Institution: Imperial College London

Unit of Assessment: 9 Physics

Title of case study: P9 - The BioLED™ microanalysis technology (Molecular Vision Ltd)

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

Molecular Vision Ltd (MV), an Imperial Innovations spinout, has developed a low-cost technology for multiplexed analysis on bodily fluids. The BioLED™ platform rapidly delivers lab-quality information from a single-sample point-of-care diagnostic device. 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. A further £1.2M in non-UK and £2.6M in UK equity investment and > £660K in non-UK grant funding has been injected via MV into the UK economy during the REF period, securing > 50 person years' employment. MV is now a key component of the Abingdon Health Group's (AHG's) strategy to create a fully integrated UK business to compete in the multi-billion pound global immunodiagnostics market. Agreements with a leading European pharmaceutical company and a large multi-national chemical company, in both cases to co-develop point-of-care diagnostic tests in the UK, are now underway.

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 Donal Bradley (Physics Department) and John and Andrew de Mello (Chemistry 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 GB2369428, 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]. As also did the use of polymer OLEDs as integrated excitation sources for detection of dyes separated by on-chip electrophoresis and OPDs for chemiluminescent quantitation of hydrogen peroxide (2 further journal papers, 133 ISI citations).

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). Close research collaborations with Bradley and colleagues have continued to the present day and resulted in a further 2 BioLED™ focused journal papers (30 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). MV also secured NHS Health Technology Device funding for collaboration with Imperial, Acrongenomics and Pearson Matthews - a design 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 and stamp transfer printing methods [4-6]; funded by [G1] and [G3]. The resulting fabrication IP was the subject of 2 patent filings: GB0523437.2 and GB0701909.4 that were successfully licensed (July 2007) to MV for use in the medical diagnostic sector. Electrode focused IP resulted in GB0713304.4. Together, this research underpinned the development of flexible substrate devices that enabled MV's participation 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, co-funded a project with MV and Imperial Innovations to further develop the interlayer lithography and stamp transfer printing processes and also supported development of the VPP-PEDOT electrode system. Eight additional papers (137 citations) resulted. More recently, research collaborations with MV have involved (i) Bradley acting as a consultant technical adviser (2009 - to date) and (ii) EPSRC-funded Knowledge Transfer Secondments from the Physics Department to MV (Drs Xuhua Wang and Monika Voigt, both 2010) and, post-AHG acquisition, from MV to the Physics Department (Dr Miguel Ramon, 2012), specifically to support the development of high throughput fabrication and manufacturing methods, including gravure printing.

Key personnel:

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

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

[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, 2005, 5, 863-868. DOI, **48 ISI citations (19/7/13)**

[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, 2006, 6, 981-987. DOI, **72 ISI citations (19/7/13)**

[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, 2007, 7, 58-63. DOI, **45 ISI citations (19/7/13)**

[4] *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 doped poly (3,4-ethylenedioxythiophene)/poly (styrenesulfonate) films*", Adv. Funct. Mater., 2005, 15, 290-296. DOI, **138 ISI citations (19/7/13)**

[5] 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., 2007, 17, 1043-1049. DOI, **34 ISI citations (19/7/13)**

[6] L. Chen, P. Degenaar, D.D.C. Bradley, "*Polymer Transfer Printing: Application to Layer Coating, Pattern Definition and Diode Dark Current Blocking*", Adv.Mater., 2008, 20, 1679-1683. DOI, **39 ISI citations (19/7/13)**

Grants:

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

[G2] BBSRC SBRI, 147/SBRI9689, £270K, 2003-05, PI: Bradley, 'A low cost point-of-care test kit for microalbuminuria'

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

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

Company Development

As a direct result of research carried out in Physics at Imperial College London, MV has been established as a robust (12 years and counting) UK technology company, generating £3.4M (> £1.2M equity, > £1.5M contract and > £660K grant funding) in *inward investment* for the UK over the 2008-2013 REF period [A-E]. A further £2.6M of *UK equity investment* has been injected into the economy via MV in this period [A, B] and it has consequently been able to provide > 50 person years of employment for its own, primarily PhD-level, UK-trained staff. MV has further supported a variety of skills enhancement activities, including EPSRC KTS project costs for two PDRAs seconded from and a MV Principal Scientist seconded to, the Physics Department, and MBA fees for another MV Principal Scientist. This represents a direct economic impact through investment funding for new activities, jobs created and protected, turnover associated with new and improved services, and priority shifts in expenditure and reallocation of budgets. Further details are given below.

In addition, MV has played a significant role in providing momentum for the fledgling UK plastic electronics industry [F, G]. In particular, it has focused attention on the opportunities for plastic electronics in the medical diagnostics sector, which had not previously been recognised. MV's BioLED^{TM} technology can also address multi-billion pound detection markets for homeland security/biodefence [E], environmental monitoring including water quality, and animal health including bovine TB.

