

Impact case study (REF3b)

Institution: University of Southampton
Unit of Assessment: 08 Chemistry
Title of case study: 08-01 Ilika plc: Driving Global Innovation in Next Generation Materials
1. Summary of the impact <p>The unique application of combinatorial chemistry in materials science at Southampton has directly underpinned the success of University spin-out, Ilika Technologies. Since 2008, the breadth of applications of the research has allowed Ilika:</p> <ul style="list-style-type: none">• to form a partnership, worth around £4m, with Toyota in the development of battery materials for electric vehicles• to optimise new phase change memory materials now used by NXP in embedded memory applications, and• to create and sell a subsidiary, Altrika Ltd, that has provided cell-based skin regeneration therapies to 50 severe burn victims. <p>Between 2008 and 2012, Ilika enjoyed considerable growth, doubling employment to 35 staff, increasing turnover by approximately 25% annually, and floating on the AIM with a market capitalisation of £18.7 million.</p>
2. Underpinning research <p>The use of combinatorial chemistry, i.e. the rapid synthesis of large numbers (libraries) of related molecules or materials, in industry, has traditionally been associated with drug discovery and catalysis in pharmaceutical companies. The recognition that the technique could be applied to materials science to create new functional solid-state materials with tuneable properties and applications spanning the electronics, energy and polymers sectors gave rise to a significant body of multidisciplinary research at the University of Southampton's School of Chemistry.</p> <p>Mark Bradley, Professor of Combinatorial Chemistry until 2005, led a successful bid to the UK Joint Infrastructure Fund (JIF) for funding of £6 million in 2000 to establish a Combinatorial Centre of Excellence at Southampton. Brian Hayden, Professor of Physical Chemistry, and Dr Samuel Guerin, then a Postdoctoral Research Fellow until 2005, now Senior Scientist at Ilika, worked together in the Centre to develop new combinatorial approaches to solid state materials discovery based on vacuum-deposited thin films on silicon micro-fabricated structures for synthesis, characterisation and screening of these materials [3.1, 3.2, 3.3]. Professor Bradley also developed combinatorial synthetic and screening methodologies for bio-polymer materials.</p> <p>Projects to prepare and screen supported heterogeneous catalysts and electrocatalysts were implemented with support from Johnson Matthey, a world leader in advanced materials technology, General Motors, who were keen to explore advances in electrocatalysts for use in electric vehicles, and the EPSRC. Initial work centred on the synthesis and screening of metal alloys, and doped oxide materials.</p> <p>This high throughput methodology was then extended to the synthesis of supported nanoparticles, most significantly allowing the characterisation of particle size and support effects in electrocatalysis, and demonstrating close analogies to heterogeneous catalysis. A range of other functional materials were synthesised and characterised, including piezoelectric perovskite metal oxides, metal hydrides and chalcogenide alloys used for phase change memory applications that are destined to replace flash memory. The high throughput physical vapour deposition (PVD) methodology was used to directly synthesise mixed metal hydrides, which are required for a high capacity, energy efficient and safe method of reversibly storing hydrogen.</p> <p>The key research outcome was the successful application of combinatorial, high-throughput discovery tools to a much wider range of materials, including polymers and solid state materials. The IP obtained through this large multidisciplinary project led to the founding of a University spin-out company, Ilika Plc. in 2004 by Hayden, Bradley and Guerin. The research resulted in several key patents and papers [3.1, 3.2, 3.3] and, in particular, the workflow for solid-state materials discovery (Hayden and Guerin) and bio-active polymer libraries and</p>

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workflow (Bradley).

With the founding of Ilika, Hayden and Bradley became consultants, and Hayden was appointed Chief Scientific Officer (CSO) in 2004, a position he still holds alongside that of Professor of Physical Chemistry at the University. Guerin was appointed as a Research Scientist at Ilika in 2005, where he is now Senior Scientist. The areas of high throughput methods and materials discovery have continued to feature strongly in Professor Hayden's research in Chemistry at Southampton [3.4, 3.5, 3.6] with considerable funding from EPSRC and industry for a range of different projects. Bradley moved to become Professor of High-Throughput Chemical Biology at the University of Edinburgh in 2005, subsequent to the formation of Ilika.

