

<b>Institution:</b> University of Cambridge
<b>Unit of Assessment:</b> UoA12
<b>Title of case study:</b> AgaMatrix
<b>1. Summary of the impact</b> (indicative maximum 100 words)  Research into electrochemical biosensors conducted at the University of Cambridge between 1998 and 2002 led to the development of the WaveSense™ line of diabetes products by start-up, AgaMatrix. By 2012 AgaMatrix had sold 3M glucose meters & 3B biosensor test strips worldwide across 20,000+ retail locations including Boots UK, and since 2010 also globally in partnership with Sanofi. [text removed for publication] AgaMatrix UK continues to grow its business with compound annual growth rates for revenue in excess of 100%. Agamatrix UK now supplies over one million glucose test strips per month to the NHS. Agamatrix has developed >10 FDA-cleared products since 2008, including the first FDA approved smartphone linked diagnostic device.
<b>2. Underpinning research</b> (indicative maximum 500 words)  The research on electrochemical biosensors was done in Professor Lisa Hall's lab in the then Institute of Biotechnology (now merged with Department of Chemical Engineering) at the University of Cambridge between 1998-2002. Hall joined the Institute as a Lecturer in 1985 before promotion to Reader in 1999 and Professor in 2003. Her group looked at biosensor construction from first principles and proposed alternative formats and measurement regimes to those currently adopted. Some of the underpinning aspects of this research received EPSRC funding and were undertaken by two PDRAs and a Marshall Scholar in Hall's group; Dr. Ian Harding, Research Associate from 1997 to 2001, now Technology officer at Agamatrix, Dr. Justin Gooding Research Associate from 1994 to 1996, now Professor at University of New South Wales and Sridhar Iyengar, Marshall Scholar 1998-2002 now Chief Technology Officer at AgaMatrix.  The idea emerged through Professor Hall's research on signal deconvolution using alternating potential wave techniques in electrochemistry where she showed mechanistic detail in enzyme linked biosensors for the first time (ref 1). This was reinforced by modelling of flow and diffusion characteristics, enzyme immobilisation, etc. with the outcomes rejecting many previous assumptions from others that used an invalid theoretical approximation, based on an incorrect assumption of uniform concentration gradients. The work provided key insight for development of an improved glucose biosensor (ref 6).  Building on this, the concept proposed by Professor Hall was that better signal processing and deconvolution would overcome the limitations identified and deliver a glucose measurement with greater integrity in an electrochemical biosensor (ref 1-5).  At the time, common practice was to apply a fixed voltage stimulus to the electrochemical sensor and measure a steady-state current. This was a simple method to determine the concentration of glucose, but accuracy depended on many factors being constant and known a priori (e.g. no chemical interferences in the sample, known electrode area, etc.). However, in real samples, many quantities are not known, and in the case of blood samples, there may be many interfering substances such as Vitamin C or paracetamol.  The principle inspiration for this impact focused on time-varying sinusoidal voltage waveforms to stimulate the electrochemical glucose sensor and generate a reciprocal sinusoidal response current, thereby enabling the extraction of time constants related to the electrochemical reactions that were either specific to the glucose reaction or to an interfering substance (such as Vitamin C). The time-varying nature of this approach inherently generated a measureable signal that contained more rich information (as compared to a steady-state response as was the common case at the time), and thus subsequently allowed for the separation of the desired glucose signal from the interfering signal.

## Impact case study (REF3b)

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

\* Indicates those references which best demonstrate the quality of the research

1. Iyengar S, Hall E A H, Skinner N G & Gooding J J. Frequency Domain Selection of the peroxide signal for Amperometric Biosensors. *Electroanalysis* 1998, 10(16), 1089 - 1095. DOI: 10.1002/(SICI)1521-4109(199811)10:16<1089::AID-ELAN1089>3.0.CO;2-M
2. \*Iyengar S, Hall EAH Data from overlapping signals at an amperometric electrode using admittance vectors. *J Electroanal Chem* 2002, 521, 61-71. DOI:10.1016/S0022-0728(01)00732-X
3. \*Iyengar S & Hall E A H. Phasor transform to extract glucose and ascorbic acid data in an amperometric sensor. *Analyst* 2000, 125, 1987-1992 DOI: 10.1039/B005967F
4. \*Iyengar S, Hall EAH Selective monitoring of the hydrogen peroxide signal in the presence of ascorbic acid. Part II: Preliminary practical realization of applying immittance spectroscopy. *Electroanalysis*, 2001, 13 (7), 517-523. DOI: 10.1002/1521-4109(200105)13:7<517::AID-ELAN517>3.0.CO;2-U
5. Iyengar S & Hall E A H. Selective Monitoring of the Hydrogen peroxide Signal in the Presence of Ascorbic Acid: part I: Theoretical Considerations. *Electroanalysis* 2001 13 (6), 437-444. DOI:10.1002/1521-4109(200105)13:73.0.CO;2-U
6. Harding I S & Hall E A H Designing the 'fill and flow' (bio)sensor to give stable measurements from a dynamic system *Sensors & Actuators* 2000, 63, 186-194. DOI: [http://dx.doi.org/10.1016/S0925-4005\(00\)00356-7](http://dx.doi.org/10.1016/S0925-4005(00)00356-7)

