

Draft of paper that was published as: Minshall, T. H. W., S. Seldon and D. Probert (2007). "Commercializing a disruptive technology based upon university IP through open innovation: A case study of Cambridge Display Technology." *International Journal of Innovation and Technology Management* 4(3): 225 - 239.

COMMERCIALISING A DISRUPTIVE TECHNOLOGY BASED UPON UNIVERSITY IP THROUGH OPEN INNOVATION: A CASE STUDY OF CAMBRIDGE DISPLAY TECHNOLOGY.

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This paper discusses the use of a university spin-out firm to bring a potentially disruptive technology to market. The focus for discussion is how a spin-out can build a technology ecosystem of providers of complementary resources to enable partner organizations to build competence in a novel and potentially disruptive technology. The paper uses the illustrative case of Cambridge Display Technology Ltd (CDT) to consider these issues from the perspective of the literature on open innovation (with particular emphasis on the role of partnerships between start-ups and established firms), the commercialization of university IP, and the commercialization of disruptive technologies.

Keywords: University spin-outs; open innovation; disruptive technologies; technology ecosystem.

1. Introduction

Data show that the U.K. economy performs well in terms of its ability to produce high quality scientific research but its ability to commercialize the outputs of such research remains poor [Livesey et al. (2006)]. This has been long recognized [Gill et al. (2007)] but in the face of strengthening innovation capacity of emerging economies (most notably China and India) the U.K., along with many other developed economies, has been seeking new ways to improve its innovation performance. Coupled with this desire to improve innovation performance has been the changing nature of the innovation process itself. Shortening product life cycles, intensification of competition and increased product complexity are driving the need for companies in certain industries to adopt a more open model of innovation [Chesbrough (2003); Chesbrough (2006); Chesbrough et al. (2006)]. One important element within the open innovation model is the way in which universities and industry can merge the strengths of each to generate value from bringing to market products and services based upon university-generated intellectual property (IP) [Etzkowitz, 1997 #121]. Private and public sectors have both recognized the potential such an approach can offer to help improve both firm and national level innovation performance. Consequently, many firms have re-structured their R&D activities to include a diverse range of links with universities, while regional and national policymakers have developed incentives and instruments that attempt to

facilitate the ability of universities and industry to collaborate more effectively and efficiently.

However, this model of innovation also presents many challenges. This is particularly clear when the university-generated IP has the potential to disrupt current markets and industries, but the low technology readiness level (TRL) [Mankins (1995)] of the IP means that substantial investment over an extended period is required to reach a point of significant value generation. The focus of this paper is a discussion of the issues that may face firms and universities when dealing with such IP using one specific illustrative case.

The remainder of the paper is structured as follows. First, we present the conceptual background to this research summarizing the three main themes from: (a) open innovation – including the role of partnerships between start-ups and established firms; (b) the commercialization of university research; and (c) the commercialization of potentially disruptive technologies. The core of the paper is a description of one case example that illustrates the main themes that emerged from our wider research activities. The paper concludes with a discussion of the implications that can be drawn from the themes highlighted in the case study.

2. Conceptual background

2.1. *Open innovation*

Innovation is an increasingly distributed process, involving development webs of multiple, players and modular production networks with a variety of possible – and dynamic – value chain configurations [Fraser et al. (2005)]. ‘Open innovation’ is one term that has emerged to describe: “[...] the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively.” [Chesbrough et al. (2006): page 1]. This is contrasted with the ‘closed’ model of innovation where firms typically generate their own ideas which they then develop, produce, market, distribute and support.

For open innovation, firms will need to develop the capability to acquire and integrate knowledge from a wide range of possible sources. The source of external ideas for the open model can be diverse. It may include customers, suppliers, joint venture partners, universities, publicly funded research institutes, and start-up firms. Of particular relevance for this paper are the links that established firms have developed with universities and their associated spin-out ventures.

Before turning to examine issues relating to university IP commercialization, there is one other aspect of the open innovation model that needs to be discussed in relation to the theme of this paper: the role of partnerships between start-ups and established firms.

Early-stage technology firms often face significant challenges in successfully bringing their ideas to market. Such firms, lacking the cash and complementary assets required to independently exploit their technology, are often resource constrained [Garnsey (1998)]. As a result, many choose to adopt some form of partnership-based business model where relations with other, often larger firms are critical to their growth [Rothwell (1983); De Meyer (1999); Fraser et al. (2005)]. However, these relationships can however prove difficult for both parties, due to the many asymmetries involved [Alvarez and Barney (2001); Fraser et al. (2005)].

