Chapter 7

EBOOK READERS: DIRECTIONS IN ENABLING TECHNOLOGY

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> It's important to resist announcements of the death of the book…To refuse to accept such claims is not, however, to deny that we are living through important cultural or technological changes. Rather it's to insist that to assess the significance of these changes and to build the resources to negotiate them, we need specific analysis not sweeping dismissals (Duguid 1996).

INTRODUCTION

This chapter discusses the role of emerging technologies in the evolution of the ebook reader.

We have seen a number of devices appear on the market over the past few years that share some of the characteristics of the book. The size and weight are approximately correct, the devices are somewhat usable and texts can be read on them. However, the ability of the object to foster and support the many complex relationships we have with books is missing. These designs offer a superficial treatment of a significant and persistent cultural artefact.

To some extent this is due to limitations of the current generation of technology. With the technology described in the first part of this chapter, ebook readers can only be rigid, heavy and in daily need of a power point. Turning the page has been replaced by pressing a button. There is no thumbing, flicking or skimming of texts – so far, the physicality of current generation ebooks has demanded that a text be read from beginning to end.

A new generation of technologies is now appearing, promising flexible screens, new heights in readability and battery life measured in months not hours. But are we ready to design the next ebook reader? We need to understand which characteristics are desirable in ebook readers in order to support all aspects of reading. Further to this, these devices should be designed to support some of the more recent practices that have evolved around electronically mediated text.

These technologies are examined in the later part of this chapter, and some discussion is entered into around the impact of these technologies on design. A new generation of ebook readers based on these technologies, and deep principles of design could act as a catalyst for the ebook market. This shift in reading practices could have a profound effect on the publishing industry as a whole, and is something that every actor in the value chain should anticipate and be prepared for.

THE CURRENT GENERATION OF EBOOK READERS

The first ebook reader to market was the Sony Bookman, released in 1992. This CDROM based device was expensive (about A$1800 at the time), heavy and had a screen that was not at all easy to read. While the reasoning behind the product was sound, the technology was not up to the task and the product failed quite spectacularly in the market.

In 1998, two second-generation ebook readers were released, the Rocket eBook reader and the Softbook. These ebook readers met with some early success and were well received by the market. The companies responsible for these readers, NuvoMedia and Softbook Press respectively, established content distribution agreements with publishers and had copyright protection systems in place.

In early 2000, Gemstar[1] (now Gemstar-TV Guide) bought both NuvoMedia and Softbook Press and in the process acquired the rights to both ebook reader technologies. A few months later, Gemstar partnered with Thomson Multimedia's RCA division. RCA agreed to develop and produce under license the 'next generation' of ebooks readers – the REB series – while Gemstar handled the secure distribution of content.

In the time since the launch of these earliest readers, numerous companies pre-announced ebook reader products. Many of these companies have been slow to deliver to market – some products seem to have been indefinitely delayed. The companies working on the Everybook reader and the Librius Millenium Ebook have

[1] http://www.gemstar-tvguideinternational.com/

announced that their product development plans have been cancelled.

Confidence in the ebook market has clearly subsided since the heady days of 1999. Disappointing sales of ebook readers and ebooks have dampened much of the early excitement. The slowdown of the technology sector in the US has caused less money to flow to new ventures. Consequently, many companies have had difficulty attracting second round funding to develop prototypes to the point where they are ready for mass production.

Lack of content and an uncertainty surrounding modes of distribution for ebooks have also slowed down activity in this sector. Standards initiatives have been progressing slowly, and a sluggish market is not indicating a clear winner. Publishers have also been understandably reticent since the file swapping frenzy that surrounded Napster was narrowly beaten into submission by the music publishing industry. The idea of 'piracy' of copyrighted works on the Internet is a terrifying one for publishers, and is used as justification for increasingly restrictive Digital Rights Management (DRM) proposals.

Clearly there are many issues surrounding the acceptance of ebooks by the market. The current mood seems to be one of consolidation, and publishers are taking the opportunity to determine what they should offer electronically and on what basis.