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

AgaMatrix was founded in 2001 to develop the research findings described above. Three members of Professor Hall's research team were involved in the foundation: Dr. Iyengar led the foundation as CTO, Dr. Harding underpinned the core technical team and Professor Gooding acted in a consulting and collaborative role. Professor Hall was on the Advisory Board. The company generated specific IP by building on Professor Hall's concept of applying a time-varying input control and better signal processing and analytics to the signals generated from an electrochemical glucose biosensor and developing noise-cancellation algorithms to improve the accuracy and reliability of medical devices. AgaMatrix developed this concept into the WaveSense™ branding. Agamatrix now manufactures a line of diabetes products that features the "WaveSense" technology, using the concept of waveform control to detect and correct for errors caused by differences in blood samples and environmental conditions. Products include the WaveSense KeyNote™ (launched 2006 and still available) Presto™ (2007 still available), and WaveSense Jazz™ (Blood Glucose Monitoring device, or BGM, (2008)), and the WaveSense Diabetes Manager™ iPhone® App (2009), an iPhone-connected BGM sold by Sanofi under the brand iBGStar, and a stand-alone BGM for Sanofi called the BGStar. Agamatrix has developed >10 FDA-cleared products in the census period, protected by a suite of more than 120 pending and granted patents worldwide (ref 7).

In March 2010 AgaMatrix and sanofi-aventis entered into an agreement to co-develop innovative solutions in diabetes management that also incorporate WaveSense™ technology. The BGStar and iBGStar range of BGM devices have been developed out of that alliance using "WaveSense" as the sensing platform. The iBGStar was launched in Europe in 2010. In December 2011, the US FDA approved the iBGStar, the first approval by the FDA of a smartphone linked diagnostic device (ref 7).

[Text removed for publication]

## Impact case study (REF3b)

## Key impact points:

- Invented and manufactured first iPhone-connected glucose meter for diabetic patients sold by Sanofi as the “iBGStar”—which was covered by the New York Times and Daily Mail and is now for sale at Boots (ref 8, 13-14).
- Out of 15,000 health/fitness/medical apps in the iTunes app store, fewer than 75 have received FDA clearance, and even fewer have developed regulated hardware. This puts AgaMatrix into an elite group of companies at the forefront of telehealth products targeted towards patients.
- The iBGStar won the prestigious Red Dot and Good Design awards for product innovation — an honor shared by Apple, BMW, Mercedes, and Bose. Products featuring AgaMatrix technology have also been honoured by Consumer Reports as “Best Buy” options in their category.
- AgaMatrix products are available for sale in over 20,000 pharmacies and retailer outlets across the globe.
- Post-market studies show products featuring AgaMatrix technology already exceed the recently released ISO standards for home glucose monitoring accuracy (within 20% of a standard lab test), achieving closer to within 10% of a standard lab test (ref 12). The ‘Up and Up’ branded product sold through Target has received commendations for its accuracy, affordability and convenience (ref 9).
- Established a UK subsidiary in the Harwell Innovation Park in 2007 with one Technology Leader and since 2008 has expanded to employ nine full time staff
- As an example of cost savings to the NHS, the Staffordshire *Sentinel* reports that 7500 new Agamatrix WaveSense Jazz meters will be given to patients in Staffordshire in 2013, resulting in a total savings of £350,000 (ref 10,11). By scaling the estimated savings to a total population of 80,000, the total savings may be estimated to be £4M /year and growing. This assumes that each PCT experiences the same overhead savings that Staffordshire experiences.

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

7. CTO, Agamatrix  
Statement on file

8. New York Times coverage, including FDA approval: [http://www.nytimes.com/2012/02/23/technology/personaltech/monitoring-your-health-with-mobile-devices.html?\\_r=4&](http://www.nytimes.com/2012/02/23/technology/personaltech/monitoring-your-health-with-mobile-devices.html?_r=4&)

9. *Consumer Reports* calls AgaMatrix Technology “Best Buy”  
PDF on file

10. Devices and Diagnostics Report 2012  
PDF on file

11. Savings to the NHS based on the article below:  
<http://www.thisisstaffordshire.co.uk/Gadget-choice-cuts-risk-7-500-diabetics/story-18510795-detail/story.html#ixzz2OYOxhd9w>

12. Prominent Diabetes Blog confirms accuracy:  
<http://www.diabetesmine.com/2012/09/why-meters-cant-tell-us-our-blood-sugar-levels.html>

13. Boots:  
[http://www.boots.com/en/iBGStar-blood-glucose-meter\\_1253400/](http://www.boots.com/en/iBGStar-blood-glucose-meter_1253400/)

14. Daily mail coverage:  
<http://bit.ly/A2WdaE>

15. [www.iBGStar.us](http://www.iBGStar.us)

**Impact case study (REF3b)**

16. Fast Company Calls AgaMatrix iPhone Meter “Revolutionary”  
<http://www.fastcodesign.com/1662351/first-look-iphone-add-on-is-a-revolutionary-product-for-diabetics-video>