2.2. Changing role of universities

The latest stage in the on-going evolution of the role of universities in a developed economy can be summarized as the integration of a mission of economic development besides the universities' traditional activities of research and teaching [Etzkowitz and Leydesdorff (1997); Leydesdorff and Etzkowitz (1998); Webster and Etzkowitz (2000)]. In the U.K., this additional role of economic development has long suffered from a poor image, particularly when compared to the U.S. [Minshall et al. (2005)]. The current U.K. Government has been a strong advocate of redressing this and has been encouraging and supporting universities to develop a 'third mission' to supplement their traditional missions of research and teaching. Since the late 1990s, the Government has developed and implemented strategies to enhance the ability of universities to support such activities – and key among these has been the development of a dedicated 'third stream' of funding for universities to develop their 'third mission' activities [Livesey et al. (2006)]. A wide range of activities can be grouped under the third mission banner including faculty consultancy, licensing of university IP to established firms, building of spin-out ventures around university IP, and the support for the creation of student and faculty-led start-up ventures. The quantity and quality of such activities within U.K universities is the subject of ongoing debate, and regular assessments of these activities are underway (see, for example, HEFCE [(2005; 2006)]). Despite significant public funding to support such activities in the U.K., various issues still impede collaboration with industry [Lambert (2003)]. This paper focuses on two of the third mission activities: licensing of IP to established firms and the spinning-out ventures around university IP.

Though research has identified the need for a framework to consider the commercial viability of university generated IP (see, for example, Stone et al. [(2005)]), those involved with the commercialization of university IP face a specific challenge when considering the best exploitation route for a particular item of IP – would this technology be best exploited through licensing directly to an established firm or through the formation of a new spin-out firm? For the university, there are pros and cons for each approach, a sample of which are given in Table 1.

Table 1. Example issues influencing the exploitation route

Licensing to an established firm		Creation of a spin-out firm	
Pros	Cons	Pros	Cons
Low investment requirement	Finding and managing licensees	Potential to capture high proportion of value generated	High risk
Potential for multiple revenue streams	Limited engagement with subsequent value creation	Provides focus for commercialization efforts	May lose 'star' academics
Limited need to access complementary resources	Complexity of multiple licensee requirements	Builds entrepreneurial image of university	Typically high levels of investment required to access range of complementary resources

There are many factors influencing the choice of exploitation route, but the option to create a new firm may be regarded as most appropriate in the following conditions [Minshall et al. (2005)]:

- for platform technologies;
- where the inventors are very keen to commercialize the technology themselves;

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when the idea needs to attract substantial investment to develop IP relating to the technology for subsequent licensing;

when the technology is not readily 'packagable'; and

for a generic technology with many different applications.

There are also indirect factors that influence the decision. These may include the wishes of a wider group of stakeholders such as the national government (which may have the creation of spin-outs as one of its performance measures for universities), the regional government (which may see spin-outs as assisting with regional job creation), and the university itself (which may, for many reasons, see benefit in building a portfolio of spin-outs) [Druilhe and Garnsey (2004)].

2.3. Disruptive technology

The final area of background that underpins the core of this paper is that of disruptive technologies [Christensen (1997)]. This concept has been extended to test its applicability in a wide range of industry sectors [Utterback and Acee (2005)] and to examine the various strategies that may be applied by firms faced with such a technology [Slater and Mohr (2006)]. If the technology that is being exploited through an open innovation model, drawing upon IP from a university, has the characteristics of a disruptive technology, (i.e., it underperforms established products in current, mainstream markets, but offers some new value proposition) then this presents an interesting additional dimension to the commercialization process [Walsh and Kassicieh (2004)]. It may be that the IP is attractive to established firms and hence they may be keen to take a license to this technology as part of a 'watching brief' to see how the technology and its application in the marketplace evolve. It may also be that they wish to access the right to manage this technology to prevent its diffusion and hence avoid disruption for a period. However, as a disruptive technology, it may be unattractive to established firms as they may not recognize its potential. It may not seem to offer a clear value proposition to the established firm's current customers [Christensen (1997)]. Consequently, this may force the university that owns the IP down the spin-out route.

