Case Study: Cambridge Display Technology Ltd.

Version: 20th January 2005

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Abstract

This case study describes the growth of Cambridge Display Technology Ltd. (known as ‘CDT’). CDT is a Cambridge, UK-based company licensing intellectual property and developing technology platforms and production processes for flat panel Organic Light Emitting Diode (OLED) displays that utilise Light Emitting Polymer (LEP) technologies. OLED displays can be used in applications currently served by smaller Liquid Crystal Displays (LCDs), but have a number of advantages over LCD’s including much improved angle of vision, no need for backlight and low power consumption. As the capability to produce larger displays is developed, it is anticipated that OLED LEP flat panel displays - the type based upon CDT’s core technology - will reach the market in TVs, laptops, computer monitors and large area displays.

The case has been written to support discussion about three major issues.

- **Intellectual property management**, and what steps a company needs to take to ensure competitive advantage through the value of its inventions.
- **Technology strategy** in general and CDT’s quest to set new standards for displays, replacing those based around Cathode Ray Tubes and Liquid Crystal Displays (LCDs).
- **Development of the partnership model** whereby CDT collaborates with materials suppliers, component manufacturers and consumer product manufacturers to determine the way forward with the technology, and exchange know how with some of the bigger players in relevant fields.

The case is particularly useful for students studying management within a technological perspective, with particular reference to introduction of leading-edge and disruptive technologies to market.

Contents

1. The Invention

The first observance of electrical activity in polymers occurred in 1977 when Alan Heeger, Alan MacDiarmid and Hideki Shirakawa made the revolutionary discovery that plastic can, after certain modifications, be made electrically conductive. They showed that a thin film of polyacetylene could be oxidised with iodine vapour, increasing its electrical conductivity a billion times. The area of conductive polymers has subsequently developed into a rich research field of great importance for chemists and physicists, and has subsequently led Heeger, MacDiarmid and Shirakawa to being jointly awarded the Nobel Prize for Chemistry in 2000.

In 1989, Richard Friend, Jeremy Burroughes and Andrew Holmes at the University of Cambridge built on this earlier work and discovered that light emitting diodes (LEDs) could be made from conducting polymers as well as from traditional semiconductors.

Burroughes had been researching the applications of conducting polymers when he noticed one sample was emitting a slight glow. “At first I thought it was the reflection of the computer screen” Burroughes later commented “I turned it off to see if the glow remained, and it did. I was absolutely amazed by this as it was something that was supposed to be impossible”

The Cambridge team had found that the polymer poly p-phenylenevinylene (PPV) emitted yellow-green light when sandwiched between a pair of electrodes. The light produced was dim even for high voltage inputs. However, by changing the chemical composition of the polymer and the structure of the device, the efficiency of the devices was gradually increased over time, bringing it above the range of conventional light emitting diodes, and achieving a five hundred fold increase on original efficiencies. This gave the field an entirely new set of phenomena to study and generated commercial interest in the possible applications of light-emitting polymers (LEPs) to form the core of Organic Light Emitting Diode (OLED) displays.

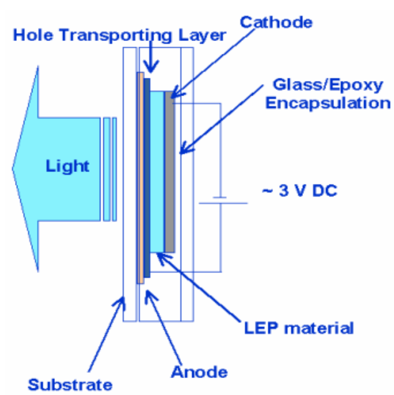


Figure 1: The operation of a LEP display

Source: CDT Ltd.

2. Advantages of the technology

LEPs had the potential to lead to display devices that had a number of advantages over existing and emergent technologies (Figure 2 presents a sample of the key technologies).

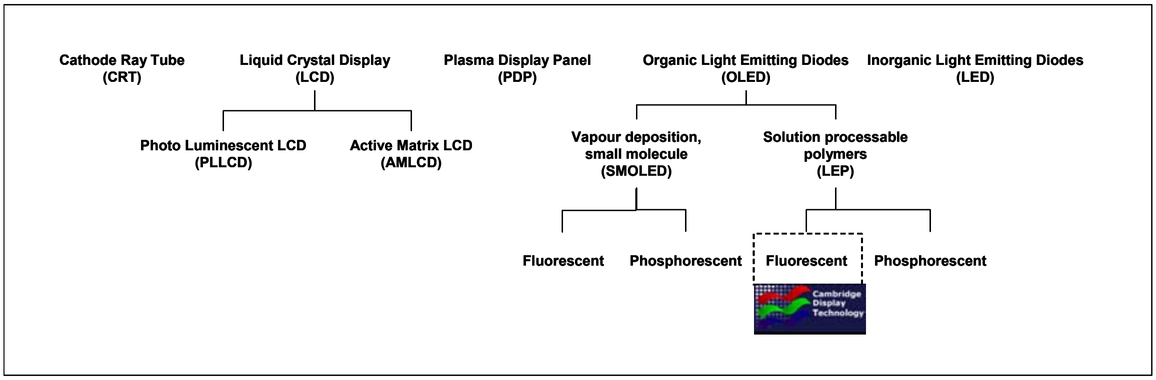


Figure 2: Core display technologies and CDT's focus as of 2001

A key difference between small molecule and LEP is the ability of polymers to be placed in solution while small molecules must remain in powder form. Therefore small molecule material must be patterned by evaporation through a shadow mask while polymers can be patterned through ink jet printing techniques, thus making the polymer manufacturing process far simpler. There is also the potential of roll to roll production – in other words continuous production of displays – with the LEP technology but not with SMOLED.