PRODUCT EXAMINATION

This section examines the ebook readers that are currently on the Australian market (mainly of US origin) and a few that are produced outside of the US. The models presented here do not represent an exhaustive list, but do provide enough coverage of the market to be indicative of the genre.

Each reader is described briefly and then the pertinent technological aspects are summarised in a table at the end of the section. For the purpose of this section an ebook reader is a device that is primarily designed and sold as an ebook reader. This classification does not include generic palmtop devices that can run reader software or software that runs on laptop or desktop computers.

RCA REB Series

The RCA REB series is manufactured under license by RCA in the USA.[2] This series of readers is distributed in Australia by E Info Solutions.[3] Two models are available in the range:

1. **REB–1100:** A base model monochrome device, the REB–1100 has been relatively successful and has been chosen as the platform for numerous ebook trials in libraries and schools. This device has the size and weight of paperback book and is designed for readers of novels, mobile professionals and 'jet setters'. It has a monochrome, touch sensitive screen with a backlight.

The REB-1100 is an upgraded version of the original Rocket Ebook reader. However, in the process of 'upgrading' the device, the RocketWriter facility of the Rocket was removed. This feature allowed owners of the device to convert their own files into Rocket format so they could be read on the device. This led to a number of owners of the original device writing and publishing their own works in Rocket format for the enjoyment of others. Presumably this feature was removed due to concerns about piracy – regardless of the implications for independent authorship.

While the contrast of the display is lower on the new REB–1100, backlight quality has been improved, leading to a very readable device. Also, the device is lighter than its predecessor. The device has 8 MB of memory built in which is expandable via a Smart Media expansion port. It has an internal v.34 (33.6 Kbps) modem and a USB port.

The retail price of this device is AUS$690 and according to the Australian distributor a new version is expected in 2002.

2. **REB–1200:** A more advanced model with more memory and a colour display, this device is an upgraded version of the original Softbook. It is slightly smaller than a magazine (although somewhat heavier), and thinner than the average hardback book. It is designed for reading magazines, textbooks and novels. It has a colour, touch sensitive screen with a backlight.

The device has 8 MB of memory built in which is expandable via a Compact Flash expansion port. It has an internal v.90 (56 Kbps) modem and an Ethernet connection.

This device retails for AUS$1375.

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[2] http://www.rca.com/product/
[3] http://www.einfosolutions.com/

Franklin Ebookman

This device[4] is a small palm sized device with a touch-sensitive display capable of 16 shades of grey. The two higher specification models offer a backlight. Each device has music and audiobook playback capability and organiser and note-taking functionality built in.

The low-end ebook reader in this range has 8MB of memory while the high-end model has 16MB, all of which can be expanded via the MultiMediaCard (MMC) expansion slot. Each device in this range has a USB port, headphone jack, speaker and microphone.

This series of readers is distributed in Australia by E Info Solutions. The three models, the EBM-900, 901 and 911 retail at AUS$299, AUS$399 and AUS$499 respectively.

Cybook

The Cybook[5] was released in January 2001 and is produced by a French company called Cytale. It has a large format, backlit, touch sensitive colour screen and is designed as an ebook reader and device for surfing the net. It has 32 MB of built in memory and has USB, PCMCIA and infrared communications ports. In addition to this it has a built-in v.90 (56Kbps) modem.

The Cybook is currently only available in France with content agreements in place for French and English language content. Distribution outside of France is not planned at the moment.

The device sells for US$600 (approximately AUS$1200).

