March 2014

Supplement to the Treatise

WOLFGANG RUNGE: TECHNOLOGY ENTREPRENEURSHIP

How to access the treatise is given at the end of this document.

Reference to this treatise will be made in the following form:
[Runge:page number(s), chapters (A.1.1) or other chunks, such as tables or figures].

The current case deals with entrepreneurship referring to a technology push situation in the context of a competitive group of firms. It includes Bioniqs Ltd. and Scionix Ltd. from the UK and the German firms IoLiTec GmbH and Solvent Innovation GmbH for which also case documents were created [Runge:B.2].

The present document covers both the individual cases of Bioniqs and Scionix.

To help readers to put financial data given as British Pounds into their ways of thinking the following exchange rates by January 2007 will suffice: 1 £ = 1.52 € = 1.96 $

Wolfgang Runge

Bioniqs Ltd.

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Bioniqs Ltd. was co-founded in December 2004 by Dr. Adam Walker and by Neil Bruce, then at the Institute of Biotechnology of the University of Cambridge in the United Kingdom (UK), as a university spin-out (RBSU – Research-Based Startup). It was located at the "Biocentre, York Science Park, Heslington, York." It provided designs of ionic liquids (ILs) and developed proprietary (ILs) which aimed to facilitate and improve *bio-chemical and bio-catalytic processes in industry*, particularly in the chemical, pharmaceutical, paper and textile sectors.

Bioniqs planned to design ILs to meet customer specifications across a heterogeneous set of industrial processes, from bioconversions and chemical synthesis to chromatography, extraction of natural products and decontamination/cleaning.

At the foundation year 2004 concerning IL startups Bioniqs was a “late entrant” into the field. The *technology, markets as well as the competitive situation for ionic liquids* is described in the Solvent Innovation GmbH and IoLiTec GmbH cases (B.2).

Bioniqs was set to be profitable by the end of 2007 [RSC 2007]. However, it went bankrupt and was dissolved in November 2011, the liquidation process lasting more than 12 months.

The Entrepreneur(s) and the Business Idea

The co-founder of Bioniqs and its driving person Adam Walker (29 years in 2007) did a Masters degree in chemistry at the University of Wales, UK. But, Walker's interest was focused on work carried out by Neil Bruce, then at the Institute of Biotechnology at the University of Cambridge, UK.

'I felt that the most *interesting work was being done at the interface between biology and chemistry*, and I wanted to move into biotechnology.” Walker succeeded to join Bruce in 2000 to study for a PhD, hoping to find a way to integrate biological catalysts into the preparation of oxycodone, an opioid analgesic. But he soon realized that the intermediates in the path to oxycodone are poorly water soluble and enzymes only function in a water-based environment [RSC 2007].

It was “ionic liquids” that Walker first started to think about after a scientific conference in 2001 [BBSRC 2008]. Through the literature, Walker came across using ionic liquids as solvents. Initial attempts with ionic liquids for biocatalysis failed. But he *persevered* and eventually succeeded in chemically modifying an ionic liquid to make it resemble water more closely, so that his enzymes and drug intermediates remained stable in one solvent.

Towards the end of his PhD, Walker was convinced that *replacing water with modified ionic liquids as solvents for industrial applications* was commercially viable – though there were already IL startups and large firms producing ILs operating in Germany and the UK.

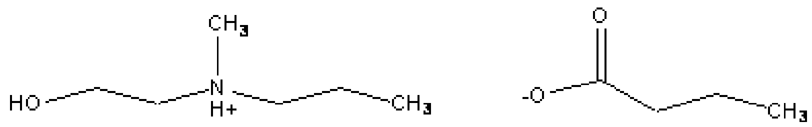
But he decided to set up a spin-out company with Neil Bruce. The University of Cambridge filed the patents for their “designer solvents”, but before Walker and Bruce could set up a spin-out company in Cambridge, Bruce was offered a position as chair of biotechnology at the Centre for Novel Agricultural Products (CNAP) at the University of York, UK [RSC 2007]. Bruce and Walker moved to CNAP.

Actually, according to Walker, "One of the problems I had was that my enzymes were subject to hydrolysis, but redox enzymes don't work in organic solvents." He tried using the more commonly available imidazolium ionic liquids as solvents, but found that they didn't work. So he went back to the basics: To work, the enzymes needed an environment with the properties of water. "So we designed an *ionic liquid that would mimic water*," Walker said, “but *would not hydrolyze enzymes*.” [Short 2006]

Ionic liquids mimicking water seemed to provide a solid value proposition. With its “Second Generation Ionic Liquids” Bioniqs (Figure 1) Walker was convinced, "We think we can *develop tailor-made ionic liquids at a competitive price*." [Short 2006]

This second generation ILs are called protic ionic liquids (PILs) as they exhibit a hydrogen atom at nitrogen which is relatively weakly bound and leave the nitrogen as a proton.

“Second Generation” Ionic Liquids



- Bioniqs has developed new types of simple ionic liquids, based on ammonium salts.
- These retain the advantages of ionic liquids, but also offer:
- - reduced viscosity.
- - low cost.
- - straightforward preparation from sustainable precursors.
- - minimal toxicity and environmental impact.
- - recyclability and biodegradability.

Figure 1: Bioniqs’ types of ionic liquids (Source: [Walker 2006].

Walker had to master a steep learning curve from the transition from science into business and coped with a rapid shift in roles and growing a company quite literally from scratch and *pushing new technology into almost non-existing markets*.

His attitude and orientation was expressed by his statement: '”The best way to learn is from people who have already done it.” [RSC 2007] The timeline of Adam Walker’s education and roles in his startup are given below.

2006 – 2011	Chief executive officer (CEO), Bioniqs, York, UK
2008 – 2006	CEO and director of operations, Bioniqs, York
2004	Academic founder and director of Bioniqs, York
2003 – 2005	Postdoctoral research fellow, CNAP, department of biology, University of York
2003	PhD, Institute of Biotechnology, University of Cambridge
2000	MChem, department of chemistry, University of Wales, Swansea
2000 – 2006	IL research funded by BBSRC *), and through the ProBio Faraday Partnership

*) The Biotechnology and Biological Sciences Research Council (BBSRC) is (was?) the UK’s principal financial backer of basic and strategic biological research.

Professor Neil Bruce had a track record in turning ideas and new knowledge into innovative commercial enterprises. “The strong basic science, with its opportunity to explore completely new ideas, combined with the lab’s ethos of always being on the look-out for commercial potential is a very potent mix,” said Neil Bruce which reflects his basis attitude [BBSRC 2008].

And working in a new strongly emerging scientific field but following the entrepreneurial path was explained by Bruce as follows: “Two factors drove the choice of a spin-out rather than other routes. First, the breadth of potential applications for the technology ruled out a license agreement with a single company. Second, each harbored a personal ambition to commercialize their research through a new company.” [BBSRC 2008]

The Opportunity, Business Model and Foundation Process

For founding Bioniqs “We came at it from a biological perspective.” Certain ionic liquids can dissolve DNA, cellulose and even coal and rocks, without attacking their glass, metal or plastic containers. By incorporating hydromimetic (water-like) properties, they allow proteins, such as enzymes, to function in the near absence of water. "Getting enzymes to work in this alien environment means *you can make things that you cannot do using existing processes*.” [Northern Echo 2005]

The company was based upon *a strong patent portfolio* arising from work performed in the Universities of York and Cambridge.

With its base on the York campus, and co-founder Neil Bruce as one of its Directors, Bioniqs could maintain strong *links to top flight academic research*.

The move to the Centre for Novel Agricultural Products (CNAP) at the University of York (UK) turned out to be a stroke of luck for Walker and Bruce, as CNAP took a very proactive approach to spin-outs. In York they found a partner in Amaethon Ltd., a technology commercialization company specifically created to commercialize CNAP research. In a sense, Amaethon allowed them to bypass some of the usual hurdles that a new spin-out venture faces. “We didn't have to go out and woo the venture capitalists to try to get money out of them,' Walker said [RSC 2007].

Funding requirements for 18 months of operation were £300,000 [Walker 2006]. *Financing* was through own and public sources as well as private investors.

The company was using a £200,000 investment from the Department of Trade and Industry-backed Viking Fund to employ more staff. A further £450,000 was also raised from the London based venture capital company IP2IPO (now IP Group plc) and other angel investors in the UK [University of York 2006].

The £5m Viking Fund was a Yorkshire-wide, co-investment venture capital fund set up with UK government capital under the DTI/Small Business Service’s Early Growth Fund. It provided early-stage risk capital to match – on the same terms – that invested by business angels or other private sector investors.

In 2006 Bioniqs could also take advantage of Connect, Yorkshire's Fast Invest Scheme – a program that offered technology businesses loans of up to £50,000 combined with business mentoring.