OLED versus LCD

There are advantages that both types of Organic Light Emitting Diodes (LEP and small molecule) have over LCD displays:

- **OLEDs have a good contrast ratio and are visible from wide viewing angles.** LCD displays have a limited viewing angle because of the nature of the light passed through or reflected. The advantage of a wider viewing angle is obvious to anyone who owns a laptop or PDA.

Figure 3: Illustration of viewing angles for OLED and LCD

Source: Kodak, 2003

- **OLEDs have extremely fast response times and have no limitations with respect to display time or response time at lower temperatures**. LCD displays have an inherent response time limitation known as latency. This deficiency is exacerbated at lower temperatures and the LCD display function stops below freezing temperatures without supplemental heating.

- **OLEDs can be fabricated as thin as an LCD without backlight.** This will provide a huge advantage in portable devices where size is a critical competitive factor.

Figure 4: Prototype comparing OLED and LCD screens for PDAs

Source: DuPont, 2003

- **OLEDs have lower overall power consumption,** including the driver electronics, when compared with LCDs with backlights - a critical advantage for portable, battery-powered applications.

LEP versus 'Small Molecule' OLEDs

Each type of OLED has strengths and weaknesses – and this is reflected in the fact that many display companies are developing interest in both technologies.

- **Small molecule** - Development of small molecule OLEDs is being led by companies including Kodak, Samsung and Pioneer. Substantial R&D in this area has led to the first SMOLED displays from Tohuku Pioneer reaching the market in 1999. Kodak is now applying this technology in its digital cameras (See Figure 5). As this material is in powder form, the production of these screens uses vapour sublimation through a shadow mask in a vacuum chamber for thin film deposition. However, the nature of the vacuum deposition approach is that it is limited to relatively small displays only, and it is not possible to use this technology for roll to roll production.

Figure 5: Kodak digital camera incorporating SMOLED screen

Source: Kodak, 2003

- **LEP** (also known as 'macro polymer' and conjugated polymers) – As the LEPs are soluble they can be deposited using ink-jet techniques and this brings advantages when compared to complex multi-shadowing techniques for depositing 'small' molecules. Key among these is that it removes some of the restrictions on the size of possible displays – Toshiba Matsushita have produced a prototype 17" screen based on LEP technology. Additional advantages of this technology is that the LEP OLED production process shares many common manufacturing steps with that used for LCDs.

Figure 6: Toshiba Matsushita Display Technology 17" LEP display

Source: Toshiba Matsushita Display Technology

3. Protecting the Invention

The Cambridge research team of Friend, Burroughes and Bradley realised that despite the significance of the discovery they had made there was still a long path to successful commercialisation. The team were surprised to find that there were no funds within the University available to help cover the costs of patenting their discovery. The inventors ending up paying for the patents themselves, with Burroughes dipping into a student loan to cover the costs.

Having filed their patent, the findings were published in *Nature*, the world renowned scientific journal. In the journal the inventors speculated that:

> "*The combination of good structural properties of this polymer, its ease of fabrication, and light emission in the green-yellow part of the spectrum with reasonably high efficiency suggest that the polymer can be used for the development of large area light emitting displays."* [1]

In 1992, ownership of the core intellectual property was transferred into the newly formed company, CDT. The inventors were therefore allowed exclusive use of the new discovery to develop as they wished, and a result of the patent CDT has taken out on the "inventive kernel" of the product, the patent is now recognised as fundamental in the field of LEPs. The patent therefore means that CDT has the exclusive right to use LEP technology and anyone wishing to build and market LEP displays must obtain a license

[1] Burroughes, J. H., D. D. C. Bradley, A. R. Brown, R. N. Marks, K. Mackay, R. H. Friend, P. L. Burns & A. B. Holmes, 1990, "Light-emitting diodes based on conjugated polymers" in Nature 347, 539–541.

from them. The patent has now been granted in all major territories including Europe, Japan and the United States.

Having obtained this initial patent for their LEP discovery, CDT was in a strong positioned to benefit from the emerging Organic Light Emitting Display (OLED) market. 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, it was important that CDT continued to invest heavily in R&D. More work was required for two reasons:

- **Commercial viability:** The initial invention had little commercial value and dramatic improvements were required to make a useful product.

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

Further research developed around the initial patent, and more intellectual property was developed. The company now has over 100 patents in the field of (LEPs) relating to all aspects of the technology, including production of the displays.

Cross Licensing

One key feature of patents is that it allows someone to take a patented invention and develop it further thus creating additional narrower patents in the process. This then gives the original developers a share in the revenues claimed from the additional patents. This occurred in two areas for CDT in the early development of the business: the actual materials involved (with The Dow Chemical Company) and the ability to inkjet displays (with Seiko-Epson):

- **Dow Chemical,** a US based materials company, heard about the development of LEPs and decided to invest in some research in the area. This research yielded new materials which proved far more efficient and long lasting than the original LEP materials that had been used in the original Cambridge research. These newer polymers were also easily placed in solution, making display fabrication far simpler. Dow therefore patented these materials, gaining a strong foothold in the LEP market.