MyFriend

The MyFriend[6] reader, produced by IPM-Net is due to be released in Italy in the second half of 2001. It has a large format, backlit, touch sensitive colour screen. The display is unique among the current generation of ebook readers as it produces a 150 Pixels Per Inch (PPI) image.[7]

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[4] http://www.franklin.com/ebookman/
[5] http://www.cytale.com/site/corporate/en/index.htm
[6] http://www.ipm-net.com/eng/products/appliances/myfriend/index.htm
[7] Pixels Per Inch: A Pixel is a ‘Picture Element’ – one of the many dots that make up the image that appears on the computer screen. ‘Pixels Per Inch’ is a measure of the

MyFriend has a USB port and infrared capability for connection to other devices. Expansion capability is provided via a PCMCIA slot and security and authentication is provided via a smartcard module in SIM format. The device has 32 MB of memory.

IPM-Net appear to also be actively exploring designs that are appropriate for different markets, particularly the children's market.[8] The company has stated that they intend to extend distribution to Europe, the US and Australia.

It is expected to retail for US$1200 (approximately AUS$2400).

hiebook

The hi*e*book is produced by the Korea ebook company and has a backlit, touch sensitive display capable of displaying 16 levels of grey.[9] It is roughly the size of a paperback and has a broad range of functions, including organiser, note taking (with hand writing recognition), drawing program, sound recording and playback (including MP3). It has 8 MB of built in memory. The device has a USB port for connection to external devices and a Smart Media Card (SMC) for memory expansion.

E Info Solutions will distribute this series of readers in Australia in September 2001 and will retail for AUS$499.

SUMMARY OF SPECIFICATIONS

While these ebook readers are all different, it is the similarities that are notable. Many of the components in these devices are based on identical technology. As a result, they are constrained by the characteristics imparted by the technologies.

Some of the specifications of these ebook readers are presented in the following table, sorted by display resolution.

Make	Model	Resolution		Display Type	Battery Technology	Battery Life* (hrs)	Size (cm)	Weight (gm)	Price (A$)
		Pixels	PPI						
Franklin	EBM-9xx	200x240	65	Grey	2xAAA	15**	8.6x13.1x1.7	184	2-499

resolution of the screen, literally the ability of the screen to resolve fine detail, expressed as the number of pixels in an inch as measured on the display.

8 http://www.ipm-net.com/eng/lab/index.htm

9 http://english.koreaebook.co.kr/index.php

Korea	hiebook	320x480	100	Grey	Lithium Ion	6-12	12.5x15.0x1.8	250	499
RCA	1100	320x480	105	B&W	Lithium Ion	20-40	12.7x17.8x3.8	510	690
RCA	1200	480x640	95	Colour	Lithium Ion	5-10	19.1x22.9x3.2	936	1375
Cytale	CyBook	600x800	100	Colour	Lithium Ion	3-7	21.5x26.5x2.8	1035	1200
IPM-Net	MyFriend	640x960	150	Colour	Lithium Ion	4-8	17.8x19.7x2.5	800	2400

** Battery life is heavily dependant on the use of the backlight. Generally, the higher figure is for no backlight use, the lower figure is for constant backlight use.*

*** Some users have indicated that battery life can be significantly lower than this, especially when the mp3 functionality is in use.*

Clearly there are trade-offs to be made between display size, backlighting, weight, and battery life. Weight increases with display size, quality and capacity to reproduce colour. As the display size increases, power consumption jumps and battery life drops off dramatically.

The following section provides an overview of the technologies used in this generation of devices, and serves to highlight some of the shortcomings.

THE CURRENT GENERATION OF TECHNOLOGY

Using the current generation of technology it is difficult to produce an ebook reader that reproduces a wide range of material with a reasonable degree of fidelity. Apart from issues of weight and battery life, the expense of the parts required, especially the display, is prohibitive.

DISPLAYS

The displays used in these ebook readers are either colour or monochrome Liquid Crystal Displays (LCD). The name *liquid crystal* comes from the substance in the display that is switched with electric current in order to block or transmit light. LCDs have been available for a number of years (RCA produced the first prototype in 1968) and they have some distinctive properties.