Fast Invest added to the limited resources of Bioniqs to help growing the business, strengthening existing commercial relationships and forging new ones. To help Bioniqs step from a purely development focus to one of sales and growth Fast Invest allowed Bioniqs to go for a business development manager, a move which was expected to turbo charge the company's growth [Connect 2006a].

Actually Fast Invest enabled Bioniqs to hire an experienced commercial director on a consultancy basis, with the necessary level of commercial acumen and experience necessary to make *inroads into Bioniqs’ major target markets in the pharmaceuticals and fine chemicals sectors* [Connect 2006b].

Bioniqs’ premises on York Science Park covered an analytical room where ionic liquids were designed and a synthesis suite, where the resulting liquids were produced in small scale (Figure 2).

Bioniqs could not compete with major chemical manufacturing companies and no resources were available for an in-house manufacturing plant. Hence, *revenue should be obtained through a royalty stream on sale of licensed products*.

Originally, Bioniqs aimed to *generate revenues through design and process development, not manufacturing* – hence, it looked for opportunity of alliance rather than competition with major manufacturers [Walker 2006].

In 2006 Bioniqs established a partnership agreement with the large German chemicals firm Merck KGaA (Darmstadt). Through this partnership, *Merck KGaA manufactured and distributed through its catalog a selected range of Bioniqs' proprietary ammonium based ionic liquids* ("catalog business"). Merck KGaA could expand its commercial portfolio through this partnership, since the Bioniqs' reagents complemented the established range of Merck Ionic Liquids perfectly [Paul Lawrence 2006].

Apart from being a developer and producer of ILs Bioniqs offered also *contract research and consulting services*. Its business model from 2006 is given in Figure 2.

The activities of Bioniqs received attention and in 2007 the Yorkshire Forward Bioscience award for the "Young Company of the Year" was given to Bioniqs [University of York 2007].

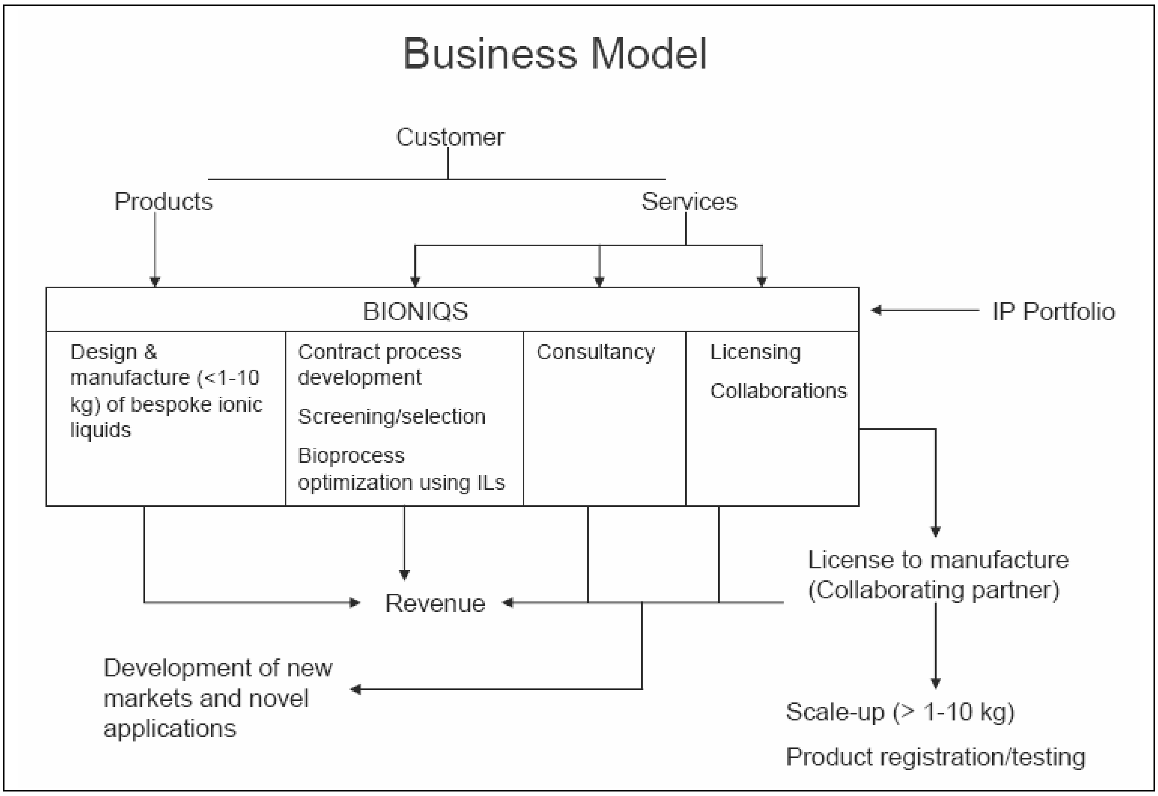


Figure 2: Business model of Bioniqs by 2006 [Walker 2006].

Market Entry, Expansion and Diversification until Bankruptcy

Every totally new technology requires information for and communication with the market and *demonstration how to advantageously use the new technology*. However, Bioniqs "consultancy services" turned out to be marketing efforts for product sales and technical service rather than a relatively separate type of service to generate a notable revenue stream.

Bioniqs envisioned *two customer segments*: industrial customers and customers from academia and public research institutes.

Dr. Walker said: “The consultancy element of what we do really helps us to understand and develop our own products. We have to talk to clients in fine detail about their needs and why one particular item is suited to those requirements or not, this gives us an advantage when designing our own solvents. We are able to offer an objective service thanks to an advanced database which provides a highly developed and systematic evaluation of existing products.” [University of York 2009]

Early IP management and research effort at Bioniqs focused on *solvents for industrial enzymes*. But it soon became clear that, despite the scientific attractiveness, this is *a difficult market to enter*. It proved difficult to get companies to risk the high investment needed to revolutionize their manufacturing processes [BBSRC 2008] (cf. similar issues of Solvent Innovation GmbH – B.2).

Hence, Bioniqs, with ionic liquids and their applications in the chemical and pharmaceutical industries, put its focus largely *on* production processes including production and distribution alliances with IL as solvents or auxiliaries for *decontamination and cleaning* of process reactors and recycling processes as well as *extraction of natural products from biomass*.

It hoped to *take advantage from the “green chemistry” and CleanTech trends* which emerged clearly by 2005/2006. As a *differentiator* Bioniqs positioned its offerings on design of environmentally friendly solvents that will provide performance and efficiency improvements over many hazardous materials and on identification of such ILs as a timely service because many conventional solvents were becoming more difficult and expensive to use due to increasingly *stringent environmental and safety legislation*, such as the so-called REACH registration for Europe. REACH tends to require replacing substances and solvents because of their negative environmental impact. This more generic approach reflects ILs as just a special category of solvents.

On its Web site of 2006/2007 this was reflected by its mission statement and listing of applications:

Mission Statement: Bioniqs exists to design and deliver the highest quality products and services to our customers in the field of solvent technology. Our aim is to achieve and maintain a world leading position as a developer and supplier of green solvents and of processes utilizing these materials.

Business: Our core offering is a solvent selection service (solventS), which is used to identify and if necessary design an optimal solvent for each customer’s requirements. This unique service can also include assistance with IP licensing, scale-up and solvent supply.

Applications:

Green Alternatives to Conventional Solvents

- Extraction of natural products
- Waste recycling
- Cleaning

Biocatalysis.

For instance, the cleaning business envisioned tailor-made ionic liquids for dissolving poorly soluble active pharmaceutical ingredients (APIs) off the walls of reactors. These kinds of applications would be serious scale – multi-ton [Short 2006].

In 2008/2009 Bioniqs was successful in winning funding from the UK government to design solvents that will enable some plastics (high performance polymers) to be recycled more efficiently. The HiPerPol project aimed to enable polymers to be separated from plastic waste-streams using lower temperature extraction processes than have been used previously. This should help to avoid tons of plastics being incinerated or consigned to landfill each year [University of York 2009].

As there was (and is) much discussion about the notion and the understanding of "green solvents" as a marketing instrument Bioniqs introduced and promoted *a green solvent certification* in response to confusion over the reality of claims made about "green chemicals" and many novel solvents [University of York 2009; Cleantech 2009; Newton 2009:10-11].

Named "*econiqs*", the certification offered reassurance to companies that the chemicals they are using conform to current guidelines. To qualify a solvent must satisfy stringent criteria including biodegradability within 14 days, low toxicity to *Daphnia magna* and green algae, and sustainability [University of York 2009]. econiqs is not designed to be a fully harmonized specification [Newton 2009:17]. This green solvent certification has been launched in Bioniqs' 2009 Solvent Catalogue which features over 200 protic ionic liquid solvents [Cleantech 2009].