- **Seiko-Epson** found inkjet printing to be an effective way of depositing the polymer onto the substrate (as required for display production), reducing production costs for full colour displays dramatically. By developing IP around the patterning the substrate with small pits, the different coloured pixels could be ink jetted onto the same substrate, allowing for the first time a full colour display:

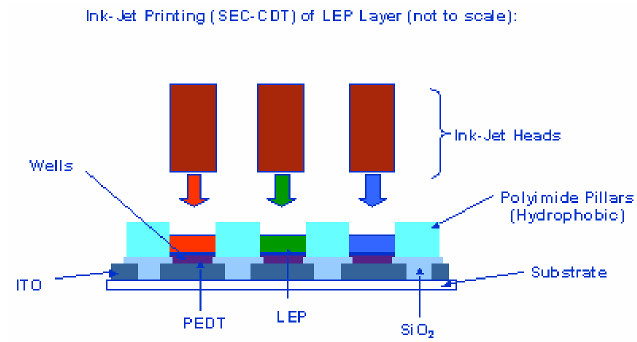


Figure 7: Seiko-Epson's inkjet printing solution

Source: Seiko-Epson

Cross-licensing had to be arranged between the CDT and Seiko-Epson and Dow Chemical to ensure a fair share of products made. This was eventually achieved through the sharing of intellectual property. Although CDT held a patent in the field that was recognised as fundamental, it was still essential to manage the cross licensing correctly to prevent the market abandoning the technology completely.

4. The market opportunity facing CDT

The display market is currently quite diverse and supports a number of different technologies. Televisions, where product cost rather than power consumption is the key issue, are usually based on the traditional Cathode Ray Tube (CRT) Monitors for desktop computer systems are now largely changing from CRT to LCD and laptops where size, weight and power consumption are important, have always been served by LCD displays. Smaller devices such as PDAs, mobile phones and mobile media devices tend almost exclusively to utilise LCDs.

Although OLED displays have the potential to displace computer and TV screens, early applications will be in the smaller devices such as PDAs, mobile telephones, mobile media devices. However, as OLEDs, especially those based upon LEPs, become cheaper to manufacture and improved brightness and power performance, they could be well placed to take over a large segment of the current larger size LCD market. Analysts predict that the market for OLED displays will reach US$3bn by 2007 (DisplaySearch, 2002). .

Potentially the LEP-OLED displays could also be produced on plastic substrates (rather than the glass substrates currently used), giving the unique possibility of flexible displays. This could lead on to roll to roll (continuous) display production, where the finished displays could simply be printed onto a roll. Displays could effectively become disposable, for example a newspaper could change itself automatically to give the next day's news. At present, inability to find a good substrate on which to print the LEPs is limiting developments in this area.

A CDT executive commented in 2002 that while SMOLED technology "*has a 10-year head-start on the LEP in terms of development, LEPs are only 2-3 years behind in commercial development. It is the potential for lower manufacturing costs associated with LEPs that is expected to help them gain a larger share of the market*."

This was reflected in the fact that by 2002 only nine licenses to apply Kodak's SMOLED technology have been sold, and only one was sold to a mainstream display manufacturer (Sanyo). In contrast, LEP licenses have been sold to major players such as Philips, Seiko Epson and Osram. Toshiba announced in 2002 that its OLED displays will be based on LEP technology, citing the production limitations of SMOLEDs as the reason for its decision.

The view of the CDT executive team is that it may not be to CDT's detriment that SMOLED technologies arrived before conjugated polymer technologies. As Keith Bergelt, then Senior V-P Strategy, Business Development and Intellectual Property commented in 2002: "*In a way it was good that Kodak got to market first as it created an interest in the [OLED] field that would not otherwise be there*."

5. Business and Product Development

Initial plans for commercial exploitation

The company's first business plan was designed to establish CDT as a manufacturer of displays, who managed the whole process in house. Burroughes realised this initial strategy was fundamentally wrong, commenting "[..] I was working at IBM and it was clear from there that millions of pounds were required to develop new products. This was something CDT didn't have". As the company's core patent on LEPs expired in 2010, it was important to exploit the technology as quickly as possible. Thus a change of direction was required.

The technology was widely recognised as being novel and innovative but it was difficult to know how to produce it cheaply and effectively. Initially many were sceptical of the market value of the invention, seeing it as an interesting "party piece" but of little commercial value, with costs of manufacturing being far too high, and the product far too inefficient to threaten conventional displays.

One of the challenges facing the application of this technology was the limited lifetime of the displays. It was found that the purity of the polymer, the method of polymer deposition and other materials used in manufacture all affect lifetime. Through extensive research and development, CDT managed to up the efficiencies of the displays to around 10%, greater than standard LEDs, and achieved lifetimes of 40,000 hours for both red and green displays, the required standard for use in laptops, with the blue materials still requiring some further development.