3. References to the research (the best 3 illustrating the quality of work are starred)

- *[3.1] S. Guerin, B. E. Hayden, *J. Comb. Chem.* **8** (2006) 66-73. “Physical vapor deposition method for the high-throughput synthesis of solid-state material libraries”.
- *[3.2] K. Brace, B. E. Hayden, A. E. Russell, J. R. Owen, *Adv. Mater.* **18** (2006) 3253-3257. “A parallel optical screen for the rapid combinatorial electrochromic analysis of electrochemical materials”.
- *[3.3] S. Guerin, B. E. Hayden and D. C. A. Smith, *J. Comb. Chem.* **10** (2008) 37–43. “High-Throughput Synthesis and Screening of Hydrogen-Storage Alloys”.
- [3.4] M. S. Beal, B. E. Hayden, T. Le Gall, C. E. Lee, X. Lu, M. Mirsaneh, C. Mormiche, D. Pasero, D. C. A. Smith, A. Weld, C. Yada, S. Yokoishi, *ACS Comb. Sci.* **13** (2011) 375-381. “High Throughput Methodology for Synthesis, Screening, and Optimization of Solid State Lithium Ion Electrolytes”.
- [3.5] M. Mirsaneh, B. E. Hayden, E. Furman, S. Perini, M. T. Lanagan, I. M. Reaney, *Appl. Phys. Lett.* **100** (2012) 082901. “High dielectric tunability in lead niobate pyrochlore films”.
- [3.6] M. Chang, M. S. Chen, A. David, S. Gandikota, S. Ganguli, B. E. Hayden, S. Hung, X. Lu, C. Mormiche, A. Noori, D. C. A. Smith, C. J. B. Vian, *J. Appl. Phys.* **113** (2013) 034107. “Novel metal gates for high κ applications”.

Funding: EPSRC projects (i) GR/M88365/01 (£5.95m) *JIF:Combinatorial Centre of Excellence* (July 00-June 04) PI:Bradley; (ii) GR/R50639/01 (£198k) *Combinatorial Screening and Characterisation of Platinum Based PEM Fuel Cell Catalysts* (Feb 02-Feb 05) PI:Hayden; (iii) EP/C003039/1 (£16k) *Electrocatalysis on Supported Metal and Alloy Particles of Controlled Particle Size* (Dec 04-Nov 05), PI:Hayden; (iv) EP/F015631/1 (£93k) *High Throughput Synthesis of $Pb_nNb_2O_{5+n}$ Pyrochlore-Structured Tunable Thin Films* (Feb 08-Jan 09) PI:Hayden.

Patents based on underpinning research prior to Ilika being founded: S. Guerin and B. E. Hayden, “Vapour deposition Method”, US patent 8163337 (filed UK 2003, granted US 2012); J. R. Owen, P. N. Bartlett, B. E. Hayden, A. E. Russell and K. M. Brace, “Electrochemical cell for testing the electrocatalytic behavior of multiple materials”, US patent 8,083,913 (filed UK 2003, Granted US 2011, Europe 2013).

4. Details of the impact

Research at Southampton that gave rise to a unique high-throughput solid-state synthesis methodology, has led to the creation of a dynamic spin-out company, **Ilika Technologies plc** [5.1]. The company has accelerated the development of the clean technologies of the future, in collaboration with leading multinationals, and boosted the global competitiveness of the UK economy. Based on Southampton's patented methodology [Section 3], Ilika's work is focused on next-generation applications for the high-growth industries of clean energy and electronics, driving forward innovation to reduce reliance on the world's diminishing supply of hydrocarbon fuels and cutting carbon emissions.