An LCD can be used in a number of ways to display an image. In its cheapest and most common form it is a simple *reflective* display. These displays operate solely on the principle of reflecting ambient light back to the viewer's eye. As the base colour of most

LCDs is grey, very little light is reflected so they perform quite poorly. This results in a display with low legibility in most situations. Some LCDs have a mirror behind the display in order to reflect light not reflected by the display itself. This can improve readability, but this type of display only works in a narrow range of ambient light levels.

LCDs can also work as *transmissive* displays. A light source is placed behind the display, such as a small fluorescent tube (also known as a backlight), which allows the display to be viewed in a range of lighting conditions. Both types of LCDs suffer serious readability problems in bright or direct sunlight.

The LCD display is a quite complex composite structure, as illustrated below.

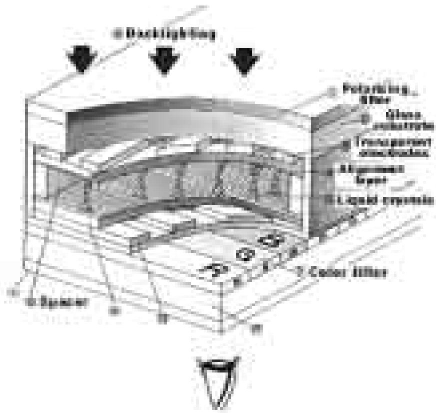

Figure 1.

The display is made up of a layer of liquid crystals sandwiched between other layers. Each of the layers, as numbered, performs the following function;

- **Polarising Filter:** The outermost layers are two polarizing filters that control light entering and leaving the display.
- **Glass Substrate:** The next two layers are glass substrates that serve to protect the liquid crystals and separate the polarising and electrode layers.
- **Transparent Electrodes:** These electrodes drive the LCD. A highly transparent material is used that will not interfere with the quality of the image.

- **Alignment Layer:** Film is used to align the molecules in a fixed direction.
- **Liquid Crystals:** The liquid crystals that twist when voltage is applied in order to block or transmit light.
- **Spacer:** Maintains a uniform space between the glass plates.
- **Colour Filter:** Colour is expressed through the use of Red, Green and Blue filters.
- **Backlighting:** The display is lit from behind to make the screen brighter. In some types of monochrome LCDs, a mirror is used in place of backlighting so the display can be seen with ambient light.

Adapted from the information found in the Sharp LCD library (Sharp 2001)

While a backlight does increase the range of conditions in which a device can be used, it does not make for an ideal reading device. Reading from backlit displays can cause eyestrain and increase the feeling of fatigue in the reader. Additionally, the small fluorescent light required for handheld devices is much less power efficient than the light used in laptop or desktop LCD displays.

The rear polarising filter absorbs over 50% of the light put out by the backlight, increasing power consumption dramatically. An increase in power consumption needs to be compensated for in the design of the device – namely there is an increase in the size of the battery in order to maintain reasonable operating times. A larger battery is more expensive and makes the device much heavier.

These polarising filters and nature of the LCD can result in displays that have a narrow viewing angle. Consequently, LCD displays are only viewable from a limited number of positions and are adversely affected by light that strikes the display at an angle.

The LCD depicted above is what is described as a *passive matrix* display. Passive matrix displays are the easiest and cheapest to manufacture, but have problems with screen update time, making them unsuitable for many applications. Passive matrix displays also suffer from bad image definition and can blur images and text when scrolling.

Another type of LCD exists, known as an *active matrix* display. Active matrix displays incorporate a Thin Film Transistor (TFT) layer, essentially a high-speed switch for every pixel on the screen. This provides improved screen update speed resulting in a crisp display that does not suffer from blurring, even during video playback. Unfortunately, the TFT layer and the circuitry required to drive it adds considerably to the cost of an LCD screen.

The glass substrates that are layered between the polarising filters and electrode layers make the display rigid, fragile and heavy. They are necessary though, as LCDs rely on an even gap between the two electrode layers in order to produce an even and consistent image (Scott 1993). Additionally, glass is required as a substrate for TFT as the temperature required to apply this layer is very high.

Finally, but importantly, LCDs require power at all times in order to display an image.