3. Research approach

The background research for this paper has sought to examine the way in which technology-based start-up firms may use partnerships with established firms as a means to access the complementary resources they need to bring their technology to market. This research has used a case study method to draw out common themes using a sample of technology-based start-ups clustered around the University of Cambridge. Applying the principles given by Eisenhardt [(1989)], the research has sought to develop theory from the use of case studies using the resource based view as the conceptual framework [Barney (1991); Barney et al. (2001)]. The themes revealed through this underpinning research have been reported in Minshall [(2005)]. For this paper, we are taking one of the cases from this background research and using it to illustrate the issue at the heart of this paper: the challenges of bringing a potentially disruptive technology, based upon university IP and which is at a low level of technology readiness, to market. The case study reported here is that of Cambridge Display Technology Ltd (CDT)^a. The evidence presented here is drawn from the series of interviews that took place over the past 5 years with the founding, interim and current management team, as well as analysis of a range of secondary data sources. In the following sections, we present the basic story of CDT

^a www.cdtltd.co.uk

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before turning to a discussion of the key issues illustrated by this case structured around the three themes given in the conceptual background.

4. Illustrative case – University of Cambridge and Cambridge Display Technology (CDT)

4.1. Cambridge context

The University of Cambridge is one of the oldest universities in the world and it undertakes research in a wide range of science and arts subjects. It is also one of the largest in the U.K. with over 18,000 students. The University has licensing income of around UK£3.3m per annum and has spun-off 46 new ventures since 1989. It is now forming, on average, 3~4 spin-outs per year (i.e., firms based around IP owned in part or full by the University) and provides support for around 30 University-related start-ups per year (i.e., firms formed by staff and students of the University but not based around University-owned IP) [CE (2007)]. The responsibility for supporting the establishment of spin-offs and the licensing of IP rests with Cambridge Enterprise, a recently incorporated entity owned by the University of Cambridge^b.

The University itself sits at the heart of a cluster of over 1,500 high tech businesses that has evolved over the past 30 years^c. Firms within this cluster now attract 8% of European venture capital (by value) and 25% of the U.K. total [LibraryHouse (2005)].

4.2. CDT

In 1989 three Cambridge academics, Richard Friend, Jeremy Burroughes and Andrew Holmes, discovered that light emitting diodes (LEDs) could be made from conducting polymers as well as from traditional semiconductors. This generated commercial interest in the possible applications of light-emitting polymers to form the core of Organic Light Emitting Diode (OLED) displays. OLEDs can be split into two main categories: Small Molecule OLEDs (SMOLEDs) and Polymer OLEDs (P-OLEDs) (See Fig. 1).

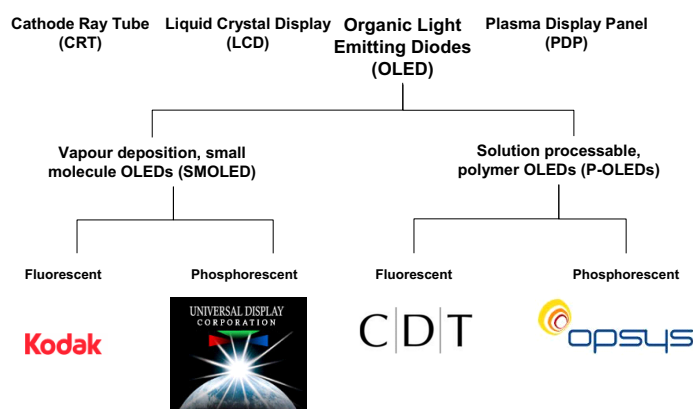


Fig. 1. Selected electronic display technologies and example firms as of 2001.

^b www.enterprise.cam.ac.uk

^c Further contextual data can be accessed via www.cambridgetechnopole.org.uk.

Both P-OLEDs and SMOLEDs have some advantages over LCD displays. These include the facts that OLEDs have a good contrast ratio and are visible from wide viewing angles; have extremely fast response times and have no limitations with respect to display time or response time at lower temperatures; can be fabricated as thin as an LCD without backlight; and have lower overall power consumption.

The production technologies required for SMOLED and P-OLED are fundamentally different. Production of displays using SMOLED uses vapour sublimation through a shadow mask in a vacuum chamber for thin film deposition. The nature of the vacuum deposition approach is that it is limited to relatively small displays only – though the technology for the production of such displays is at a high Technology Readiness Level (TRL) and is gaining a foothold in the market – and it is not possible to use this technology for roll-to-roll production. P-OLEDs are soluble, can be deposited using ink-jet techniques and have the potential to be produced using roll-to-roll techniques. At the time of initial data gathering for this research, P-OLEDs had yet to gain a significant foothold in the display market.