Clean technology: Governments have introduced incentives to stimulate the development of electric vehicles (EVs), but mass-market roll-out is being hindered by inadequate battery performance. Ilika's technology, which allows rapid synthesis and screening of new cell

chemistries, has increased the energy capacity and charge rates of *solid state lithium-ion batteries*, a market set to be worth \$32 billion a year by 2018. In a significant collaboration with Toyota, who since 2008 have invested ~£4 million revenue directly into this research [5.1, 5.2], Ilika has also filed 9 patents in the period 2008-13 to facilitate further advances in EV through the creation of new battery materials and compositions [5.3]. These are being integrated into batteries for future generations of Toyota's hybrid vehicles, also offering very significant safety benefits over liquid electrolyte batteries. Reducing catalyst materials costs is a key driver in delivering Toyota's vision for fuel cell hybrid vehicle roll-out. Mr Taniguchi (Toyota) states, "**Ilika's fuel cell catalyst formulation is key to Toyota's strategy for cost reduction**", while according to Mr Okajima (Project Manager, Toyota's Frontiers & Advanced Engineering Strategy Department, R&D Management Centre, Japan), "**Ilika's high through-put techniques are essential to overcome some of the technological barriers we face in the development of leading-edge technologies**" [5.4, 5.5]. Ilika has also made an impact in other areas of the automotive industry, working with CeramTec to develop more environmentally-friendly lead-free piezoelectrics in sensors and actuators used for triggering airbags and in fuel injection systems. These are now in use in several German automotive vehicle brands [5.4].

The International Energy Agency estimates that by 2020 hydrogen fuel cell vehicles will be responsible for 10% of the new car market, achieving an 8 million tonne reduction in UK CO₂ emissions between 2010-2020. The prohibitive cost of Proton Exchange Membrane (PEM) fuel cells has hindered the growth of this industry. Ilika has worked with Japanese chemicals and materials company Asahi Kasei to develop unique palladium alloy (Pd/Co/W) electrocatalysts [5.1] which are ~70% cheaper than 'standard' platinum catalysts, making the market penetration of fuel cell vehicles more viable. Ilika has been awarded 3 Carbon Trust Grants to take this work forward (total: ~£438k), plus £150k equity investment in 2012 [5.1, 5.6].

The future of hydrogen as an energy source is very dependent on the ability to store it safely. Current solutions consume large amounts of energy and raise safety concerns. Ilika worked with Shell to develop a solid metal hydride [5.1, 5.3, 5.4], which is currently being scaled-up and commercialised with Sigma Aldrich, a US-based specialist chemicals company.

Digital memory: Phase change memory (PCM) is an emerging technology expected to replace flash in solid-state memory for computers, smart phones, *etc.*, due to its higher performance and capacity to extend battery life. In 2008 Ilika began collaborating with NXP Semiconductors [5.1, 5.3] to optimise new PCM materials through its high throughput screening technology. These are now being used by NXP in embedded memory applications [5.6].

Biomaterials: Research into polymers, carried out by Bradley at Southampton, with researchers at the Universities of Edinburgh and Sheffield, produced biomedical applications. This led to the founding of **Altrika Ltd** in 2009 [5.7], a wholly-owned subsidiary of Ilika, marketing cell-based skin regeneration therapies to treat burns and hard-to-heal wounds. In 2011, its **Myskin®** and **Cryoskin®** products were being sold to seven NHS trusts, leading to accelerated recovery, reduced scarring, reduced time in hospital and increased quality of life for ~50 patients with particularly severe burns. In December 2012, Altrika was sold to Adiposet Ltd. [5.7], providing them with quality systems and licenses-to-operate from the Human Tissue Authority and Medicines and Health products Regulatory Agency, for expanding its cell bio-processing and bio-banking projects. This strategic decision enabled Ilika to focus on its core cleantech programmes, now 90% of its business.

Economic Impact: The direct economic impact on the UK economy is through the formation of a PLC which now employs 35 staff (doubling since 2007), including 25 skilled scientists. Its annual turnover has increased from £0.97m (2007) to £2.01m (2012), growing ~25% pa since 2008. Ilika, listed in The Guardian Clean Tech 100, attracts inward investment into the UK, with 83% of its revenue from international companies. It was floated on the Alternative Investment Market of the London Stock Exchange in 2010 [5.8] at a market capitalisation of £18.7m and raised ~£5.2m, with a further £5m in May 2012 [5.1, 5.3, 5.9]. Ilika received the New Energy Awards University Spin-out of the Year in 2012 [5.10]. Its business is supported by sales offices in Japan, USA and Germany.