BATTERY

The batteries in the majority of these ebook readers are rechargeable Lithium-Ion. These batteries are the most compact and efficient rechargeable batteries currently available. Unlike previous generations of batteries they can utilise a plastic rather than metal case and can be made in a range of shapes.

However, they do have some disadvantages, in that they can be volatile, and require cooling and safety circuits so that they don't catch fire. Lithium-Ion batteries are also quite expensive compared to previous battery technologies and can add considerably to the cost of a device.

DESIGNING FOR READABILITY

While technology currently constrains the design of ebook readers it is worth examining some of characteristics of print that we want to preserve, especially those that contribute to readability. When we understand what physical characteristics of the printed page consumers prefer, we can easily identify which new technologies are important.

In order to maintain readability and legibility it is crucial to preserve the appearance of text as it appears on the printed page. This means that the resolution of the display must be high enough to accurately reproduce the details of individual characters and typefaces. In addition to this, precise control over spacing between lines and characters must be possible. Research conducted at IBM during the development of their prototype *Roentgen* displays (Bassack 1998; IBM 2000) found that improvements in kerning, the spacing of letters relative to each other, occurred in the resolution range between 150 and 200 PPI. High display resolution is also very important for faithful depiction of non-Latin, ideographic text, such as that associated with Chinese or Arabic scripts.

Human visual acuity, at a viewing distance of approximately 45 centimetres from the screen, allows the reader to resolve detail down to one tenth of a millimetre (1/200th of an inch) (Wisnieff and Ritsko 1999).[10] It would seem then that a display resolution of 200 PPI should be considered a minimum for comfortable screen reading and accurate depiction of characters and text. However, given that an ebook reader may be held closer to the eyes than this, say 30 centimetres, then the minimum resolution for comfortable reading would be higher again – closer to 300 PPI.

Current display technology is not ideal for reading, delivering an onscreen resolution of somewhere between 80 and 100 PPI. Laser printers routinely produce output in the range of 300–600 Dots Per Inch (DPI), the equivalent measure of resolution for printers. Commercial printers can produce much higher resolution. Displays clearly have a long way to go in terms of resolution.

The way in which paper reflects light and the clarity of ink on paper need to be taken into account when thinking about suitable displays for reading. These characteristics of paper can be expressed as the *white state reflectance* and the *contrast ratio*, and can be measured for electronic displays as well.

White state reflectance is a measure of how much light reflects off the white state of the display and reaches the users eye as compared to a perfectly white control sample. This works for reflective display types, but in order to evaluate displays that are not reflective (like CRTs which are emissive, or backlit LCDs which are transmissive) we use the general term *luminance.* This provides a way of expressing how much light reaches the eye, or in short the brightness of the display.

Contrast is expressed as a ratio between the white state and dark state reflectance of the display. Basically the difference between the light reflected by the page and the ink respectively.

Paper is an entirely reflective medium – the light in your surroundings, ambient light, is reflected back to your eye by the paper. Light is absorbed by the black print, resulting in high contrast

[10] The limit of the human vision system to resolve detail.

between print and the page that it appears on. Paper performs well under varying light conditions, except of course darkness. Both the white and dark states are affected by changes in ambient light, resulting in varying luminance, but constant contrast. This characteristic of paper makes reading in naturally and artificially lit environments easier on the eyes.

Emissive and transmissive displays such as CRTs and LCDs perform well when there is limited light and have good contrast and luminance under office and domestic lighting conditions. However, their performance drops off dramatically, when used in naturally lit environments, especially direct sunlight. This is because light increases the luminance of the dark state only, reducing contrast.

Computer monitors and laptop screens generate their own light, which can contribute to fatigue and eyestrain from reading. Additionally, most CRTs are updated at the rate of about 60 times per second. This can cause perceptible 'flicker' in the display and make on-screen reading uncomfortable for anything other than short periods of time.