In 1992, ownership of the core P-OLED intellectual property was transferred from the University into a newly formed company, CDT Ltd. Having ownership of this core intellectual property provided the company with a potential revenue stream from those wishing to apply and develop these ideas without CDT having to wait until products based on this technology had reached the market.

However, CDT needed to invest heavily in R&D for two reasons:

Commercial viability: The initial invention alone had little commercial value and significant improvements were required to make a saleable product.

Commercial positioning: CDT needed to consider ways of ensuring a strong competitive position beyond 2010, when the basic P-OLED patent expires.

The company's initial business plan would have established CDT as a manufacturer of displays. The management team soon realized this initial strategy was unrealistic as it would have required significant up-front investment and an unacceptably high risk and long payback period. As the company's core patent on P-OLEDs expired in 2010, it was important to find ways to exploit the technology as quickly as possible. Thus a change of direction was required.

The technology was widely recognized as being novel and innovative but it was difficult to produce it cheaply and effectively. Analysts and investors were skeptical of the market value of the invention, seeing it as interesting but of little near-term commercial value. The costs of manufacturing were perceived to be too high, and the product too inefficient (in terms of lifetime) to threaten conventional displays.

A new CEO was brought in 1996 to change the direction of the company with a business model geared to licensing the newly acquired technology. Philips Electronics N.V. became one of the first licensees of the technology. CDT initially had very little capital to be able to develop its products to begin with, but did have the bargaining power of holding the intellectual property on a technology that had the potential to generate high value in the longer term. Partnerships based around licensing were formed that were commercially attractive to both sides: CDT gained credibility by being partnered with commercially successful, established and trusted companies. The established firms had access to what could be a significantly influential invention for the display industries.

In July 1999 a tender offer was made for 100% of the issued share capital of CDT by a venture capital consortium comprising Kelso and Company, Hillman Capital and associated investors. This takeover also resulted in a change in CEO. The new owners of CDT revised the business model and structured it around six key areas. These were:

- device physics;
- material deposition;

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P-OLED materials;
device electronics;
optics enhancements; and
process equipment.

By forming partnerships with companies involved with all aspects of the production of the displays, potential licensee could approach CDT and be able to access the range of competences needed for P-OLED display production. In addition, a licensee could have access to materials required for display manufacture.

CDT wanted to develop multiple partnerships in each area of its six key business areas as outlined above, and its eventual aim was to have 2 or 3 partners or suppliers in each field. This would allow the partners to compete to make the best products and services, and meant that there was more than one company in each aspect of development, helping to speed time to market.

CDT designed its licensing agreements such that whenever a product with a P-OLED display was sold, a royalty was collected. This increased CDT's revenue stream without committing the licensee to significant upfront payment. These royalties were also negotiated for primary products such as the P-OLED materials thus allowing CDT to gain royalties from materials purchased in readiness for production rather than waiting for revenue from products.

For each P-OLED display sold, CDT would collect up to four streams of royalties: two for the basic materials when they were sold on to display manufacturers (representing the two types of materials used), one for the display driver and one for the overall product. If the market were to take-off, it was anticipated that the royalties from P-OLEDs would far outstrip the license fees (see Fig. 2).

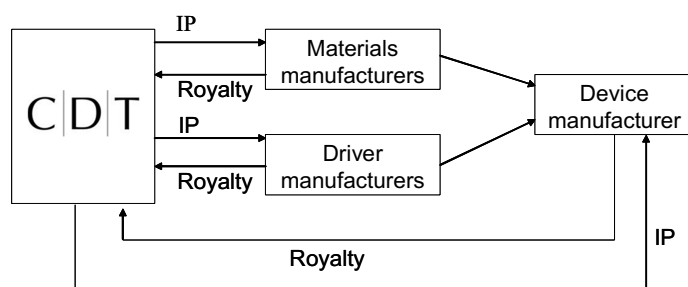


Fig. 2 CDT's licensing and royalty model (CDT Ltd).

In addition to its licensees, CDT also established joint development partnerships with Covion Toppan Printing, Thomson Multimedia, Samsung Electronics, Seiko Epson and Sumitomo Chemical.

