Institution: Imperial College London

Unit of Assessment: 8 Chemistry

Title of case study: C2 - The BioLED™ microanalysis technology: Molecular Vision Ltd

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

Molecular Vision Ltd ("MV"), which was spun-out of Imperial Innovations, develops simple-to-use, point-of-care diagnostic devices (known as the BioLED™ platform) that quickly produce lab-quality information from a single sample of bodily fluids. Since 2008 MV has validated the platform, including demonstration of its Cardioplex™ triple test for myoglobin, CK-MB and troponin-I in a serum sample, and undertaken >£1.5M of contract work for a variety of customers including Acrongenomics Inc, Microfluidic ChipShop and L'Oreal; addressing analysis problems relating to kidney and cardiac health, pathogen identification and cosmetics. During the REF period the Company has generated a total of over £3.4m in investment, contract revenue and non-UK grant funding and created greater than 50 man years of UK employment, primarily at the PhD level. Abingdon Health Group acquired a majority stake in MV in 2012 as part of its strategy to create a fully integrated business in the UK that is able to compete in the large and global immunodiagnostics market.

2. Underpinning research (indicative maximum 500 words)

MV was founded in 2001 to develop and commercialize instrumented, lab-on-a-chip, microanalysis systems invented at Imperial College London by Professors Andrew and John de Mello (Chemistry Department) and Donal Bradley (Physics Department). This innovation was informed by long-term research undertaken by Bradley and John de Mello on organic light emitting diodes (OLEDs) and photodiodes (OPDs) and by Andrew de Mello on microfluidic chip structures. The resulting Imperial College intellectual property (IP), focused on the combination of OLEDs and OPDs with microfluidic structures, is protected by granted patents including GB 2369428, US 6,995,348 and EP 1336089, assigned to MV by Imperial Innovations.

Initial research at Imperial College underpinning the BioLED technology was funded by EPSRC [G1] and by MV, supported by a BBSRC Small Business Research Initiative grant [G2]. This involved both Imperial College and MV staff and Imperial students using facilities in the College. It proved the principle of the BioLED platform and demonstrated the competitive performance of OLED and OPD instrumented microfluidic structures. The first application of polymer OLEDs as light sources for microchip based fluorescence detection, the fabrication of dye-doped microfluidic structures that integrate an efficient long-pass filter function and the use of polymer OPDs as detectors for microscale chemiluminescence resulted from this work [1-3].

By mid-2006, MV had signed a development contract with Acrongenomics Inc to work on kidney function, cardiac markers and sexually transmitted diseases, with an initial focus on the detection of microalbuminuria (a kidney disorder). It had also moved into the Imperial Bioincubator to establish its own > £275K R&D facilities to develop BioLED prototypes and test them on bodily fluids. Bradley and Andrew de Mello were appointed Founder Directors and John de Mello Chief Scientific Officer (CSO), later joining the MV Board also. Close research collaborations between the founders and MV have continued until the present day and resulted in a further 2 BioLED focused journal papers (DOI: 10.1016/j.snb.2004.10.005 and 10.1039/b313503a, 133 ISI citations). These address the use of polymer OPDs as detectors for microscale chemiluminescent antioxidant capacity screening (2009) and an optimized system for fluorescence immunoassays for cardiac markers myoglobin and CK-MB as an early diagnostic of myocardial infarction (2011). Additional work and publications between Imperial and MV have covered the development of low cost, high performance optical filter technology for use with diode-based sensors, see e.g. [4]. MV also secured NHS Health Technology Device funding for collaboration with Imperial, Acrongenomics and Pearson Matthews - a design development company specializing in the healthcare sector - to develop prototype diagnostic devices. A PDA-based USB powered demo was shown in early 2007 and a battery powered version with a built-in display followed late the same year. Eight conference papers also resulted from the BioLED focused research at Imperial between 2004 and 2008.