As Bioniqs strived for assisting the chemical community in developing increasingly sustainable, safe and ecologically efficient working practices it used its "solventS" service to work with their customers to develop solvents which they claim are *optimized for their technical, economic and environmental performance*."

This service was based on the high-throughput screening and design capabilities of Bioniqs' solvent modeling software and proprietary database of over 12 million solvent permutations (including both ionic and molecular solvents) [Connect 2008].

The ROSETTA solvent simulation database [Newton 2009] combined advanced structure-property alignment tools with a series of databases to evaluate the performance and properties of solvents along with other requirements, such as cost and toxicity/environmental impact. The molecular modeling for solvent optimization was based on pharmaceutical industry techniques and was refined using solubility parameter algorithms [Connect 2008].

This screening and evaluation was related to the 'solventS' service by two stages. The first was a small solvent screening study which evaluates about 450 commercially available green solvents, including Bioniqs' protic ionic liquids (PILs). If a suitable solvent is not available a larger design study can be undertaken to create a new unique solvent that meets all of the customer's requirements.

By 2008 Bioniqs had implemented *new market leading prices for their catalog range of "green" solvents*. Due to the development of new manufacturing processes they were available from as little as £49/kg which Bioniqs claimed to be cheaper than products of other providers [Tornado-Insider 2008] – but still very high compared with conventional solvents.

As a marketing instrument, ahead of its 2009 product catalog, Bioniqs launched three solvent kits; "Product Catalogue Starter kit", "Low Viscosity kit" and "Hydrophobic kit." These offered a representative selection of ammonium salts and would address researchers who are new to protic ionic liquids (PILs). "The kits offer an easy, low-cost entry route for those interested in assessing the suitability of PILs for novel applications" said Marketing Manager Robert Newton. [Angel News 2008].

Concerning the "*extraction of natural products*" potential with ionic liquids Bioniqs had, for instance, successfully extracted artemisinin (also called artemesinin), the anti-malaria drug precursor, from both fresh and dried plant material following an *in silico* (performed on computer or via computer simulation) solvent design process from a database of some 350 proprietary ionic liquids [Syllivan 2006].

The drug artemisinin, approved by the World Health Organization (WHO) for the treatment of malaria, is found in the leaves of the plant species *Artemisia annua* and is produced by extraction methods. The solvent selection is a major parameter of the extraction process for artemisinin fulfilling international standard. Each extraction process has strengths and weaknesses.

Extractions can be carried out with various solvents, such as hexane, or ethylacetate or ethanol, hydrofluorinated solvents (hydrofluorocarbons (HFC-134a), or supercritical carbon dioxide. At present on an industrial scale, hexane, petroleum ether, ethanol or mixed solvents such as hexane – ethylacetate or petroleum ether – ethylacetate are currently used for artemisinin extraction. The real process involves a number of sub-processes, for instance, recovery of solvent from post-extraction biomass, recovery of precipitated artemisinin (and removal of residual solvent), removal of water, and purification.

But when Bioniqs entered the artemisinin field scientists previously devised a semi-synthetic route to artemisinin based on the intermediate artemisinic acid – a compound that can be produced by specially engineered yeast. That technology was developed by a group led by Jay D. Keasling, a professor at the University of California, Berkeley, and was developed commercially by the biotech firm Amyris, founded in 2003 [Runge:Table I.97].

Amyris has licensed the technology to the giant pharma firm Sanofi with the hope of bringing semi-synthetic-artemisinin-based therapies to the market by 2013. Gaining access to the antimalarial compound artemisinin could also become easier and less expensive, thanks to a continuous-flow synthetic procedure developed by researchers in Germany [Halford 2012].

In 2008 Bioniqs had secured £50,000 of investment from Viking Fund to enable continuing to fund its work with the anti-malaria drug artemisinin [PharmiWeb 2008; Angel News 2008]. And Adam Walker was quite optimistic about the role extraction of artemisinin could play: “The investment from the Viking Fund and IP Group will allow us to demonstrate the artemisinin extraction process at scale and fulfill the commercial potential of our ionic liquid. This will be a significant milestone for Bioniqs and will help to improve the technical, economic and environmental performance of extracting artemisinin for anti-malaria drugs.” [PharmiWeb 2008]

But, Bioniqs’ approach to artemisinin extraction turned out to be a scientific investigation rather than a recipe for implementing a real process – it was not a demonstration of the artemisinin extraction process at scale and fulfilling the commercial potential of Bioniqs’ ionic liquid.

The investigation evaluation of ionic liquids was extended to include an indirect comparison with hydrofluorocarbon (HFC) solvents, supercritical carbon dioxide and ethanol. The work performed during the course of this study had yielded information regarding the parameters necessary for the design of an ionic liquid for the extraction of artemisinin.” [Bioniqs 2008]

The study revealed that *further fine tuning can lead to the end product of an ionic liquid* optimized for the needs of the real process. A set of process parameters were revealed and it was recommended that these parameters are used as the basis for a final product specification and that multi-parameter screening is used.

In addition, the involvement of chemical engineering specialists was recommended “in order to address process issues, such as more effective recovery of solvent from post-extraction biomass, recovery of precipitated artemisinin (and removal of residual ionic liquid) and removal of water from the post-precipitation supernatant in order to recycle the ionic liquid. Addressed together, optimization of both the solvent and the process is anticipated to deliver an efficacious and practical solution for the extraction of artemisinin.” [Bioniqs 2008]

Some Metrics and Remarks Concerning Bioniqs’ Failure

On foundation in 2004 Bioniqs consisted of three people, but was growing to employ eight people in 2007 [RSC 2007].

There is no explicit information on the organization of Bioniqs. However, as an indication of organization, the small group of less than ten employees can be characterized by the roles of a team of six people given by Newton [2009]:

- Dr. Adam Walker, CEO & Co-Founder
- Dr. Guy A. Hembury, Senior Scientist
- Dr. Neil Sullivan, Commercial Advisor
- Lauren Tate, Project Scientist
- Gayle Fairless, Project Scientist
- Robert Newton, Marketing Manager.

The company had a mixed public/private financing. Equity split post-investment was [Walker 2006]:

- Founders 16 percent
- Amaethon 44 percent
- IP2IPO 24 percent
- University 12 percent
- Staff 4 percent.

Public financial resources included, for instance, Connect and money from Research Councils of the UK, such as the Biotechnology and Biological Sciences Research Council (BBSRC).

The financial decline of Bioniqs towards a financial collapse was already reflected by some financial indicators, such as "cash at bank" and "net worth", comparing 2006 and 2007 data [Company Check 2012]:

Cash at Bank: £131, 534 (2007), ca. £380,000 (2006; from graphics) Cash at Bank and "cash in hand" is the bank balance for Bioniqs Ltd. at the end date of the period the accounts were for.	*Net Worth*: £191,626 (2007), ca. £390,000 (2006, from graphics) The company's Net Worth is calculated as Shareholders Funds minus Intangible Assets.

After five years of existence, Bioniqs was no longer viable. The key steps of the liquidation process started by mid of 2009 [DUEDIL]:

2009, Jul. 11: Appointment of Administrator
2010, Mar 11: Appointment of Liquidator
2011, Aug. 20: Final Meeting of Creditors.

There were still tremendous *issues of market entry* in terms of *cost of ILs* and *replacing existing processes* including a fight against switching cost and attitude and risk aversion of customers to implement a totally new technology – industrial customers did not want to act as the "guinea pigs."

Bioniqs Ltd remained largely a *curiosity-driven research endeavor* with (probably) meager revenue in an entrepreneurial environment relying on perceived potential or unexpected commercial opportunities without a clear identification and focus on its major markets and executing related market entry or, at least, convincing demonstrations.

Over its period of existence it looked like a scientific exercise exploiting the potential of a novel class of patented ammonium-based ionic liquids.

Over its time of existence Bioniqs can be assumed to have had little direct contacts with the market or contacts insufficient to build sales activities with potential customers. Competing with other IL startups concerning contract research and consulting services for revenue generation may have suffered from the same services offered by the more established other IL startups.

The end was a state of the firm without enough cash and probably no chance for further financing due to the Great Recession.

Competition

The overall business and competitive situation of ionic liquids is described by an overview of Runge [A.1.5] and the Solvent Innovation GmbH case (B.2). Bioniqs was a late entrant in the field; it showed up several years later than the other startups in IL.

Due to the myriad applications that can be envisioned for ionic liquids direct competition by firms can be avoided – or will be harsh if firms will provide competitive offerings.

In the 1980s, Prof. Kenneth Seddon, now of Queen's University, Belfast, and others recognized that ionic liquids might have broader potential, particularly as reaction solvents and separations media. Since then, a growing community of researchers has studied their properties and application.