By 2000, the management of CDT realized that there was a major opportunity that had not been addressed – generating revenue from the process knowledge required to enable companies new to the P-OLED displays market to set up production facilities. As P-OLED technology approached commercially viable production readiness for displays, CDT decided to invest in a commercial-scale development facility. The US\$25m Manufacturing Development Centre was officially opened in April 2002 by Lord Sainsbury, the then UK Minister for Science.

The Manufacturing Development Centre was set up with three principal purposes:

To develop IP and know-how – enhancing the value and attractiveness of CDT's licenses to companies with limited knowledge of display production.

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To train licensee staff – to help resolve production-related problems, thereby enhancing and accelerating royalty income.

To develop process and engineering packages – which would be sold to new licensees to speed displays into production.

Once a reasonable level of production process knowledge had been generated at the process plant, CDT anticipated turning their attention to low volume display manufacturing.

The process knowledge developed by CDT at its process plant could then be sold on to potential display manufacturers, in the form of a “process package”. The package would be an optional addition to a CDT license.

In October 2002, CDT acquired the IP and UK operations of Opsys, an Oxford University spin-out that was working in the field of dendrimer OLED technology (See earlier Fig. 1). This acquisition provided CDT with capability in an alternative high efficiency solution processable polymer display technology, though one which was at a lower level of technology readiness. This acquisition also served the purpose of strengthening the position of P-OLEDs as competition from the SMOLED market grew. At this time, Kodak had already begun shipping digital cameras incorporating SMOLED displays. In addition, the Universal Display Corporation had been developing high efficiency SMOLED displays that provide a small molecule alternative to the advanced Opsys technology. It is also interesting to note that Opsys had been a licensee of Kodak’s SMOLED technology, and that Toppan Printing, an investor in Opsys, also became an investor in CDT following the acquisition.

In July 2003, CDT announced a major restructuring of its operations coupled with a loss of around 30 jobs (approximately 20% of workforce).

At around the same time it was announced that the Manufacturing Development Centre was no longer to be seeking opportunities to produce devices for niche markets. Emphasis instead would be placed on developing licensable process technologies – and this led to the first ‘process packages’ being sold.

In 2003, CDT also sold 50% of its share in Litrex, the U.S. company that it had acquired in 2000 in order to gain inkjet printing capability. CDT’s business model was revised in the light of these restructuring activities, as shown in Fig. 3.

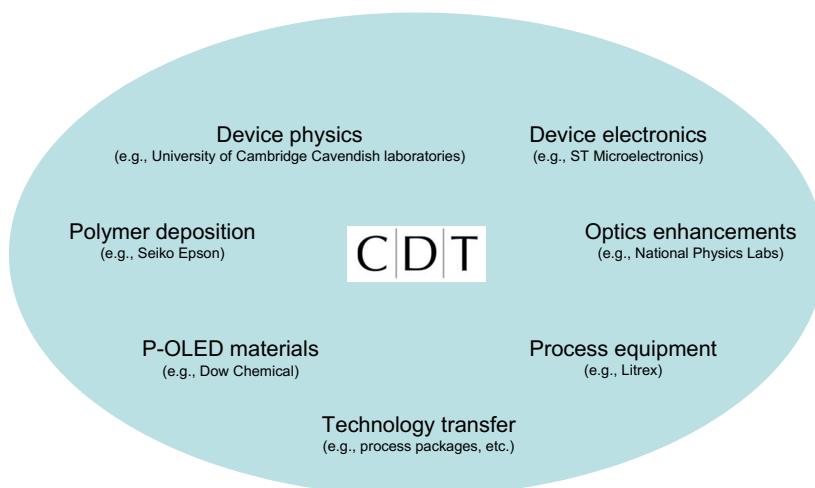


Fig. 3 CDT’s Business model as of 2003 showing example partnerships (Source: CDT Ltd).

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In December 2004, shares in Cambridge Display Technology Inc. were floated on the NASDAQ (with the ticker 'OLED'). CDT was the first spin-out from the University of Cambridge to be floated on the NASDAQ. Since formation in 1992, the company has received over US\$200m of investment, been granted 100 patents. A summary of CDT's financial performance since IPO is given in Table 2.

Table 2. Summary of CDT's post-IPO performance (US\$,000s) [CDT (2007)].