A second strand of research concerned materials development and fabrication methods for OLED and OPD devices, respectively vapour-phase polymerized poly(3,4-ethylenedioxythiophene) (VPP-PEDOT) as an ITO-replacement electrode and interlayer lithography [5,6]; funded by [G1]. The resulting fabrication IP was the subject of a patent filing GB/GB0523437.2 that was successfully licensed (July 2007) to MV for use in the medical diagnostic sector. This research underpinned the development of flexible substrate devices that enabled the participation of MV in contract work for Microfluidic ChipShop and sub-contracted work for Cambridge Display Technology (TSB OPALS project). In 2007, a Royal Society Brian Mercer Award for Innovation to Bradley and John de Mello [G3] co-funded a project with MV and Imperial Innovations to develop further the interlayer lithography method and a stamp transfer printing process that had been developed by Bradley and co-workers in the physics department. The Brian Mercer Award also supported development of the VPP-PEDOT electrode system. Eight additional papers (137 citations) resulted.

Key personnel:

- Prof Andrew de Mello, RF, lecturer then Prof of Chemical Nanosciences Imperial College London, 1997-2011 (with Chemistry) and 2013-present (with the Faculty of Medicine)
- Prof John de Mello, Prof of Nanomaterials, Imperial College London, 2000-present
- Prof Donal Bradley, currently Vice-Provost (Research), Imperial College London, 2000-present

3. References to the research (* References that best indicate quality of underpinning research)

N.B. publication of journal articles was generally delayed to accommodate patent protection and technology development projects.

[1] O. Hofmann, X. Wang, J.C. deMello, D.D.C. Bradley, A.J. deMello, "*Towards Microalbuminuria Determination on a Disposable Diagnostic Microchip with Integrated Fluorescence Detection Based on Thin-film Organic Light Emitting Diodes*", Lab. Chip, 5, 863-868 (2005). DOI, **47 citations (as at 21/7/13)**.

[2] * O. Hofmann, X.H. Wang, A. Cornwell, S. Beecher, A. Raja, D.D.C. Bradley, A.J. de Mello & J.C. de Mello, "*Monolithically Integrated Dye-doped PDMS Long-pass Filters for Disposable On-chip Fluorescence Detection*", Lab. Chip, 6, 981-987 (2006). DOI, **71 citations (as at 21/7/13)**.

[3] * X.H. Wang, O. Hofmann, R. Das, E.M. Barrett, A.J. de Mello, J.C. de Mello, and D.D.C. Bradley, "*Integrated thin-film polymer/fullerene photodetectors for on-chip microfluidic chemiluminescence detection*", Lab. Chip, 7, 58- 63 (2007). DOI, **44 (as at 21/7/13)**.

[4] M. Yamazaki, O. Hofmann, G. Ryu, L. Xiaoe, T. K. Lee, A. J. deMello and J. C. deMello, "*Non-emissive colour filters for fluorescence detection*", Lab Chip, 11, 1228-1233 (2011). DOI, **4 citations (as at 21/7/13)**.

[5] * J. Huang, P. F. Miller, J. S. Wilson, J.C. de Mello, A.J. de Mello, D.D.C. Bradley, "*Investigation of the Effects of Doping and Post-Deposition Treatments on the Conductivity, Morphology, and Work Function of Poly(3,4-ethylenedioxythiophene)/Poly(styrene sulfonate) Films*", Adv. Funct. Mater., 15, 290-296 (2005). DOI, **137 citations (as at 21/7/13)**.

[6] J. Huang, R. Xia, Y. Kim, J. Dane, O. Hofmann, X. Wang, A. Mosley, A.J. de Mello, J.C. de Mello, D.D.C. Bradley, "*Patterning of Organic Devices by Interlayer Lithography*", J. Mat. Chem., 17, 1043-1049 (2007). DOI, **34 citations (as at 21/7/13)**.

Grants:

[G1] EPSRC, GR/R58949/01, 'Polymeric Detection System for Microanalysis', 01/04/02-31/03/05, PI: AJ de Mello, Co-Is: Bradley and J de Mello, £ 521,390.

[G2] BBSRC SBRI, 147/SBRI9689, 'A low cost point-of-care test kit for microalbuminuria', 2003-2005, PI-Bradley, £270K.

[G3] Royal Society Brian Mercer Award for Innovation, 'Novel Patterning Processes for Nano-Scale Organic Semiconductor Devices', 01/02/07-31/12/09, PI: Bradley, Co-I: J de Mello, £250K.