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Fostering the Impact: Essential to the realisation of the impact was the involvement of the University of Southampton's Centre for Enterprise & Innovation (CEI), which assisted with the protection and exploitation of the IP. Company incubation was supported via SETsquared (Southampton, Surrey, Bath, Bristol & Exeter Universities). Southampton Chemistry fostered Ilika's success by reducing Hayden's workload to enable him to commit 50% of his time as CSO (2005-present). According to Graeme Purdy (CEO, Ilika), "*Brian's role is extremely valuable to Ilika, both in a business development capacity and in providing scientific and technical leadership and credibility with customers*" [5.4]. Ilika occupied research and office space in Chemistry before relocating to the University of Southampton Science Park in 2007. Graeme adds, "*Southampton Chemistry was critical in nurturing Ilika's growth through structured access to space and a close cooperation in the early days of the company*". Ilika continues to hold a facilities agreement with the University, enabling them to access specialist equipment on a commercial basis.

Strong collaborations between Southampton Chemistry and Ilika have also continued through industrial CASE studentships, MChem placements, academic consultancies and joint patents. Southampton Chemistry also trained many of the scientists employed by Ilika.

5. Sources to corroborate the impact

[5.1] Ilika plc web-site: www.ilika.com (includes Company History; Annual Reports; Edison Investment Research Report; press releases)

[5.2] Press releases - Ilika-company partnerships: Toyota: <http://www.ilika.com/Toyota-Motor-Corporation-Japan-Contract-Renewal.aspx>; <http://www.ilika.com/Ilika-and-Toyota-Extend-Partnership.aspx>; <http://www.ilika.com/Solid%20State%20Battery%20Development.aspx>
Ceramtec: <http://www.ilika.com/Ilika%20and%20Ceramtec%20enter%20into%20Joint%20Development%20Project.aspx>; Sigma-Aldrich: <http://www.ilika.com/hydrogen-Storage-Collaboration-with-Sigma-Aldrich-Materials-Science.aspx>; Toshiba: <http://www.ilika.com/New%20contract%20with%20Toshiba.aspx>; Energizer: <http://www.ilika.com/Joint%20Development%20agreement%20with%20Energizer.aspx>;

[5.3] Ilika patent holdings.

[5.4] Corroborating contact, Chief Executive Officer, Ilika plc.

[5.5] Alternative corroborating contact, Chairman, Ilika plc.

[5.6] Carbon Trust press releases: <http://www.ilika.com/Ilika-awarded-Carbon-Trust-Research-and-Development-Grant.aspx>; <http://www.ilika.com/Carbon-Trust-Grant-and-New-Customer-Contract-for-Battery-Materials-Screening.aspx>; <http://www.ilika.com/Carbon%20Trust%20Investment.aspx>; Carbon Trust grant award information: 2007/10: £166,788; 2010/11: £98,281; 2011/12: £173,110. Total: ca. £438k, plus £150k equity investment in 2012.

[5.7] Altrika Ltd web-site: <http://www.altrika.com/>; Adiposet Ltd. acquisition of Altrika: <http://www.adiposet.com/adiposet-news/>; 2010 – Altrika Ltd awarded £100k TSB funding, winning the healthcare category of the competition for Disruptive Solutions, for its development work on a spray formulation of its Cryoskin® donor skin cell product, <http://www.altrika.com/altrika-awarded-100000-funding-by-the-technology-strategy-board.aspx>; 2011 – Altrika Ltd leads consortium awarded £452k grant by TSB for further developing its cell labelling technology, <http://www.altrika.com/Altrika%20grant%20award%20and%20new%20JDP.aspx>

[5.8] London Stock Exchange announcement: <http://www.londonstockexchange.com/exchange/prices-and-markets/stocks/summary/company-summary.html?fourWayKey=GB00B608Z994GBGBXASQ1>; flotation: <http://www.ilika.com/Ilika-Announces-Successful-Completion-of-IPO-on-AIM.aspx>

[5.9] Summary of Ilika's key financial data since 2007;

[5.10] New Energy Award 2012 – press release: <http://www.ilika.com/Ilika%20wins%20New%20Energy%20Award.aspx>