For instance, Bioniqs had German NTBF competitors being active also in biotechnology and/or biocatalysis. Solvent Innovation (B.2) emphasized enzymatic biocatalysis, IoLiTec (B.2) worked on enzymatic reactions and protein crystallization.

During its life-time Bioniqs operated vis-à-vis a competitive startup in the UK, Scionix Ltd., with already several years of existence. The company was set-up in 1999 to commercialize the industrial use of a novel class of solvent systems, focusing on specific ILs. Its development until 2009, however, provided no framework for considering Scionix to be a competitor for Bioniqs.

Scionix Ltd.

Much earlier than the science venture Bioniqs there was another scientific startup in the UK, Scionix Ltd. Both startups focused on commercialization of university research, but had *different target markets and also different approaches to the related technology transfer processes*. Scionix. founded in 1999, is still alive and therefore, interest will refer essentially to the development of Scionix and its status by around 2009 amidst the Great Recession.

A German competitor Solvent Innovation (B.2) was also founded in 1999. And in the same year QUILL was established in the UK. The Queen's University Ionic Liquid Laboratories (QUILL) Research Centre was founded in April 1999 as an industrial consortium, with members from all sectors of the chemical industry. It is based on a concept of a university/industry cooperative research center (I/UCRC).

Ionic liquids (IL) for broad chemical and biotechnological industrial and research applications emerged only by the end of the 1990s though they were known for decades [Runge 2006:538-540].

In 2004 just before the foundation of Bioniqs in December 2004 Alan Curzons, from the corporate environment, health and safety department of GlaxoSmithKline (GSK, UK), seemingly condemned ionic liquids (ILs) to a long-term future with only academic interest rather than the industrial applications that have long been heralded by research leaders [West 2005].

> “At the present rate of progress, unless there are significant changes in the state of the art, I think that it is unlikely that we will see widespread use of ionic liquids within the next 10 years.'

But, one month after Curzons’ statement Scionix won the prestigious Crystal Faraday Green Chemical Technology award for developing two processes using ILs. According to Crystal Faraday, these processes “offer significant improvements in chemical processes, products and services so to achieve a more sustainable, cleaner and healthier environment as well as creating competitive advantage.” And the German startup Solvent Innovation was developing continuously ionic liquids and in 2008 ultimately was acquired by the large German firm Merck KGaA for its ILs.

Scionix now produces ionic liquids on a ton scale, primarily for use with metal finishing applications, such as metal deposition and electropolishing. But by March 2014 on the Web site of Scionix one can still read:

“Scionix is one of the world’s largest manufacturers of ionic liquids and *aims to commercialize* the use of ionic liquid technology.” (Emphasis added)

Scionix is a *joint venture* between the University of Leicester and Genacys Ltd. (a wholly owned subsidiary of the Whyte Group Ltd.).

Whyte Group Ltd. (Whyte Group Chairman, Melvyn Whyte) is large privately owned business in the UK and has a number of diverse activities, including manufacturing, distribution and R&D. The flagship of the group is Whyte Chemicals Ltd. Whyte Chemicals is one of the largest private distributors of chemicals and polymers in the UK and it also manufactures pharmaceuticals: both formulation and active pharmaceutical ingredients (APIs).

Genacys is a special external organization acting as a *corporate venturing company (CVC)* and on the basis of bringing together research ideas and entrepreneurial spirit, targets to turn early-stage technologies into separate successful corporate entities through collaborations, strategic partnerships and joint ventures. Genacys, therefore, provides technology assessment, due diligence, also intellectual property guidance and licensing facilitation and commercial expertise in addition to legal and accounting support. Genacys has been fundamental in patenting the technology and commercializing the research carried out at the University of Leicester.

Looking at Genacys’ portfolio on its current Web site, one observes Scionix to be the only firm listed. But one read: “One of Genacys’ flagship technologies is Scionix Limited.” (Now one reads “Our flagship company, which is reaching maturity, is Scionix Limited.”)

The Entrepreneur(s)

Andrew Abbott gained his PhD in electrochemistry from Southampton University in 1989. Following post-doctoral studies at the universities of Connecticut and Liverpool, he became a (senior) lecturer at the University of Leicester in 1993, and Professor of Physical Chemistry there in 2005. Since 1999, Professor Abbott has been also Research Director of Scionix Ltd. [Endres et al. [2008]. He acted also Head of the Department of Chemistry [Genacys].

He can trace his career in Chemistry to his chemistry teacher at school. If he could not be a scientist, he always wanted to be an artist and had it not been for his lack of talent he would have surely made it. Chemistry was his fallback position [Badcock 2012].

His research is based on the design, fundamental studies and applications of ionic liquids and deep eutectic solvents in the context of Green Chemistry. Therefore, he is interested in developing sustainable materials and focusing on metal deposition and dissolution as some of the most pressing issues in green chemistry. Particularly reducing aqueous effluents of heavy metals are some of the most pressing issues because of the acute toxicity and large volumes of the processes [Badcock 2012].

Prof. Abbott views the conservative tendency in manufacturing as main challenge facing Green Chemistry which leads to only small incremental change. “The challenge from an academic point of view is retaining credibility for new technologies. We still tend to go in fads such as supercritical fluids or ionic liquids and see them as a panacea.” [Badcock 2012]

He has carried out extensive research into the characterization of supercritical fluids and ionic liquids. The research has encompassed diverse applications including electrochemistry, synthesis, novel materials and biocatalysis, in particular,

- Ionic Liquids
- Metal Processing (also called Ionometallurgy)
  Processes have been developed for the deposition of Cr, Al, Co, Ni, Cu, Zn, Sn, Pb, Pd, and Ag.
- Lubricants
  The group is characterizing the lubricant properties of ionic liquids (cf. Solvent Innovation, B.2).
- Thermoplastic Wood
  The goal is to emulate the chemistry of plants to produce a range of versatile plastics from purified starch and cellulose. Professor Abbott hopes for waste starch to act as an alternative source of raw material to oil in support of a sustainable future. He has been investigating complex chemical mixtures which are biomimetic of cell fluids, and varying their compositions to investigate the properties of resultant plastics.

The Leicester team has been studying ionic liquids that offer a clean way to *carry out chemical processes, in contrast to strong acids*. They found that mixtures of *zinc chloride and choline chloride* form non-volatile liquids at ambient temperatures that can be used as solvents. These mixtures (salt plus complexing agent) are also much cheaper than the ionic liquids used previously and do not contain aluminum, which can cause environmental damage [Harvey 2001].

A group at the University of Leicester, through its joint venture company Scionix, is developing alternative electropolishing electrolytes using novel eutectic mixtures (types of ionic liquids). The ionic liquids are based on the biodegradable pro-vitamin choline chloride (Figure 3), a bulk commodity chemical produced on Mton scale.

A lot of the current activity is concerned with the *application of ionic liquid technology to an industrial scale*.

Two processes have built on commercial scale (~1 ton) and seven further processes at pilot scale (between 50 and 250 kg). The laboratory contains unique demonstrator facilities of a range of metal processing techniques including metal polishing, immersion coating and electrodeposition. Used ILs will be recycled.

Electropolishing, known as electrolytic polishing (especially in the metallography field), is an electrochemical process that removes material from a metallic workpiece. It. dissolves metal off. It is used to polish, passivate, and deburr metal parts (burr: a rough area on a piece of metal that is left after the metal is cut). It may be used in lieu of abrasive fine polishing in microstructural preparation [Wikipedia-1]. Electropolishing is electroplating in reverse. Instead of depositing a coating of another material on a surface, the action of electropolishing is to remove a surface layer, typically 20-40 micro-meters in depth in the case of stainless steel.

Electroplating is a process that uses electrical current to reduce dissolved metal cations so that they form a coherent metal coating on an electrode. The process used in electroplating is also called *electrodeposition*. It is analogous to a galvanic cell acting in reverse. The part to be plated is the cathode of the circuit. In one technique, the anode is made of the metal to be plated on the part [Wikipedia-2].

Prof. Abbott is a scientist with a commercial mindset. Reasons for him to look at spinning out a company comprise, for instance, [Abbott 2009]:

- Unfettered capital income
- Kudos (status, reputation)
- Demonstration of research relevance
- Access to addition funding sources
- Interaction and input from industrial partners.

The Particular Technology

Most of the ILs Scionix has developed are based on ammonium salts (Figure 3) as did later Bioniqs (Figure 1). Its ionic liquids are based essentially on choline chloride (related to vitamin B4) [Wikipedia-3].