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

1) Company Development

As a direct result of research carried out at Imperial College, a company with twelve years' operational history has been established in Central London, generating more than £3.4M over the 2008-2013 REF period (> £1.2M equity, > £1.5M contract and > £660K grant funding) in inward investment for the UK. MV has provided > 50 person years of employment for its own, primarily

PhD-level, UK graduates and it has also supported training activities, paying MBA fees for one of its Principal Scientists, a CASE studentship at Imperial College, and a contribution to EPSRC KTS project costs for two postdoctoral researchers seconded from Imperial College and a Principal Scientist seconded to Imperial College. This represents a direct economic impact through investment funding for new activities, jobs created and protected, and turnover associated with new and improved services.

MV has additionally been an important component in developing momentum for the creation of a UK Plastic Electronics industry [A], being one of two Plastic Electronics companies based in Central London. In 2008 MV was starting to be recognized as a "*successful multi-million pound enterprise*" [B], being the focus of an article in The Engineer [C] and a September 2008 visit by Phil Willis MP, then Chair of the House of Commons Innovation, Universities and Skills (IUSS) Committee, as part of the Committee's Engineering Inquiry [D, B]. In August 2008, joint development partner Acrongenomics (an investment and commercialization company listed on the USA Nasdaq) took a £1.1M equity position in MV [E]. Commenting on the deal Platon Tzouvalis, President of Acrongenomics, said, "*This is a great day for our company. This agreement with Molecular Vision is a major milestone for Acrongenomics, since it marks our substantial sharing in everything that this technology has to offer…This will allow Acrongenomics and Molecular Vision to focus on the goals of developing the technology and bringing great products to the market, thus increasing our shareholder value and substantially contributing to the betterment of the healthcare system in general*" [E].

In February 2009, Peter Woodford, a diagnostics industry veteran of 35 years standing, including 15 years with Roche Diagnostics, joined the company as Chairman saying "*I am excited by the clear potential of Molecular Vision's technology platform*" [F]. In September 2009 MV raised an additional £2m from Imperial Innovations and other investors including Acrongenomics to further the commercial development of the BioLED technology platform [G]. A significant contract with "*a global cosmetic company*" was also announced in 2009 [G]. In 2010 MV launched the development of its CardioPlex fluorescence based triple test for cardiac markers myoglobin, CK-MB and troponin-I, concluding a successful demonstration in 2011. In 2011, Imperial Innovations invested a further £750k and MV announced the appointment of Chris Hand as CEO [H]. In 2012, Abingdon Health Group (AHG) led a £3M investment round in which it acquired a 50.1% stake in MV. As part of the same deal, Imperial Innovations invested in AHG, widening its portfolio of healthcare sector investments [I]. Recently, agreements have been put in place with a leading European pharmaceutical company and a large multi-national chemical company to co-develop point-of-care diagnostic tests in the UK [J].

2) Health Care Benefits

MV has pioneered a novel microanalysis technology that offers a step change opportunity for point-of-care in-vitro diagnostics. In particular, MV's BioLED platform provides a simple-to-use, portable, low-cost, rapid, quantitative diagnostic tool. It allows efficient, accurate, multi-analyte measurement in a generic format that can utilize absorption, turbidity, fluorescence, phosphorescence and chemiluminescence detection schemes with existing assays on blood, saliva and urine samples and at the cost of a few dollars, i.e. some 1000-times lower than the typical bench-top readers with which it competes in terms of sensitivity and accuracy. The availability of such devices as routine tools in general practice would directly address key objectives of health providers in the UK, Europe and the US, notably: (i) reduced treatment time; (ii) improved quality of treatment; (iii) reduced inequality of treatment by extending facilities available to remote surgeries; and (iv) improved ongoing care via home-based preventative and post-treatment monitoring of at-risk patients [K]. The BioLED platform has the potential to become a *de facto* standard for medical testing and the significance of this disruptive technology was recognized by AHG in March 2012 when they acquired a majority shareholding in MV. Abingdon founder Dr Chris Hand commented "*This is an important step towards our strategy of creating a fully functional, specialist diagnostics business. Early detection is critical for improved treatment outcomes and there is a significant need for simple, faster and more accurate point of care tests. Working with some of the world's leading experts we are developing disruptive technologies and are well placed to take a share of the US$11.2bn global immunodiagnostics market*" [I]. In a later comment for Wired Magazine, in which

MV technology featured as “One of the Big Ideas for 2012”, he added "*If you can test someone in an ambulance on their way to hospital, or in A&E, that's a big benefit. It's all about getting care to the patient more quickly and efficiently*" [L]. In a letter Dr Hand states *"I believe that the Molecular Vision technology offers us a current and future competitive advantage in the diagnostics sector. It allows us to expand current markets, and with similarities to our previous activities at Cozart, allows us to create new, currently untapped markets for the benefits of the user, the patient and the healthcare system"* [J].