In 2008 MV had developed its first prototype devices, being the focus of an article in *The Engineer* [C, H] 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 [C, I]. 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*" [J]. In September 2009 MV raised an additional £2m in a round led by Imperial Innovations to further the commercial development of the BioLED^{TM} technology platform, with Innovations CEO Susan Searle commenting *"Point-of-care diagnostics is becoming increasingly important in the provision of patient care and through its innovative technology, Molecular Vision is well placed to provide healthcare professionals with highly advanced solutions"* [A]. A significant contract with L'Oreal was also announced [D] and MV joined the European Defence Agency PathoID-Chip project as a sub-contractor to Microfluidic ChipShop with a budget reallocated from Nanoident [E]. MV further participated from January 2010 in the EU Photo-FET project (FP7-ICT 248052 *Integrated Photonic Field-Effect Technology for Bio-sensing Functional Components*), completed at the end of 2012 [K]. In 2010 MV additionally launched the development of its CardioPlex^{TM} fluorescence based triple test for cardiac markers myoglobin, CK-MB and Troponin-I. CardioPlex^{TM} was co-funded by Acrongenomics and was successfully demonstrated in 2011. In February 2011 Dr Chris Hand, another diagnostics industry veteran with 20 years prior experience, including founding, floating and selling Cozart plc, was appointed MV CEO [C]. He, together with Abingdon Health Group colleagues, subsequently raised funds to acquire a 50.1% stake in MV as part of a wider £3M deal that saw Imperial Innovations also invest in Abingdon [A-C]. Most 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 [B].

Healthcare Benefits

The novel microanalysis technology that MV has pioneered offers a step change opportunity for point-of-care *in-vitro* diagnostics [B]. In particular MV's BioLED^{TM} 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 pounds, i.e. some 1000-fold cheaper than the typical bench-top readers with which it competes in terms of sensitivity and accuracy. It is anticipated that these tests will become a routine tool in general practice. The availability of such devices 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 the facilities available to remote surgeries; and (iv) improved ongoing care via home-based preventative and post-treatment monitoring of at-risk patients [L]. The cost-performance profile of the BioLED™ platform is also well suited to addressing the growing development of stratified medicine and personalised health and beauty products. The disruptive nature of MV's technology was recognized by the Abingdon Health Group, which acquired a majority shareholding in MV in March 2012. Dr Hand, Abingdon founder and CEO, 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"* [B].

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

[A] Imperial Innovations annual reports and press releases: http://www.imperialinnovations.co.uk/investor-relations/documents/ (e.g. 2012 Annual Report), http://www.imperialinnovations.co.uk/news-centre/news/imperial-innovations-leads-2-million-funding-round/ (archived at https://www.imperial.ac.uk/ref/webarchive/1lf on 6/6/13), http://www.imperialinnovations.co.uk/news-centre/news/innovations-leads-3m-funding-round-abingdon-health/ (archived at https://www.imperial.ac.uk/ref/webarchive/2lf on 6/6/13)

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

[C] Molecular Vision news: http://www.molecularvision.co.uk/show.php?page=10&subnav=12

[D] Acrongenomics press release '*Acrongenomics maintains its stake in Molecular Vision',* http://www.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)

[E] European Defence Agency Contract A-0379-RT-GC *PathoID-Chip*: http://www.eda.europa.eu/docs/documents/JIP-FP_contracts.pdf (page 6, archived here). MV joined this project as a sub-contractor to Microfluidic ChipShop: http://www.joanneum.at/en/materials/sen/projects/robust-and-autonomous-airborne-threat-detection-system-as-lab-on-a-chip-device-with-integrated-optoelectronic-sensors-and-combined-pathogen-enrichment-pathoid-chip.html?&print=1&no_cache=1 (archived here on 6/6/13)

[F] Page 15, *Physics: Transforming Lives*, IOP Publications, June 2013, http://www.iop.org/publications/iop/2013/file_60314.pdf (archived here) and pages 8 & 58, 2012 UK Plastic Electronics Capability Guide:http://ukplasticelectronics.com/wp-content/uploads/2012/09/PE_CapabilityGuide_V1prJun12.pdf (archived here)

[G] Slide 11, Plastic Electronics Leadership Group presentation, May 2012: http://www.ukplasticelectronics.com/wp-content/uploads/2012/05/UKPE-Slides1.pdf (archived here)

[H] Medgadget, '*Portable Diagnostic Technology from UK's Molecular Vision',* 28/5/08, https://www.imperial.ac.uk/ref/webarchive/chf

[I] 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)

[J] MV Press release, '*Molecular Vision Appoints Peter Woodford as Chairman',* *http*://www.molecularvision.co.uk/show.php?page=28&subnav=12 (archived https://www.imperial.ac.uk/ref/webarchive/4lf on 6/6/13)

[K] FP7-ICT 248052 project *PhotoFET*: http://cordis.europa.eu/projects/248052 (archived at https://www.imperial.ac.uk/ref/webarchive/5lf on 6/6/13)

[L] 'Technology', Molecular Vision website, http://www.molecularvision.co.uk/show.php?page=20&subnav=9 (archived at here on 22/5/13)