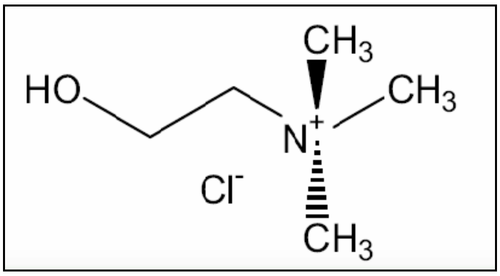


Figure 3: Choline chloride (vitamin B4.

Choline chloride is mass-produced and is an important additive in feed especially for chickens where it accelerates growth.

Total production of choline chloride reached 98,000 tons per year in 2001 (forecasted to reach 515,000 tons in 2017) propelled by increasing demand as supplement in various end-use industries, such as feed for poultry, swine and fish farming. Choline was also classified as an essential nutrient. Based on such a mass product related ionic liquids could be assumed to be applicable to large scale, low cost processes [University of Leicester].

Being produced on an Mton scale, its *low price* was (is) ca. €2/kg. Other important *"green" features* include [McKenzie 2006]

- Non-toxicity (vitamin B4 RDA (recommended daily allowance) – 550 mg)
- Non-toxicicity and biodegradability
- Its use does not have to be registered.

With urea choline chloride forms a deep eutectic solvent.

Eutectic based ionic liquids containing choline chloride have been shown to be *useful for electrochemical applications that currently use aqueous solutions*. For instance, they provide a practical alternative to the use of phosphoric and sulfuric acid mixtures for the electropolishing of type 316 stainless steel.

A *deep eutectic solvent* [Wikipedia-4] is a type of ionic solvent with special properties composed of a mixture which forms a eutectic with a melting point much lower than either of the individual components. The deep eutectic phenomenon was first described in 2003 for a mixture of choline chloride and urea in a 1:2 mole ratio, respectively. Choline chloride has a melting point of 302 °C and that of urea is 133 °C. The eutectic mixture can remain in the liquid state to temperatures as low as 12 °C. There are four types of eutectic solvents:

Type I Eutectic	metal salt + organic salt (e.g. $ZnCl_2$ + choline chloride)
Type II Eutectic	metal salt hydrate + organic salt (e.g. $CoCl_2{\cdot}6H_2O$ + choline chloride)
Type III Eutectic	organic salt + hydrogen bond donor (e.g. choline chloride + urea)
Type IV Eutectic	metal salt (hydrate) + hydrogen bond donor (e.g. $ZnCl_2$ + urea)

Deep eutectiic solvents dissolve a wide range of solutes, for instance, salts, polar organics, metal oxides, amino acids, enzymes and surfactants. The electropolishing process of Scionix was running on a larger scale (at a 1,300 liters scale) at Anopol Ltd. (Birmingham), a cooperation partner of Scionix. Other applications having been developed at Leicester University included biocatalysis (biodiesel purification) and antistatics [McKenzie 2006].

Special Processes Providing an Opportunity for Scionix

The following outline summarizes market considerations of Prof. Abbott (Senior Lecturer at that time) and Dr. Khalid Shukri of Genacys, later Business Manager of Scionix [Genacys].

In most developed countries corrosion of metals in the environment costs between 3 and 5 percent of GNP every year. Electrodeposition of a metallic coating is a key method of reducing corrosion that passivates on contact with the environment and prevents an oxidizing agent reaching the substrate. This kind of surface protection has a fundamental position within global engineering industries, with applications in a wide range of industrial sectors.

On the other hand in 1990, the electroplating market in the UK was valued at £700m, with a projection in excess of £1.3bn by 2005.

The major disadvantages of the current process of chromium plating are:

- It requires the use of chromic acid-based electrolytes comprising hexavalent chromium – Cr(VI).
  The toxicity and carcinogeneity associated with Cr(VI) has resulted in wide-ranging environmental legislation in the USA and Europe to reduce its use.
- The economics of the existing technology are unfavorable due to the low current efficiency of the reduction of Cr(VI) in acid media. Acid-based electropolishing is an inherently inefficient process: only 10–20 percent of the energy supplied is utilized for electropolishing.

As response to this opportunity Scionix has developed a series of ionic liquids containing a variety of metals that can be used for *electrodeposition* (electroplating).

> In particular, its chromium deposition processes use Cr(III) salts, which are significantly less toxic than the carcinogenic Cr(VI) species (new ionic liquid mixes choline chloride with CrCl3·6H2O).
>
> In addition, the Scionix processes operate with >90 percent current efficiency. This decreased power consumption does not only reduce the cost but also greatly reduces the overall environmental impact of the chromium deposition process, making the ionic liquid technology a more environmentally benign form of plating.

Moreover, since these are not aqueous solutions, there is negligible hydrogen evolution. Hence, essentially crack free, highly corrosion resistant deposits are possible. This may also allow thinner deposits thus reducing overall material and power consumption even further.

Furthermore, as the plating baths do not produce any toxic chromic acid vapors, the working conditions for operators are also dramatically improved.

Additional benefits include: required effluent treatment is minimized and air pollution control measures are also made redundant.

The technology developed by the university project is generic to most metal plating systems and as such should represent a significant advancement for the environmental sustainability of a major industrial process

Electropolishing of stainless steel is an effective way of increasing corrosion resistance. Electro-polished components also decrease wear and increase lubricity in engines, decreasing a major cause of engine failure.

And Scionix identified to offer several other functional benefits. Current electropolishing technology uses harsh aqueous mineral acids such as sulfuric and phosphoric acids. These are naturally corrosive, harmful to work with and must be neutralized before disposal. The scale of this activity worldwide represents a significant environmental concern.

Based on this opportunity the Leicester Group was developing a commercially viable medium-to-large-scale electropolishing plant process using their novel electrolytes in collaboration with UK companies Anopol and Whyte Chemical. The related development project should optimize electropolishing parameters and develop a protocol for commercial electropolishing surface treatment using these electrolytes. The Group was also evaluating the long-term stability, recyclability and reprocessing of the ionic liquids.

The medium-scale plant to be constructed, based initially on a 500-liter electrochemical cell, would be the largest industrial application of this type of solvent.

Awards and Publicity

During its first six years of existence Scionix was regularly awarded with various awards that motivated its staff [Scionix].

Mid of 2009: Andrew Abbott of Leicester University with Scionix is the winner of the Green Chemistry Award [Royal Society of Chemistry].

December 2006: Scionix wins the National Energy Efficiency Award.

July 2004: Scionix wins the Crystal Faraday Green Chemical Technology Award.

The prestigious Crystal Faraday Green Chemical Technology Award was for developing two processes using ILs. According to Crystal Faraday, these processes “offer significant improvements in chemical processes, products and services so to achieve a more sustainable, cleaner and healthier environment as well as creating competitive advantage.”

As often the awards were associated with expectations and high hopes which later did not materialize as anticipated.

- In 2004 Dr. Abbott, who led the research, said “We hope that the improved current efficiency together with their environmental compatibility will lead to the wide-spread adoption of these liquids.” [Scionix 2004].
- In 2005 Dr Khalid Shukri (of Genacys and Business Manager of Scionix) said “this project will revolutionize the way we currently look at metal waste and it will turn hundreds of tons of hazardous waste into a useful commercial product.”

The Business Idea and Foundation Process

Around 1998 Andrew Abbott and his colleague David Davies (both senior lecturers) produced some new ionic liquids that were comparable in cost with many commonly used organic solvents and could be made from readily available materials, such as zinc chloride and choline chloride.

"Within the university system it is difficult to set up and finance *a spin-out company that requires significant research and development expenditure*. Amazingly, within 18 months of the initial experiments both scientists had formed the joint-venture company Scionix, obtained industrial backing and *filed three patents covering more than 50,000 new ionic liquids* (Table 2). Our luck was to find a synergistic industrial partner" – Genacys Ltd. of the Whyte Group [Abbott 2001] (Emphasis added).

Andrea Whyte has been cited to be involved in the founding of Scionix Ltd. [1]

The turning point for Scionix came when one of the processes presented *an economically viable solution to a perceived urgent industrial problem*. Chrome plating is used to prevent corrosion and wear, as well as for decorative purposes. EU and US legislators were (and are) seeking to limit its industrial use. But the lack of an alternative method had delayed the phase-out [Abbott 2001].

For funding foundation and further development several options were taken into consideration ("How do we want to fund it?") [Abbott 2009]

- Industrial Partner (Money + financial & technical expertise)
- Business Angel (Money + financial expertise)
- Venture Capital.

"When I started this research, I was inexperienced about how business worked, but the past three years {1998-2001} have been a roller-coaster ride through the intricacies of patent law. I am now as familiar with SWOT analysis, Gantt charts and critical-path analysis as I ever was with chemical thermodynamics. I have learnt that a *joint-venture company* needs synergy between the partners, an *academic interested in the applications* as well as the theory, a *multidisciplinary team* and an *idea that is timely*. It may be heresy, but there are many aspects of business management that are useful in academia." [Abbott 2001]

Scionix *believed* that by initiating *collaborations and strategic alliances* will bring process advantages to the users much quicker and in a way that allows the users to influence and design the final process properties. Its people did not believe this is a mere means of diluting risk but an effective way of improving the processes and to make them commercially viable.