In addition to the medical diagnostics market, the BioLED technology is also suited to environmental testing including water quality ($4Bn market), homeland security/biodefence including pathogen detection ($8Bn market), veterinary testing including bovine TB ($2Bn market) and substances of abuse testing ($2Bn market) [M].

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

[A] Pages 8 & 58, 2012 UK Plastic Electronics: Capability Guide, http://ukplasticelectronics.com/wp-content/uploads/2012/09/PE_CapabilityGuide_V1prJun12.pdf (archived here).

[B] Institute of Physics response to a House of Commons IUSS Committee Inquiry on plastic electronics engineering, 14th March 2008 (available here).

[C] ‘Doctor on a Chip’ article, The Engineer, 19/5/08, http://www.theengineer.co.uk/news/doctor-on-a- chip/306204.article (archived at https://www.imperial.ac.uk/ref/webarchive/bhf on 22/4/13); See also Medgadget Portable Diagnostic Technology from UK’S Molecular Vision 28th May 2008: http://www.medgadget.com/2008/05/portable_diagnostic_technology_from_uks_molecular_vision.html (archived at https://www.imperial.ac.uk/ref/webarchive/chf on 22/4/13)

[D] House of Commons IUSS Committee, ‘Engineering: turning ideas into reality’ report, http://www.publications.parliament.uk/pa/cm200809/cmselect/cmdius/50/50i.pdf (archived here).

[E] Reuters article, 21/5/08, ‘Acrongenomics Increases its Shareholding in and Restructures Relationship with Molecular Vision’, http://uk.reuters.com/article/2008/08/21/idUS224476+21-Aug-2008+BW20080821 (archived at https://www.imperial.ac.uk/ref/webarchive/hhf on 22/4/13)

[F] Reuters article, 23/2/09, ‘Acrongenomics` Business Associate Molecular Vision Ltd Appoints Peter Woodford as Chairman’, http://www.reuters.com/article/2009/02/23/idUS221627+23-Feb-2009+BW20090223 (archived at https://www.imperial.ac.uk/ref/webarchive/ghf)

[G] Reuters article, 22/10/09, ‘Acrongenomics maintains its stake in Molecular Vision’, ‘http://uk.reuters.com/article/2009/10/22/idUS194327+22-Oct-2009+BW20091022 (archived at https://www.imperial.ac.uk/ref/webarchive/khf on 22/4/13)

[H] OSA Direct newsletter, 2/2/11, ‘Molecular Vision receives further investment and appoints Dr Chris Hand as Chief Executive Officer’, http://www.osadirect.com/news/article/433/ (archived at https://www.imperial.ac.uk/ref/webarchive/l8f on 19/11/13)

[I] Manufacturing Chemist article, 26/3/12, ‘Abingdon Health raises £3m’, http://www.manufacturingchemist.com/news/article_page/Abingdon_Health_raises_3m/76983 (archived at https://www.imperial.ac.uk/ref/webarchive/ykf on 22/5/13)

[J] Letter from CEO of Abingdon Health, 24/5/13 (available on request from Imperial)

[K] ‘Technology’, Molecular Vision website, http://www.molecularvision.co.uk/show.php?page=20&subnav=9 (archived at https://www.imperial.ac.uk/ref/webarchive/zkf on 22/5/13)

[L] Wired magazine, 3/1/12, ‘25 big ideas for 2012: The lab on a postage stamp’, http://www.wired.co.uk/magazine/archive/2012/01/features/the-lab-on-a-postage-stamp (archived at https://www.imperial.ac.uk/ref/webarchive/nhf on 22/4/13)

[M] ‘Applications’, Molecular Vision website, http://www.molecularvision.co.uk/show.php?page=21&subnav=10 (archived at https://www.imperial.ac.uk/ref/webarchive/1kf on 22/5/13)