Move to a licensing-based business model

Danny Chapchal joined CDT as CEO from Siemens in February 1996. Prior to that he was CEO of Atex where, over an 18-month period, he turned a company with losses close to US$27 million into a profitable and thriving enterprise, which was subsequently taken over by a Scandinavian public company.

Chapchal, renowned for his business acumen and with a fierce reputation as a company "doctor," had extensive experience turning small start-up companies into successful enterprises. He changed the direction of the company, with a business model geared to licensing the newly acquired technology. This was successful, as Philips, a big name display manufacturer, became a licensee 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 could be hugely successful in the near future.

The partnerships looked after the interests of both sides: CDT gained credibility by being partnered with big name companies, while the big names had access to what could be a hugely influential invention. Chapchal continued the licensing model and gradually built up the company's value.

Company takeover - 1999

In the late 1990s, growth had become harder to achieve. CDT could not accumulate enough process know how to be attractive to smaller potential licensees. They had little knowledge of production processes and possibilities, and thus smaller scale display companies were unable to buy in to "the CDT display revolution", thus reducing CDT's potential license base.

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. After a disagreement with the New York based investors, Danny Chapchal left the company, thus being ousted by the very investors he sought to attract.

David Fyfe, a man with 30 years experience of the global chemical and engineering industries, joined CDT as chief executive officer in August 2000. Fyfe had previously studied Natural Sciences at the University of Cambridge before working for CDT's current owners in America.

Eric Lucas joined the company as Senior Vice President, General Counsel and Director of Intellectual Property in June 2001. Despite being based in Chicago he is responsible for managing CDT's general legal affairs, including responsibility for managing and developing the company's intellectual property portfolio.

Several other members of the senior management team were also headhunted, all with distinguished public sector experience in chosen fields. Jeremy Burroughes and Richard Friend were also appointed to the board. Jeremy Burroughes returned from IBM to take charge of the Product Business Unit, while Richard Friend was appointed Chief Scientist and Research and Technology Director.

The revised business model

The new owners of CDT revised the business model and structured it around initially six key areas (with a seventh added through manufacturing services). The aim of the business model is to provide a 'one stop solution' for licensees. By forming partnerships with companies involved with all aspects of the production of the displays, any potential licensee could approach CDT and be able to immediately acquire all the knowledge required for display production. This rather than simply being able to have access to the technology but be forced to do independent development work. In addition, and perhaps most importantly, a licensee can have immediate access to all materials required for display manufacture.

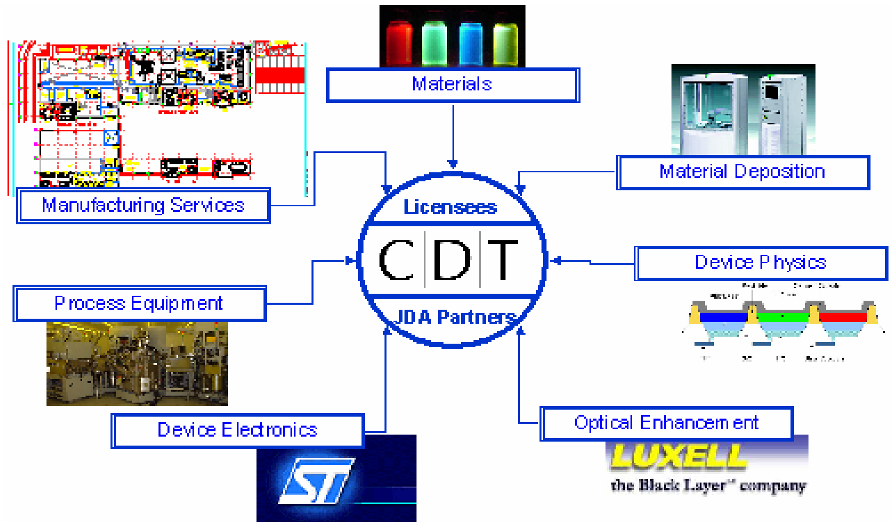


Figure 4: Seven areas of the business model, including manufacturing services as of 2001

Source: CDT Ltd.

6. Partnerships to enable the business model

CDT considers it important to develop multiple partnerships in each area of the business model as outlined above, and its eventual aim is to have 2 or 3 partners or suppliers in each field. This allows the partners to compete to make the best products and services, and means that there is more than one company in each aspect of development, speeding up time to market. As Keith Bergelt, (Senior V-P Strategy, Business Development and Intellectual Property) commented in 2002:

> *"The supply chain should be a win-win situation for all concerned. If a company is not making profit from it, the quality of their products is not good enough."*

Device physics

The underlying science of the LEP displays continues to be researched and developed in the Cavendish Laboratories, the Physics Department of the University of Cambridge, and CDT retains strong links with this organisation.

Material Deposition

This refers to inkjet spraying technologies developed by Seiko-Epson who are now a partner of CDT.

However, Seiko-Epson was not the only inkjet printing partner for CDT. Seeing an alternative ink-jet opportunity in struggling US company Litrex, CDT moved swiftly to purchase the company in 2000. Litrex was the first company to be wholly owned by CDT. One motive for this acquisition was given by David Fyfe, CDT's CEO:

> "*We did this because Seiko-Epson seems torn between making its ink-jet technology widely available and restricting it*".