A corresponding Private-Public-Partnership (PPP) would allow *fundamental and applied research to be carried out at the university while providing the production, marketing and licensing capability by the private organization*. Scionix Ltd. holds three worldwide patents that cover over a million (!) ionic liquids for product licensing [University of Leicester].

The related model was (Table 1) [Abbott 2009]:

Table 1: The structure of the joint venture Scionix and the division of tasks.

UNIVERSITY of LEICESTER	GENACYS Ltd.	WHYTE GROUP Ltd.
Scientific Competence:	Commercial Competence:	Commercialization:
Electrochemistry	Startup Expertise	Bulk Chemistry
Synthesis	Finance	Logistics
Inorganic Chemistry	Intellectual Property	Distribution
Analytical Chemistry	Licensing	Accounting

After further development work concerning commercialization in 2001 Scionix got a Business Development Manager [Rozenberg]. Gregor Rozenberg of Rozenberg & Co, a biotech and venture consulting firm, acting as Business Development Manager 2001-2003 claimed to have transformed Scionix into a global ionic liquids company. In addition he claimed to have initiated clean-tech chromium electroplating and electropolishing businesses with revenue forecasts in excess of £30m.

In May 2003 Dr. Khalid Shukri joined Genacys to then fill the role of a Business Manager and later Commercial Director of Scionix.

Dr Khalid Shukri graduated from University College London (UCL) with an honors degree in chemistry. He then went on to complete a PhD in chemistry/material science from UCL in 1998. He started his career working at Capteur Sensors in Oxfordshire where he was part of the team that commercialized gas sensors, especially in the US and Europe. Before joining Genacys he was working in Virginia, USA where he was responsible for developing the business.

> The founders expressed the conviction that “the strength of Scionix is that it is not a one-product or one-solution company.” “This is the right technology at the right time and, above all, it is the right color – green.” [Abbott 2001]

During its early phase Scionix obtained funding from the UK Department of Trade and Industry (DTI) and the Engineering and Physical Sciences Research Council (EPSRC).

A project, funded by the sustainable technologies initiative (STI) from the DTI and the EPSRC, addressed the replacement of chromic acid for chromium electroplating by the new sustainable technology based upon Cr(III) containing ionic liquids. The project’s goal was to take the technology from bench idea to industrial reality. The project-related funded group included structurally a company that will manufacture and recycle the ionic liquid, an electroplating business and an aerospace manufacturer that will use the finished pieces [Abbott 2001].

In particular, the project consortium involved close co-operation between; 1) the University of Leicester which was developing the new methodologies, 2) Poeton Industries Limited which was to develop and test the technologies on a pilot industrial scale (baths up to 1,000 liters), 3) Smiths Aerospace Actuation Systems-Cheltenham which would apply and validate these techniques on high-tech industrial examples and 4) Whyte Chemicals Limited, which had to formulate the novel ionic liquids and supply them to the end users. The whole project was managed by Scionix Ltd.

In 2004 the Crystal Faraday Green Chemical Technology Award was in recognition of two key ionic liquid technologies; an alternative to chromic acid in the chromium plating industry and a substitute for sulfuric acid for the *electropolishing of stainless steel*.

The new (“*potentially revolutionary*”) way of electropolishing stainless steel had been developed by a Basic Technology project funded by the Department of Trade and Industry (DTI). The project involving Anopol Ltd., Whyte Chemicals Ltd., Scionix Ltd. and the University of Leicester used ionic liquid analogues in place of harsh mineral acids in current technology. The project stemmed from fundamental research carried out at the University of Leicester. Anopol Ltd. should develop the technology in pre-production scale. Whyte Chemicals Ltd. should produce the new liquids; it had capability to manufacture in multi-ton batches [Scionix 2004]. The electropolishing process was running at 1,300 liters scale at Anopol Ltd (Birmingham) [McKenzie [2006].

Anopol Ltd. is the UK’s largest group offering electropolishing, pickling, passivating and cleaning treatments for *stainless steel, nickel and nickel alloys*. Anopol operates from 2 sites, one in Birmingham and the other in Bordon, Hampshire. With over 40 years experience, Anopol claims to be the market leader in chemical and electrochemical processing of stainless steel, and other metals, for a wide spectrum of industrial, decorative and functional applications. [2]

Anopol’s main services, pickling and electropolishing of stainless steel items, includes castings, forgings, pressings, wirework and welded fabrications. Ancillary treatments also available are general cleaning and passivation of stainless steel.

Anopol processes, for instance, *parts for Apache helicopters, nuclear reactors and medical implants*. By 2011 it employed 39 people at sites in Birmingham and Hampshire and recorded its best ever year exceeding £3m sales after it bounced back from the recession by identifying new markets and investing in the total quality and service of its surface finishing for the customer [Engineering Capacity 2012].

Scionix *developed several technologies in the fields of metal polishing, plating, metal recovery, recycling and cleaning*.

In 2005 Scionix has been awarded a one million-pound project from the DTI for a project entitled “Recycling of Electric Arc Furnace Dust Using Ionic Liquids”. It was a two year project with four other partners and Scionix acting as the lead coordinator for the whole project. This project aimed to neutralize hazardous waste from the steel industry and convert it into useful products. The process will isolate heavy metals, recover useful constituents such as zinc and recycle iron oxide. Their new ionic liquids were at the core of this procedure [DEFRA 2008].

Electric Arc Furnace Dust (EAF) produces ca. 15-20 kg of dust per ton of steel [McKenzie 2006].

- The dust is classed as a toxic waste because of the high heavy metal content.
- Several million tons of dust is produced per annum.

The process will eliminate the necessity to dispose of hazardous electric arc furnace dust in land-fill sites. The process was seen as economically profitable because of the reduced landfill costs and the recovery of useful metals [Scionix 2005].

Also in 2005 (March) the biotechnology orientation Scionix led to offer a Biokit product.

Further Development and Diversification

Scionix' *business strategy* was to embrace Sustainable Development (SD) in a positive and financially rewarding context and triple bottom line (Economic, Environmental and Social) accounting was adopted as a means to long-term success.

Scionix positioned its offerings as “green solvents” with favorable performance criteria given and Scionix’ focus was on metal polishing, metal plating, catalyst recycling, cleaning applications, biocatalysis, and synthesis.

Further development of Scionix can essentially be seen in the context of the project IONMET which was initiated under 6th FP (Sixth Framework Programme) of the EU [IONMET 2007; 2020 HORIZON].

The FP6 Integrated Project had 33 partners to develop a step change in metal finishing. The project coverd the following themes:

- Fundamental properties of ionic liquids
- Depositions of metals and alloys
- Deposition of composite materials
- Electroless deposition of metals
- Electropolishing of new metals/alloys.

It should support the development of new knowledge-based and sustainable processes and eco-innovation. The focus of the project was the introduction of a breakthrough technology with the potential to transform the scope and competitiveness of industrial metal finishing processes.

Genacys acted as the project coordinator (Dr. Khalid Shukri). The consortium consisted of leading European SME’s in plating and printed circuit technology. Among others partners from the UK were University of Leicester, Anopol Ltd, Poeton Limited, PW Circuits Limited and Ashton & Moore Limited. Project time and funding were:

- Start Date: 2005-04-01
- End Date: 2009-12-31
- Project Cost: €11,703,291
- Project Funding: €7,086,000
- Project Status: Complete.

The project would build 5 demonstrator modules and involved scale-up of all viable projects.

In 2009 an Ionic Liquid Demonstrator (ILD) has been funded through the EU IONMET project involving Scionix and the Leicestershire Economic Partnership (LSEP) [ILD]. The ILD is a multi-application pilot plant facility to showcase the application of ionic liquids primarily in the area of metal processing.

The ILD project builds on the historic and *ongoing research and development activities* in the Green Chemistry Group at the University of Leicester to *transfer its ionic liquids applications know-how to Leicestershire business*. The project working with *local businesses* shall encourage end-users explore and evaluate, in a tangible way, the benefits of industrial processes based on ionic liquids.

The new pilot plant in Leicestershire should demonstrate how many industrial processes could be made cleaner and greener with ionic liquids. It will *investigate the potential* for replacing harsh acidic solvents used in metal-related processes such as electropolishing and electroplating.

Professor Abbott said: "This is a fantastic opportunity for us to collaborate with *local industry* and *hopefully* bring new technology to expand their product ranges. Our *local partnerships* have so far been very successful and we would like to extend them using this unit." (Emphases added) All ionic liquids are prepared at Grosvenor Chemicals (part of Whyte Group Ltd.) in Huddersfield.

