces.

[4] Imhof, R.E. Method and Equipment for Measuring Water Vapor Flux from Surfaces. Patent Application PCT/GB03/00265 (2003).

[5] Xiao, P., Packham, H., Zheng, X., Singh, H., Elliott, C., Berg, E.P. and Imhof, R.E., "Opto-Thermal Radiometry and Condenser-Chamber Method for Stratum Corneum Water Concentration Measurements", Appl. Phys. B, 86, 715-719, 2007. Doi: 10.1007/s00340-006-2541-2

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

This case study relates to research that has delivered an economic impact through the continued success of a University spin-out, Biox Systems Ltd. Biox was created in 2000 as a special purpose vehicle to bring to market a novel, more versatile and reliable TEWL measurement instrument, Aquaflux.

With close and continued input from the Group's research, Biox has, since 2008, continued to invest and develop in what has been independently described as the "gold standard" device for TEWL measurement [1].

The Biox Aquaflux instrument is being deployed globally by world leading research and commercial organisations in the health, cosmetics and consumer goods sectors, for example, Unilever, Proctor and Gamble, Gillette, Colgate-Palmolive, Boots, Pierre Fabre Dermocosmestique (France), International Speciality Products (USA), the Universities of California, Heidelberg and Manchester, and the National Physical Laboratory [2].

Based upon the research findings and, specifically, the promise shown by the novel condenser based close-chamber measuring technology, Professor Imhof and LSBU agreed to commercialise the technology through a spin out company. Biox Systems Ltd was incorporated in 2000.

Since 2008, the Company has [3]:

- Generated sales of 148 Aquaflux instruments producing revenues of £1.37million and net

profits of £190k;
- Exported into 15 countries accounting for 82% of revenues;
- Established a sales and support agency network overseas e.g. USA, and China;
- Reinvested (£200k) in new product development;
- Created 3 new full time technical level jobs;
- Delivered consultancy and training to over 50 organisations on the science and performance benefits of AquaFlux;
- Provided 4 graduate internship opportunities each year to students from the UK, France and Spain.

Independent consultants have solicited feedback from users of Aquaflux [1]. This has affirmed the instrument's market leading position and performance capabilities. Testimonial evidence includes:

- A senior technologist at Proctor and Gamble stated that they have 12 Aquaflux instruments and have found AquaFlux to be the best instrument on the market in terms of accuracy and repeatability. P&G have employed AquaFlux to support the testing and development of household brands in areas such as baby care, laundry and beauty products. He further commented that because AquaFlux is built on good scientific principles, it is the standard reference machine used in P&G and in European multi-centre trials.
- A second independent consultant with over 20 years skin-related research experience and a visiting professor at the School of Pharmacy, UCL, commented that AquaFlux represents the "gold standard" for TEWL. He went on to state that there are requirements from the Advertising Standards Authority (ASA) in the UK for manufacturers to provide evidence to support product claims via Clearcast. AquaFlux provides such companies with confidence about the robustness of their claims.
- A project leader at LTS Lohmann stated that the AquaFlux instrument is used in research and development. It is used to measure the quality of animal and human skin prior to Vitro permeation studies to test transdermal formulations. The AquaFlux is less sensitive to environmental conditions compared to competitor systems and thus speeds up trials and reduces costs.

Further testimonials showing the versatility of the Aquaflux device include [2]:
- *"In our Institute we are using the Aquaflux in an unusual application to evaluate the water behaviour of fabrics and textile components"* – R&D Projects Manager, IFTH, France.
- *"We are exploring with this equipment the quantification and early detection of malfunctioning sudomotor neurons in patients suffering e.g. diabetic neuropathy, CRPS, small fibre neuropathy... which may contribute to a new diagnostic clinical tool"* – Senior researcher in the Department of Anaesthesiology and Intensive Care Medicine, University of Heidelberg

Use of AquaFlux has been instrumental in a number of important discoveries. In a recent example (2012), a senior researcher at St John's Institute of Dermatology, Kings College, London, commented that the AquaFlux was selected for a special study as a result of its world-leading reputation. The study involved 1,302 participants and investigated the prevention of food allergies in young people in collaboration with the Food Standards Agency and MRC EAT (Enquiring About Tolerance). The researcher found that AquaFlux was a highly accurate instrument to identify levels of water loss in skin as an indicator of food allergies [4]. The researcher also stated that AquaFlux was instrumental in their "fundamental finding" that skin barrier properties of 3-month old infants are similar to those of adults [1]. This finding will benefit the understanding and potential treatment of skin allergies in infants.

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

[1] Report of independent consultants (The Innovation Partnership, 2013): Contact: Managing Director, The Innovation Partnership (tipl@innopartners.com). Provides interviews with 4 purchasers of AquaFlux and their views on its benefits and efficacy

[2] www.biox.biz – provides information on AquaFlux and customer testimonials received since 2008
[3] Contact: Chairman, Biox Systems Ltd (info@biox.biz)
[4] www.eatstudy.com.