Jeremy Burroughes, CDT's chief technology officer, offered another perspective:

> "*I believe that [Litrex's] approach to ink-jet printing is technically better than Seiko-Epson's - it is more adaptable*."

Fyfe did not believe that the acquisition of Litrex would cause problems with CDT's relationship with Seiko-Epson:

> "*We're still in active discussions with Seiko-Epson. The issue for us is how to facilitate the growth of this industry. We need to make it easy for people to get into it, and in the end I don't really care whether they get in with a Seiko-Epson machine or a Litrex machine.*"

LEP Materials

CDT had originally planned to manufacture its own LEP materials for mass production, but it soon became clear that this was an unrealistic business model. Partnerships were therefore formed with a number of what CDT described as "dedicated and well-resourced chemical companies" including Dow Chemical, Covion, Sumitomo and Bayer.

Combining the expertise of these companies and with CDT's was expected to accelerate the development of LEP displays. CDT planned to make available all of its intellectual assets related to LEPs, as well as its process and scale-up knowledge. The materials companies were to focus on LEP materials development, performance and scale manufacturing allowing CDT to pursue further development and licensing of its technology for LEP displays.

Device electronics

It was clear to CDT management that to ensure the devices worked successfully, high quality driver software was required. To achieve this, CDT formed a partnership with ST Microelectronics, one of the world's largest semiconductor manufacturers.

Jeremy Burroughes , CTO, commented:

> *"Previous flat panel display technologies have suffered from a lack of sophisticated drivers to deliver optimum display performance, resulting in lost opportunities."*

In the case of plasma displays, the products were held up as the device electronics was generally considered to be 3-5 years behind the technology itself. CDT clearly did not want to fall into this trap.

Optics Enhancement

In June 2001 CDT announced an agreement with Luxell Technologies Inc, the developer and manufacturer of the patented 'Black Layer' technology for flat panel displays The agreement was the result of a joint evaluation by CDT and Luxell that successfully demonstrated that LEP displays integrated with the 'Black Layer' technology provide enhanced contrast while preserving brightness, offering extended operating life for all colours, lower power consumption and the potential for simplified, lower cost manufacturing.

Process equipment

In May 2001 CDT entered into a multi-million dollar joint development agreement with Tokki Corporation in Japan, a leading developer of engineering and manufacturing equipment for the global display industry.

David Fyfe commented on the formation of this partnership:

> *"Efficient, low cost manufacturing technology is key to the success of our licensees. This joint development with Tokki will bring focus to the achievement of this objective at an early stage in the commercialisation of LEP technology."*

7. Business Model Strategy

Licensing strategy – display manufacturers

CDT's licensing model is structured to allow display manufacturers to license LEP display technology at different levels of information content. Initially licensees are able to take out a limited information content license to cover displays in near market applications with the opportunity to extend the license to higher information content displays at a later date. This was done by granting with each license a limit as to the number of pixels that could be marketed for the display under the current agreement.

Originally, CDT offered only two types of license:

- Low-Information Content (<100000 pixels)
- High-Information Content (unrestricted)

Management soon realised that this was too simplistic and too artificial a model to use. Therefore, as the business model was developed, the licenses were restructured to respond to the required usage of the displays. CDT began to offer an initial license to manufacture displays up to QVGA information content (76800 pixels) and a defined path to higher information contents – VGA, SVGA, XGA, SXGA, UXGA - with each discrete step being the subject of further up-front fees.

CDT deliberately limited the number of licenses it offered, as Stewart Hough, VP of Business Development described in 2002:

> *"We have been approached by many potential licensees, but we do not want to overlay too many licensees in any one market segment, so we practice critical selection, and evaluate potential licensees for their ability to drive the market. [..] We also work closely with players from less obvious industry segments, exploring the possibilities for integrating LEP technology into other industry specific applications. These include players in the paper, food packaging, printing, architectural display and other segments."*

Licensing has been limited to ensure that any company allowed access to the technology will have something positive to contribute to its development, and to ensure the licenses are highly coveted arrangements.

In addition to the standard licenses, CDT offers a "Research License" whereby it transfers know-how on device structuring and testing for R&D purposes only. The licensee has the right to send staff to CDT for training and to call on CDT staff to advise at its own facilities. The purpose of this license is to speed a recipient company along the path to a higher value license, and to ensure that any such decision is taken based on the most recent advances in LEP technology.

Licensing strategy - supply line

In addition to display manufacturers, supply line manufacturers have also been awarded licenses. This allows the licensees to access all intellectual property generated by CDT in the supply line areas of materials and electronics. The materials suppliers that have been awarded licenses are Dow, Covion, Bayer and Sumitomo, while the electronics suppliers that have been awarded licenses are Plastic Logic and ST Microelectronics.

Royalties

CDT has worked all its licensing agreements so that whenever a product with an LEP display is sold, a royalty is collected. This increases CDT's revenue stream without committing the licensee to too much money upfront. These royalties have been negotiated for primary products such as the LEP materials so CDT can make royalties from materials are purchased in readiness for production rather than waiting for revenue from products.

For each LEP display sold, CDT will have collected 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 takes off, it is anticipated that the royalties from LEPs will far outstrip the license fees, thus ensuring CDT still hold a large stake in their own success.