ILD functions similar to what currently exists as a Technical Service Center of a large firm. The Ionic Liquid Demonstrator has the following technologies which can be accessed:

- Immersion deposits (silver on copper, copper on aluminum or magnesium and a wide variety of others)
- Electropolishing of stainless steel and Ni or Co alloys
- Chromium electroplating from Cr(III) based liquids
- Aluminum electroplating
- Nickel plating (with or without composite particles)
- Electroplating of zinc tin alloys
- Copper composite electroplating.

But the description of the status of Scionix' development on its current Web home page and Prof. Abbott's Web page [University of Leicester] make one assume that Scionix, though it has made 200 kg batches of ten ionic liquids and one IL made on the ton scale [Abbott 2009], is still in a market development phase [3]:

Current Web: "Scionix is one of the world's largest manufacturers of ionic liquids and *aims to commercialise* the use of ionic liquid technology." (Emphasis added)

In the same line of attitude on its Web one reads for the description, for instance concerning IL technology for cleaning, about a potential rather than about products as offerings the supplier is convinced of their superiority over other offerings: ILs …"exhibit the ability to dissolve …. coupled with the low production costs associated with the raw materials, *would make them* ideal *candidates* for use as cleaners both in the household and in an industrial environment,"

After ten years of existence by mid of 2009 Prof. Abbott's comments concerning development of Scionix were:

- Scionix was slow to develop [Abbott 2009:10]
- Be conservative when estimating the time taken to bring products to market. Focus on projects that have a very strong driver to utilize the technology. [Abbott 2009:17].
- Not enough funds initially [Abbott 2009:18];
  Companies won't invest in potential – they want to buy solutions. We underestimated development time. Work with small companies – It is a lot easier!
- Resistance to new technology – *Legal drivers are important (Cr)* [Abbott 2009:18]
- Underestimated timescale – *Some companies take a long time to reach decisions on funding, even for relatively small amounts of money (~£25,000)* [Abbott 2009:18]
- Hard to predict which areas are most likely to be successful [Abbott 2009:18]
- Never give up [Abbott 2009:21].

Patents

Scionix Ltd. holds three worldwide patents that cover over a million ionic liquids based around quaternary ammonium salts [University of Leicester; [Abbott 2009]. As the University of Leicester is a constituting organization of the JV Scionix patents owned by the University and Andrew Abbott and other inventors (Table 2) do not require consideration of licensing issues.

Table 2: Patents and applications of Andrew Abbott as inventor and University of Leicester or Scionix as assignees.

Inventor	Applicant	Publication info	Priority date
8.) New ionic liquids			
Abbott Andrew Peter, Hadi Abood	Univ Leicester	CN102666935 (A) 2012-09-12	2009-11-25
7.) New Polysaccharide-Based Materials			
Abbott Andrew Peter, Ballantyne Andrew	Univ Leicester, Abbott Andrew Peter (+1)	WO2011001142 (A1) 2011-01-06	2009-06-29
6.) Eutectic Mixtures Based upon Multivalent Metal Ions			
Abbott Andrew Peter	Univ Leicester	US2009194426 (A1) 2009-08-06 US8518298 (B2) 2013-08-27	2005-07-06
5.) Cytochrome P450 electrochemical system			
Roberts Gordon, Abbott Andrew (+3)	Univ Leicester	US6492132 (B1) 2002-12-10	1998-10-09
4.) Ionic Liquids			
Abbott Andrew Peter, Davies David Lloyd	Univ Leicester, Abbott Andrew Peter (+1)	WO0056700 (A1) 2000-09-28	1999-03-24
3.) Ionic liquids and their use.			
Abbott Andrew Peter, Davies David Lloyd (+3)	Scionix Ltd.	ZA200303272 (A) 2004-05-26	2000-09-27
2.) Ionic liquids and their use as solvents.			
Abbott Andrew Peter, Davies David Lloyd (+3)	Scionix Ltd.	ZA200303270 (A) 2004-05-26	1999-03-24
1.) Ionic Liquids			
Abbott Andrew Peter, Davies David Lloyd	Scionix Ltd.	US6573405 (B1) 2003-06-03	1999-03-24

The Current State of Scionix

For the period after 2010 Scionix seems to live on public funding and cooperation with some few (potential) customers as well as licensees.

Scionix has developed several technologies, including *several pilot plant-stage technologies*, as well as having *license agreements* with multi-national companies. It has a license agreement in place for *cleaning engine parts* for the aerospace industry, and a license with Arcelor Mittal [InnovateUK 2013].

Seventy UK companies, universities and research organizations are to share over £7 million of government funding to undertake research that could lead to the development and commercialization of innovative approaches to sustainable manufacturing for the process industry. Among these Scionix would work with the University of Leicester and Rolls Royce, which will research and develop a novel process for *electropolishing aerospace castings* using ionic liquids [Angel News 2012].

Scionix investigated a wide variety of chemical reactions in ionic liquids and aimed to develop the first large-scale production using an ionic liquid at Whyte's manufacturing site in Huddersfield.

Technologies pursued according to the current Web site of Scionix include:

- Plating General
- Chromium Plating
- Metal Polishing (electropolishing stainless steel and nickel alloy)
- Metal Reprocessing
- Arc-furnace Dust (AFD) Recycling
- Cleaning Products
- Materials.

The subject “metal reprocessing” covers *ore processing*. A process was developed to extract metals from ore samples using ionic liquids and recover the metals using electrodeposition. A spin-off process to recover Pt and Pd from spent car catalysts was scaled up.

On the other hand, the areas of *synthesis* and *cleaning* are also tackled by other suppliers of ionic liquids. Ionic liquids have been considered rather broadly for cleaning applications.

ILs offer potential as alternative cleaning agents, but one has to take *toxicology* into account which may depend sensitively on the specific anions and cations. For example, 1-ethyl-3-methylimidazolium chloride (EMIM Cl) is non-toxic, while a close derivative, 1-butyl-3-methylimidazolium chloride (BMIM Cl) is toxic [Yerti et al. 2012].

Moreover a cleaning business may encounter issues of *specifications and standards* for using ILs. As an example, a literature search and vendor survey identified suitable IL chemistries for cleaning applications at the paint/depaint and plating facilities Air Logistics Centers (ALCs) in the US. Here 2-ethylhexyl lactate (2ehl), an organic chemical, “partially green” solvent, was tested as a cleaner. Also EMIM acetates were tested. Performance requirements for cleaning operations were derived from technical orders and military specifications supplied by ALCs [Yerti et al. 2012].

According to its current Web site the Scionix team comprises the following members with related roles expressing a rather strong focus on R&D.

- Prof. Andy Abbott - Research Director
- Dr. David Davies - R&D Team Leader
- Dr. Rob Harris Industrial/Manufacturing (Metal reprocessing, ionic liquid synthesis & chemical properties)
- Dr. Katy McKenzie R&D (Electroplating, electropolishing & physical properties)
- Dr. Karl Ryder Team Leader
- Dr. Khalid Shukri Commercial Director.

By 2013 the total number of employees of Scionix was 7 [InnovateUK 2013] which means, with the exception of one additional employee, the total personnel is listed above.

A new orientation to look for an opportunity for Scionix is gaining exposure in China, leading to a successful collaboration with a Chinese company [InnovateUK 2013]. Its field for operation has been prepared by a patent application in China (patent 8 in Table 1).

Irrespective of the fact that some few people, say ca. four, may be working in “production” and “distribution” at a facility of the Whyte group for Scionix (Figure 4), compared with its German counterpart IoLiTec (B.2; Table 2) with 22 employees in 2012 (9 PhDs; nine year after foundation) Scionix shows almost no growth (expressed in terms of number of employees) after thirteen years of existence. There seems to be an issue of innovation adoption.

In 2009 Scionix, ten years after foundation, made 200 kg batches of ten ionic liquids and one IL made on the ton scale. IoLiTec, ten years after foundation in 2013, had 10 ILs industrially available with > 1 metric ton and a capacity of 25 metric tons (B.2).

Strange to say IoLiTec sells electrolytes for electroplating apparently rather successfully. Furthermore, according to its founder the focus of IoLiTec is still in research (B.2).

Compared with the very large spectrum of ionic liquids and the broad diversity of applications by IoLiTec (B.2) Scionix is focused essentially on just few eutectic ion liquids based on choline and a narrow scope of applications.

The Business Model and Position Concerning a New Process Environment

Scionix targets to be a research and development firm and a producer, distributor of particular classes of ionic liquids and licensor of its technology (Figure 4).

Related complementary aspects of its business model follow almost a text book approach for founding and developing a technology venture with a PPP-structure [Runge:Table I.101].