	2006	2005	2004
Operating revenues			
License fees, royalties and other license-related	3,176	3,285	7,691
Technology services and development	2,943	7,478	4,982
Equipment and supplies	1,817	7,330	613
Total operating revenue	7,936	18,093	13,286
Cost of sales			
License fees, royalties and other license-related	42	47	195
Technology services and development	1,617	3,798	1,481
Equipment and supplies	1,375	5,880	318
Total cost of sales	3,034	9,725	1,994
Gross profit	4,902	8,368	11,292

5. Discussion

CDT illustrates a number of the themes that our underpinning research revealed as we investigated the role partnerships between start-ups and established firms can play in bringing a new technology to market. In particular, it revealed the interplay of issues that increase the complexity of this type of activity when the core IP was generated from university research, and the technology has the potential to be disruptive. In the following sections, we discuss the example of CDT from the three areas of open innovation (with particular emphasis on development of a technology ecosystem), commercialization of university IP, and the exploitation of disruptive technologies.

5.1. *Open innovation*

This case illustrates the role that a new firm based around a novel technology can play in supporting established firms in seeking to operate an open innovation model. Given their lack of complementary resources and unproven nature of their technology, CDT did not build one-to-one relationships with individual companies around the licensing of the core IP, but attempted to make a range of partner companies part of a P-OLED 'ecosystem' [Moore (1996)]. It was hoped that the P-OLED ecosystem would make it easier for those companies taking an open innovation approach to considering exploiting P-OLEDs. As a very small player, CDT needed to position itself very carefully within this ecosystem to ensure that it could continue to generate value beyond the expiry date of its core IP in 2010. This P-OLED ecosystem required CDT to maintain control over the seven core areas of know-how needed for P-OLED exploitation: device physics, polymer deposition, P-OLED materials, device electronics, optics enhancement, process equipment and process know-how.

Being located within a successful and growing European high tech business cluster provided certain advantages for CDT. At the time of CDT's formation in 1992, Cambridge, U.K. was becoming recognized as a business cluster with the potential to generate reasonably significant returns for national and international institutional investors. CDT's actual and perceived links with the University of Cambridge, plus the fact that one of the inventors of the P-OLED technology is one of the world's most cited physicists (Prof. Sir Richard Friend), helped support CDT's brand building activities. An additional contextual factor is the link to inkjet printing. Cambridge has been home to a significant grouping of industrial ink jet printing firms [IfM (2007)]. As P-OLED technology can be deposited using ink jet techniques, having access to substantial embedded expertise on this technology locally was extremely helpful to CDT.

CDT faced challenges in raising investment to bring its largely unproven technology to market. Taking a partnership-based approach to build a technology ecosystem led to additional opportunities to access resources. Some of those that had become partners went on to become investors in CDT, thus providing additional direct support for the growth of the firm.

Work at the University's Optoelectronics Group has led to a second spin-out company, Plastic Logic, based around conducting polymers. Plastic Logic's development activities are focused on the development of devices and process related to polymer electronics, and the company has signed non-exclusive cross licensing agreements with CDT to support the commercialization of formable displays. This, it was hoped, would widen the ecosystem being developed around all the core product and process technologies for addressing demand for formable displays.

One result of the emergence of this regional capability in polymer displays has been the establishment of Kodak's European Research Laboratories in Cambridge in 2005. One area of development for this new facility is novel display technologies.

5.2. *University commercialization activities*

At the time CDT's formation in 1992, the University of Cambridge's then very under-resourced technology transfer office had somewhat limited options. Licensing this potentially disruptive technology at a very early stage of technology readiness would require substantial and sustained marketing resource. The technology transfer office and the inventors agreed that spin-out would be the preferred exploitation route. However, despite being located within a high technology business cluster, attracting the initial investment proved difficult as the business model for the CDT at that time was neither

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clear nor convincing to potential investors. The initial investors ended up being a small local venture capital fund (Cambridge Research and Innovation Ltd - CRIL) and some of the Colleges of the University. The University itself received shares in return for the transfer of IP. Further investment was then received from business angels (including members of the rock group Genesis who saw potential in novel display technologies for their concerts). The main institutional investment came five years after start-up.

The University of Cambridge received equity in CDT in return for the transfer of IP. When Kelso and Company, Hillman Capital and their partners sought to take a majority position within CDT in 1999, the University sold part of its shareholding in return for around UK£2m. The University retained a small equity stake in CDT and also kept an on-going licensing agreement relating to the IP.

CDT has maintained its links with the University and with the Optoelectronics Group in particular, as this forms a key element within the CDT's P-OLED ecosystem. The relationship with the Optoelectronics Group is part of CDT's own open innovation system as it seeks to draw in novel IP to supplement that generated by its own internal R&D.