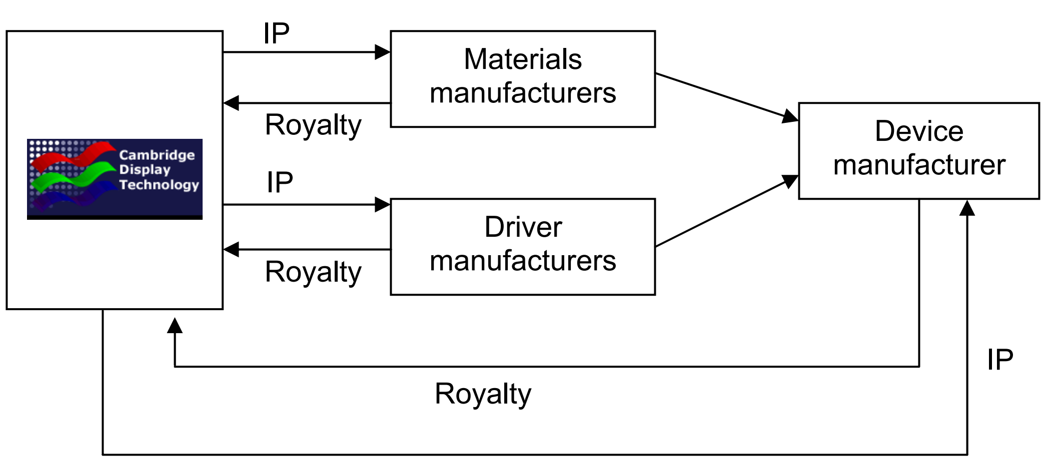


Figure 5: CDT's Royalty Streams

Table 1: CDT's Licensees

Company	License Type
Bayer	Materials
Covion	Materials
Dow Chemical	Materials
Sumitomo	Materials
Dai Nippon Printing	Devices
Delta Optoelectronics	Devices
DuPont Displays	Devices
Eastgate (Singapore)	Devices
MicroEmissive Displays	Devices
Osram Opto Semiconductors	Devices
Philips	Devices
Seiko Epson Corporation	Devices
Plastic Logic	Auxiliary Components
ST Microelectronics	Auxiliary Components

In addition to its current 14 licencees, CDT also now has six joint development partners:

Table 2: CDT Joint Development Partners

Covion	LEP materials development
Toppan Printing	High efficiency patterning
Thomson Multimedia	AM prototypes
Samsung Electronics	AM prototypes
Seiko Epson	Blue lifetime / inkjet printing
Sumitomo Chemical	High efficiency materials

CDT has also received over UK£2m from the UK Department of Trade and Industry (DTI) and the European Commission for various research and development projects.

8. Developing and leveraging production capability

By 2000, the management of CDT realised that there was still one major opportunity that had not been addressed – generating revenue from the process knowledge required to enable companies new to the LEP displays market to quickly set up a manufacturing facility. As LEP technology approaches commercial manufacturing status for displays, in order to stay at the cutting edge of the technology and develop new IP of direct relevance to manufacturers, CDT decided to invest in a commercial-scale development facility. In late 2000 a project to build such a facility, at a cost of $25m, was approved and construction began in April 2001 in Godmanchester, 15 miles from Cambridge. The facility was officially opened in April 2002 by Lord Sainsbury, the UK Minister for Science.

The manufacturing facility 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
- **To train licensee staff** in advance of their own start-up and to help resolve problems, thereby enhancing and accelerating royalty income
- **To develop process and engineering packages** which will be sold to new licensees to speed them into production

Once enough process knowledge is generated at the process plant, CDT anticipated turning their attention to low volume display manufacturing.

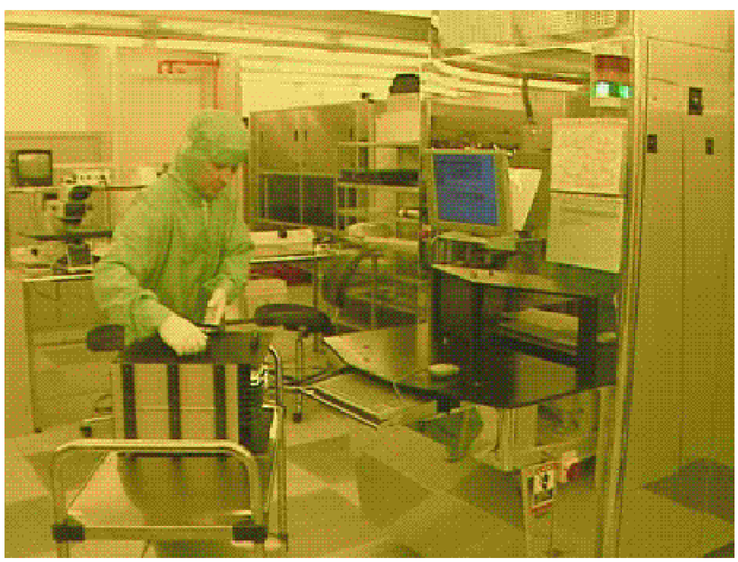


Figure 6: CDT's Manufacturing Development Centre in Godmanchester

Keith Bergelt (Senior V-P Strategy, Business Development and Intellectual Property) commented:

> *"The aim of the pilot plant is to try to stay one step ahead of our licensees in the development of our technology, thus pushing them on to achieve even greater success"*

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

Patenting Decisions at the Manufacturing Development Centre

Often a manufacturing process can be as important to a product's success as the invention itself. Therefore processes can be patented in a similar way to products. However, the decision to patent is less clear cut with a process than with a product. For example, to determine the optimum temperature for manufacturing is very useful process knowledge, but it would not be sensible to patent these conditions as:

- Patent costs are expensive (approximately £30000 over a period of several years)

- The conditions would become public knowledge, allowing other people to copy them. If it is not easy to spot if the techniques have been copied, patenting would be counter-productive

Although it would be illegal to copy patented process conditions theoretically, in practice it could be impossible to prove a patent infringement. Therefore, these optimum manufacturing conditions are generally kept as secret know-how. The company will therefore know the best conditions, and can continue to use them without having to make them public. As manufacturing staff are committed to confidentiality agreements, it will be unlikely that the process knowledge will be copied.

9. CDT at the end of 2001

One of the challenges facing CDT at the end of 2001 was how to increase the lifetime of its blue polymer (still at 3000 hours compared with more than 40,000 hours for red and 20,000-30,000 hours for green). It had in place an interim "mitigation" solution. This entailed running the blue polymer at a lower brightness per unit area but making it into a bigger pixel at the expense of the size of the green: halving the brightness of the blue polymer doubles its lifetime.

New market opportunities for the core technology were also being considered. One example of this is seeking ways to exploit the material's photovoltaic potential - i.e., putting light in to get electricity out. Funding had been secured for initial-phase funding from the UK government.

The aim of the core business of CDT was to move from monochrome displays to full colour passive displays and then on to full colour active displays and flexible substrate displays.

10. Developments 2002-2004

Acquisition of Opsys

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. This acquisition was provided CDT with capability in a high efficiency solution processable polymer display technology that although was not likely to be ready for market for around another 4-5 years, it had the potential to make significant steps forward in terms of performance of LEP-OLEDs. The positioning of this technology is illustrated in Figure 7 below:

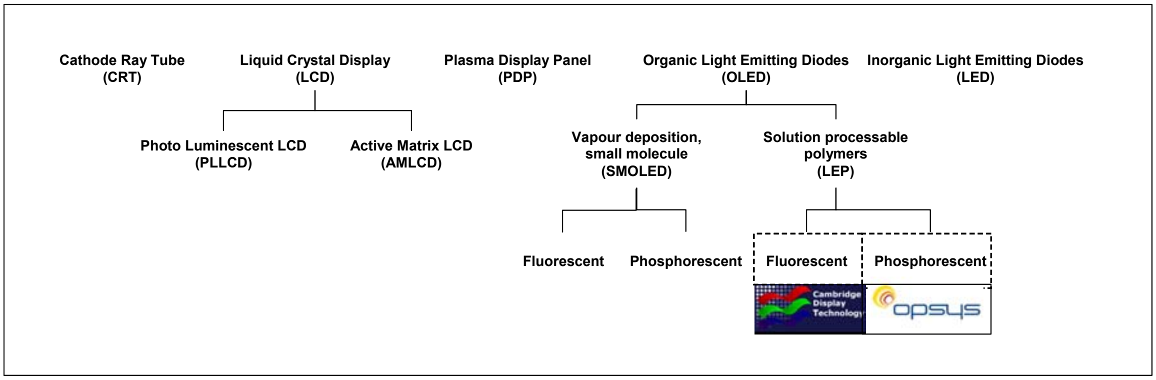


Figure 7: CDT and Opsys relative positioning in OLED technologies

This acquisition also served the purpose of strengthening the position of LEP-OLEDs as competition from the SMOLED market grew. Kodak has already begun shipping digital cameras incorporating SMOLED displays. In addition, the Universal Display Corporation has 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.

Restructuring

In July 2003, CDT announced a major restructuring of its operations coupled with a loss of around 30 jobs (approximately 20% of workforce). The reason given for this was given in part by the need for integration of activities following the acquisition of Opsys the previous year. The activities of the former Opsys facilities in Oxford were moved to Cambridge.

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 would be placed on developing licensable process technologies – and this has led to the first 'process packages' being sold.

In 2003, CDT also sold 50% of its share in Litrex, the US company that it had acquired in 2000 in order to gain inkjet printing capability.

CDT's business model has been revised in the light of these restructuring activities, as shown below in Figure 8:

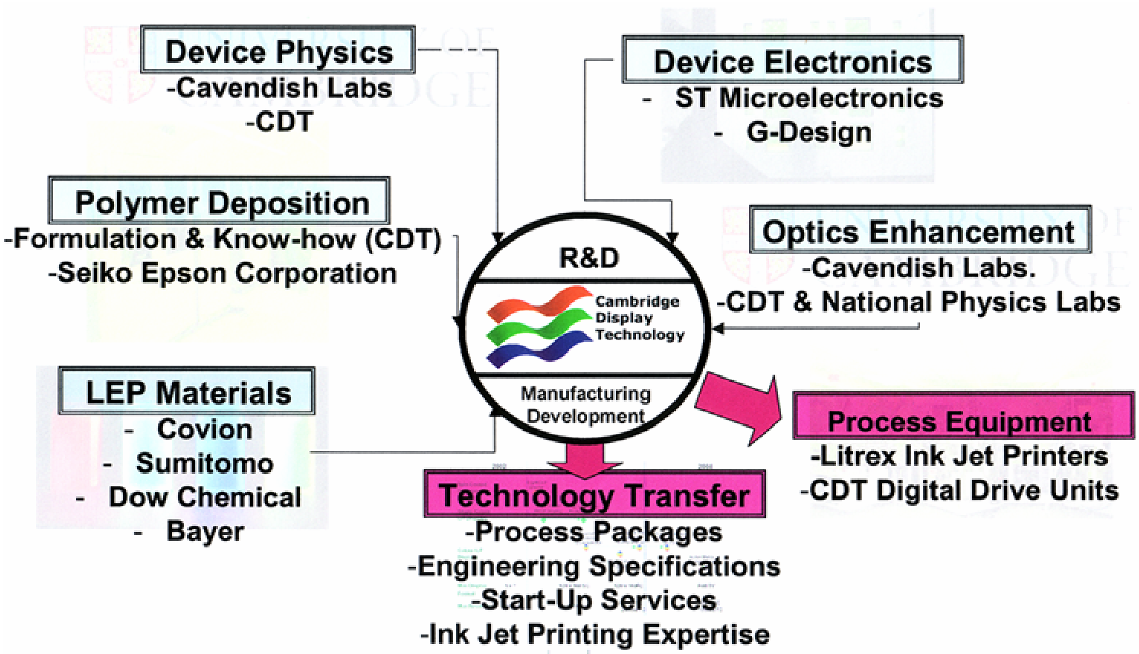


Figure 8: CDT's Business model 2003

Source: CDT Ltd.

Despite increased competition and faster speed to market of the competing SMOLED technology (led by Kodak and its licencees), CDT is still confident of the potential of its LEP technology. The benefit of having a solution processable LEP technology that can be applied to production lines currently making LCD displays is considerable. This, coupled with its partnership based business model, gives CDT its confidence in the future. As Keith Bergelt, (Senior V-P Strategy, Business Development and Intellectual Property) commented in 2002:

> *"Companies could feel exposed to Kodak – the company could put materials prices up should they want to and there is nothing the licensee can do. With CDT's model this problem does not exist, it's an open market"*

CDT hopes the increased flexibility of its supply chain could help to establish and maintain its competitive advantage.

Initial Public Offering

In December 2004, shares in Cambridge Display Technology Inc. were floated on the NASDAQ (with the ticker 'OLED'). Its initial public offering of 2,500,000 shares of common stock was priced at $12.00 per share. CDT is now the first spin-out from the University of Cambridge to be floated on the NASDAQ.

11. References

Company websites

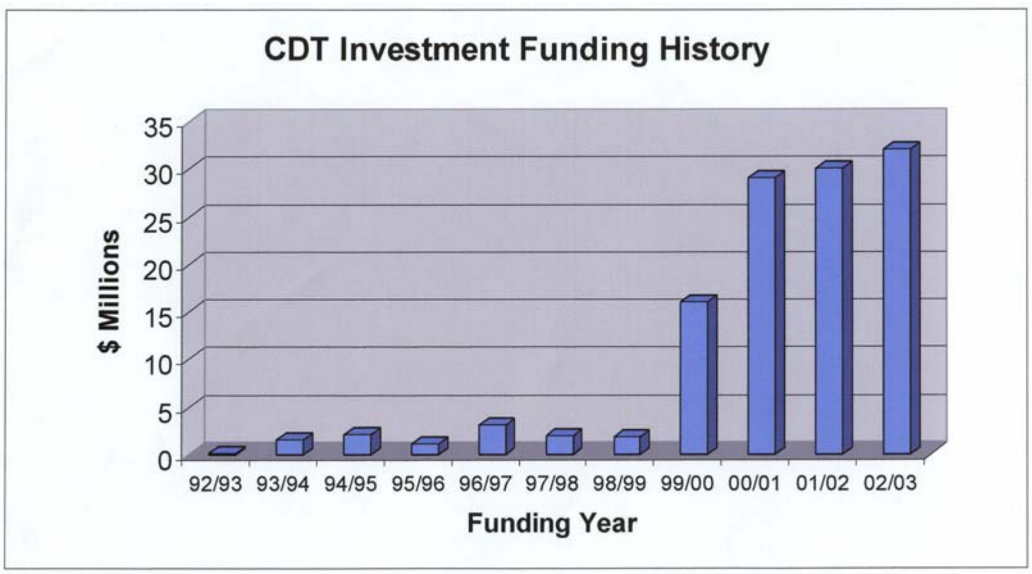
CDT – www.cdtltd.co.uk

Universal Display Corporation – www.universaldisplay.com

Kodak - www.kodak.com/US/en/corp/display

DuPont Olight - www.olight.com

Appendix 1 – CDT Investment history



Year	92/93	93/94	94/95	95/96	96/97	97/98	98/99	99/00	00/01	01/02	02/03
$ Millions	0.2	1.6	2.1	1.1	3.2	2.0	1.8	16.0	29.0	30.0	32.0

Total Investment – 12 + 107 + $119m