- A complementary leadership: A researcher with a business mindset and sufficient business knowledge and an experienced business manager (Commercial Director from industry) with (chemical) knowledge.
- If necessary infrastructure of the parent university can be used
- Technology (products and processes) is protected by patents
- It is timely: “This is the right technology at the right time.”
- A funding basis for R&D is relying on various public funds and publicly funded projects
- Differentiation: Using eutectic based ionic liquids which are different from other ionic liquids supplied by other firms
- Specifically using trivalent chromium, Cr(III), for chromium plating instead of hexavalent Cr(VI) which is toxic and carcinogenic
- Availability of scaling up production volumes for the offerings
- Ionic liquids based offerings which are very cheap compared with common ionic liquids as they are based on mass-produced raw material which is non-toxic. Their use does not have to be registered.
- Targeting engineering oriented firms which provide processing services for many Industries which have a need for reducing cost and comply with already existing regulations or regulations to become even more strict. This means there is a need for customers to become “greener.”
- Contacts and cooperation (networking) with reference industrial customers exist.

A shortcoming could be that Scionix is largely focused on local customers.

The number of industrial partners of Scionix for R&D and as potential customers (Figure 4) is much smaller than that of IoLiTec. The amount of *networking* providing external resources in terms of project partners and potential customers from various industries and in (specifically

German) competence networks for various applications of ILs are a basis of IoLiTec's strengths. IoLiTec is known – even in the US (by its subsidiary).

Also the intensity of marketing efforts via its newsletter "Ionic Liquids Today" with more than 6,500 subscribers and more than 550 customers having access to ca. 300 ionic liquids and the possibility for contract production of ILs specifically requested by customers provides another advantage of IoLiTec. And the broad variety of the volume of ILs requested by customers can be responded to by IoLiTec's micro-reactor technology (MRT) based production.

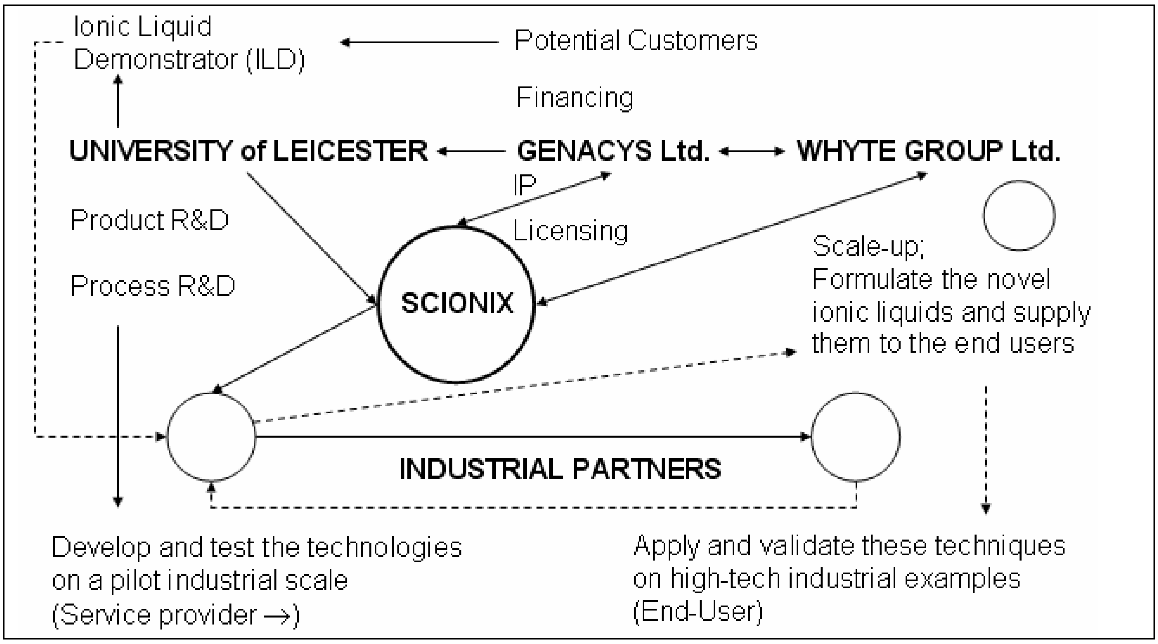


Figure 4: Essentials of the business model of Scionix.

Scionix seems to be *focused on one generic process for industries* to serve their (end-use) markets rather than the set of specific sub-processes of customers. Technical process development and the need of development of customers having a large variety of requirements seem to be associated with a disconnect. Adoption of technology push innovations requires essential involvement, commitment and close customer relations of the innovators [Runge:p. 399].

Inquiring specifically into the industry targeted by Scionix reveals some striking pitfalls. We shall concentrate for illustration on (electro)plating and specifically chromium plating and dealing with some important context-related questions concerning the Scionix process.

Is the offering (process) of Scionix a solution of a key problem or need of its customers or is it only a part of an extended problem, for instance, just a response to one particular step of a process chain of its (potential) customers? And what about the assumed advantage to replace a Cr(VI)-process by a Cr(III)-process? What about switching cost for the customers?

For the US, taken as a generalizable model, there are no companies with a dominant market share in the metal plating and treating industry. This means the industry/markets are highly segmented including few key and very many niche players [IBIS 2013]. For the UK specifically Plimsoll's Electroplating (UK) analysis reports about the 170 largest electroplating (UK) companies [ReportLinker 2013] (cf. Anopol Ltd. mentioned above).

The business situation is very diverse concerning the very many metals particular to the industries in which they are used. Plating is used extensively in the following representative industries.

Automotive	Semiconductor, Electronic	Printing
Pharmaceuticals	High Vacuum	Jewelry
Medical	Architectural	Oil & Gas
Pulp & Paper	Aerospace	

We follow a US outline [PNPPR] to describe the essentials of the industries. Metal finishing is generally the last operation before sale or assembly. It can require capital intensive operations but may have a minor financial impact on the overall value-added of the product.

Metal finishing is chemical intensive, generates waste streams that are expensive to treat, and is heavily impacted by environmental regulations. There are 46 different processes regulated under metal finishing standards (in the US) featuring different technologies, operational steps, inputs, and outputs.

As a result of these characteristics, firms decide to outsource their metal finishing requirements to “job shops.”

A significant amount of metal finishing is found within companies that manufacture products rather than those that specialize in metal finishing. These are referred to as "captive" operations. However, a great deal of metal finishing is contracted to independent establishments, the service providing "job shops."

Almost all the substances and products used in electroplating can be found in the wastewater, for instance, acidic solutions, toxic metals, solvents, and cyanides. Basically the wastewater contain is high in heavy metals, cyanides, fluorides, oil and greases. This contamination is a consequence of the different process steps such as spillage, rinsing and dumping of process baths.

Regulatory reporting requirements focus on these releases (effluents) and transfers about metals and the various chemicals used in the plating process with its many steps.

While *the exact process used at any one shop is very site specific*, the simple, generalized process flow shown step by step below is representative of the process used in most shops:

1. Part Cleaning
2. Post-Clean Rinse
3. Acid Dip
4. Post-Acid Dip Rinse
5. Part Plating
6. Post-plating Rinse
7. Part Drying.

Total Economics

Apart from the core process, two ancillary processes are found in almost every metal plating shop – metal stripping and wastewater treatment.

Like many other industries, quality, low price, and delivery time are three important competitive issues for metal finishing companies. In fact, it may be one of the most price competitive industries in existence!

Consequently, it is *the overall cost structure* of seven plus x steps and the related compliance with regulatory waste handling and reporting that determine whether or not to integrate a new, seemingly advantageous process step into the shop’s operations. A corresponding change would require considering switching costs.

Finally, for chromium plating substituting hexavalent by trivalent chromium does not require (eutectic) ionic liquids which may enter decision-making whether to introduce an ionic liquid based “Cr(III)-process.” There is chromium plating with Cr(III) using the related chromium sulfate or chromium chloride as the ingredient serving as an alternative to hexavalent chromium (Cr(VI)).

A trivalent chromium plating process is similar to the hexavalent chromium plating process except for the bath chemistry and anode composition There are three main types of “normal” trivalent chromium bath configurations [Wikipedia-5]:

- A chloride- or sulfate-based electrolyte bath using graphite or composite anodes, plus additives to prevent the oxidation of trivalent chromium to the anodes.
- A sulfate-based bath that uses lead anodes surrounded by boxes filled with sulfuric acid (known as shielded anodes), which keeps the trivalent chromium from oxidizing at the anodes.
- A sulfate-based bath that uses insoluble catalytic anodes, which maintains an electrode potential that prevents oxidation.

The trivalent chromium-plating process can plate the workpieces at a similar temperature, rate and hardness, as compared to hexavalent chromium.

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