Lessons learned from the formation of CDT have been used to ensure a smoother start for the second spin-out from the Optoelectronics Group, Plastic Logic. Key among these learnings has been (1) the need to draw in the expertise to develop the appropriate, realistic business model for a technology – which may need to be adapted over time – and (2) to have a capability to build multiple partnerships with those who can provide access to complementary resources for generating value from the IP as it moves through different stages of maturity.

5.3. Disruptive technologies

Applications for P-OLEDs were anticipated to be split into a number of application areas, some of which would be disruptive, some of which would be sustaining for incumbent firms and their markets. One application area was using P-OLEDs as a replacement for LCDs in mobile devices (PDAs, mobile phones, digital cameras) where low power and high brightness of displays were key advantages. Coupled with the fact that P-OLED production shared many common stages with LCD display production, this was viewed as one key market to target that would be sustaining for the incumbent firms. However, LCD performance has continued to improve, and where there has been a clear need for brighter displays (such as for digital cameras) the SMOLED technology developed by Kodak and others has been gaining a strong foothold. The use of P-OLEDs for high information content large displays has been shown to be technically feasible by CDT partner companies such as Seiko Epson, but there is strong competition from the incumbent plasma and LCD technologies. Formable displays, i.e., displays ink jet printed onto a flexible substrate using roll-to-roll technologies does seem to be one area that illustrates the disruptive potential of P-OLED technology. Faced with challenges in getting P-OLED lifetimes up to the level required for TV applications, opportunities have emerged at the low end. Point-of-sale labels using low resolution, low cost P-OLED displays are thought to be one area where this technology may gain a foothold, and from where it may be able to improve performance to the level demanded by customers at the low end of traditional electronic display applications.

6. Conclusions and further work

The example of CDT highlights a range of issues relating to the use of a university spin-out to bring a potentially disruptive technology to market. Key amongst these is the

building and managing of an ecosystem of providers of complementary resources to enable partner organizations to apply the principles of open innovation to enter (and withdraw from) a novel technology area and support the raising of its readiness level to commercial viability.

The work reported in the paper, and illustrated through the example of CDT, is now being taken forward to investigate further how applicable the partnership / ecosystem model is for other technology and business areas, as well as different geographic contexts. The role of the geographic context within which firms such as CDT are located raises a number of interesting research questions related to how resource-constrained start-ups can be helped to access complementary assets through regional networks and intermediaries, and how this may differ depending on the national context. We believe research in this area is of particular importance for a nation such as the U.K. which, despite remaining in a strong position in terms of the generation of IP from its universities, continues to struggle in its efforts to build sustainable firms around the commercialization of predominantly publicly-funded IP.

7. Acknowledgements

The research underpinning this paper has been supported by a grant from the EPSRC-funded Innovative Manufacturing Research Centre (IMRC) at the University of Cambridge Institute for Manufacturing (<http://www.ifm.eng.cam.ac.uk/imrc/>). This grant was for a project that ran from January 2004 to December 2005 entitled: "Alliance based business models for early-stage technology ventures".

8. References

- Alvarez, S. A. and J. B. Barney (2001). "How entrepreneurial firms can benefit from alliances with large partners." *Academy of Management Executive* **15**(1): 139-148.
- Barney, J. B. (1991). "Firm resources and sustainable competitive advantage." *Journal of Management* **17**(1): 99-120.
- Barney, J. B., M. Wright and D. J. Ketchen (2001). "The resource-based view of the firm: Ten years after 1991." *Journal of Management* **27**: 625-641.
- CDT (2007). www.cdtttd.co.uk.
- CE (2007). Cambridge Enterprise Ltd, www.enterprise.cam.ac.uk.
- Chesbrough, H. (2003). *Open Innovation: The new imperative for creating and profiting from technology*, Harvard Business School Press, Boston, MA, USA.
- Chesbrough, H. (2006). *Open Business Models*. Cambridge MA, Harvard Business School Press.
- Chesbrough, H., W. Vanhaverbeke and J. West, Eds. (2006). *Open Innovation: Researching a New Paradigm*, Oxford University Press.
- Christensen, C. M. (1997). *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail*. Cambridge MA, Harvard Business School Press, ISBN: 0875845851.
- De Meyer, A. (1999). "Using strategic partnerships to create a sustainable competitive position for high tech start-up firms." *R&D Management* **29**(4): 323-328.
- Druilhe, C. and E. W. Garnsey (2004). "Do academic spin-outs differ and does it matter?" *Journal of Technology Transfer* **29**: 269-285.
- Eisenhardt, K. M. (1989). "Building theories from case study research." *Academy of Management Review* **14**(4): 532-550.
- Etzkowitz, H. and L. Leydesdorff (1997). *Universities and the global knowledge economy: A triple helix of university-industry-government*, Pinter:London.

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- Fraser, P., T. H. W. Minshall and D. Probert (2005). The distributed innovation paradigm: Evolution and dynamics. 6th International CINet Conference Continuous Innovation - (Ways of) Making Things Happen, Brighton, 4-7 September 2005.
- Fraser, P., T. H. W. Minshall and D. Probert (2005). Them and us - asymmetric dyads involving early-stage technology firms. 27th R&D Management Association (RADMA) Conference 2005, 6-8 July, Pisa, Italy.
- Garnsey, E. W. (1998). "A theory of the early growth of the firm." Industrial and Corporate Change 7(3): 523-556.
- Gill, D., T. H. W. Minshall, C. Pickering and M. Rigby (2007). Funding Technology: Britain Forty Years On. Cambridge, St John's Innovation Centre and Institute for Manufacturing, ISBN 1-902546-50-4.
- HEFCE (2005). "Higher education-business and community interaction survey 2002-03." http://www.hefce.ac.uk/pubs/hefce/2005/05_07/.
- HEFCE (2006). "Higher education-business and community interaction survey 2003-04." http://www.hefce.ac.uk/pubs/hefce/2006/06_25/.
- IfM (2007). <http://www.ifm.eng.cam.ac.uk/pp/inkjet/community.html>.
- Lambert, R. (2003). Lambert Review of Business-University Collaboration: Final Report. London, HM Treasury, www.lambertreview.org.uk.
- Leydesdorff, L. and H. Etzkowitz (1998). "Triple Helix of Innovation: Introduction." Science and Public Policy 25(6): 358-364.
- LibraryHouse (2005). Flight to quality: The Cambridge cluster report 2004, LibraryHouse, Cambridge, UK.
- Livesey, F., T. H. W. Minshall and J. Moultrie (2006). Investigating the technology-based innovation gap for the United Kingdom: A report for the UK Design Council. Cambridge, UK, University of Cambridge Institute for Manufacturing, ISBN 1-902546-49-0.
- Mankins, J. C. (1995). Technology Readiness Levels: A White Paper, NASA: From: <http://www.hq.nasa.gov/office/codeq/trl/trl.pdf>.
- Minshall, T. H. W. (2005). Alliance business models for university start-up technology ventures: A resource-based perspective. New technology-based firms in the new millennium Volume IV. W. Daring, R. Oakey and S. Kauser. Oxford, UK, Elsevier, ISBN 10-0-08-044619-1: 203-218.
- Minshall, T. H. W., W. Wicksteed, C. Druilhe, A. Kells, M. Lynskey and J. Siraliova (2005). The role of spin-outs within university research commercialisation activities: Case studies from 10 UK universities. 13th High Tech Small Firms Conference, 26-27 May 2005, Manchester Business School, University of Manchester, UK.
- Moore, J. F. (1996). The death of competition: Leadership and strategy in the age of business ecosystems, Wiley.
- Rothwell, R. (1983). "Innovation and firm size: A case of dynamic complementarity." Journal of General Management 8(6): 5-25.
- Slater, S. F. and J. J. Mohr (2006). "Successful development and commercialisation of technological innovation: Insights based upon strategy type." Journal of Product Innovation Management 23: 26-33.
- Stone, H. J., K. J. Iwamasa, S. S. Lundine and J. W. Jasper (2005). "Picking winners: a framework for evaluating success potential of technology commercialisation." International Journal of Technology Transfer and Commercialisation 4(3): 255-278.
- Utterback, J. M. and H. J. Acee (2005). "Disruptive technologies: An expanded view." International Journal of Innovation Management 9(1): 1-17.
- Walsh, S. T. and S. K. Kassicieh (2004). "Models for the commercialisation of disruptive technologies." International Journal of Technology Transfer and Commercialisation 3(2).

T.H.W. Minshall et al.

Webster, A. and H. Etzkowitz (2000). "The future of the university and the university of the future." Research Policy **29**(2): 313.