Clearly, display types other than those currently available are required if reading is to be a comfortable and natural activity with ebook readers. A number of companies are working towards providing display technologies that reflect light much like paper and provide impressive contrast and resolution. These technologies, which will make the next generation of reading devices cheaper, lighter, less power hungry and much easier to read, are outlined in the following section.

A NEW GENERATION OF TECHNOLOGY

Recently, electronic displays have been developed that reflect light efficiently, and perform very well in most lighting conditions, especially bright and direct sunlight. These displays produce an image that is easy on the eye, and does not cause eyestrain or fatigue. A number of new technologies are emerging in parallel that have the potential to change the form of ebook readers dramatically. These technologies are described in this section.

DISPLAYS

One of the limiting factors with the current generation of dedicated reading devices is the display. A number of new display technologies promise to overcome some of the shortcomings of LCDs, and some offer some tantalising new possibilities.

One of the keys to the suitability of these new displays is that they are reflective displays. This means that they simply reflect ambient light back to the reader's eye. This gives these displays very similar readability to paper.

These displays are also bistable, which means that they can display text and images without consuming any power. In fact, power is only required to update the display, for example to display the next page of a book. This property, combined with the fact that a backlight is not required leads to power consumption that is significantly lower than LCD displays.

In this section, I will analyse the two major displays that fit into this category; E Ink produced by the E Ink Corporation and SmartPaper™ produced by Gyricon Media.

E Ink

E Ink was founded in 1997 in order to commercialise an electrophoretic ink technology developed by Joseph Jacobson at MIT.[11] Jacobson was inspired by the earlier work of Nicholas Sheridan at Xerox PARC.

In 1999, E Ink first tested their electronic ink technology in a wireless sign product called Immedia, designed for in-store retail signage. These signs were unique because they allowed the display to be remotely updated. The Immedia displays were capable of about 5 PPI, and had some issues with contrast and viewing angle, making them useful only for large format posters. Since the initial test period, E Ink has been working on a second-generation signage product due out at the end of August 2001.

In parallel with their work on Immedia, E Ink has been working on improving their display technology so that it can be used in applications that require portability and high resolution.

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[11] http://www.eink.com

HOW IT WORKS

A sheet of E Ink is composed of millions of tiny microcapsules, each about the diameter of a human hair (100 microns). These microcapsules are each filled with positively charged white particles and negatively charged black particles, suspended in a clear fluid.

When a negative electrical field is applied to the top electrode, the white particles move to the top of the microcapsule. At the same time a positive electrical field is applied to the bottom electrode, pulling the black particles to the back. The white particles are made of titanium dioxide (the 'whitest substance known to man'), so in this state the display has a paper white appearance. Applying the opposite charge to the top and bottom electrodes causes the position of the particles to be reversed, making the display appear black to the user.

This principle is illustrated in Figure 2.

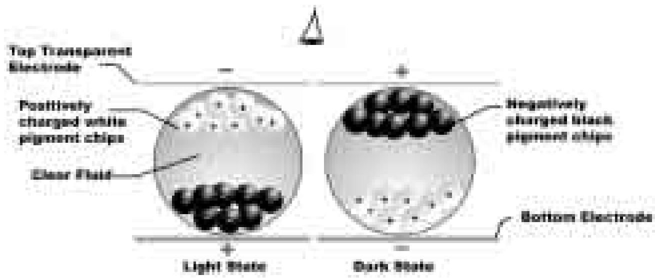

Figure 2: E Ink.
Source: E Ink Corporation

The top electrode is a transparent sheet of Mylar coated with Indium Tin Oxide (ITO) while the bottom electrode is a transistor layer. Each transistor is effectively a switch, which can swap the state of a cluster of microcapsules. Each 'cluster' is a dot (or pixel) on the display surface. Each dot can be individually switched on and off, allowing the display to represent text and images in black and white. Electronic fields drop off gradually at the edges, providing an automatic smoothing of text and image outlines.

In addition to this, the particles can be suspended at different levels in the microcapsules, allowing eight levels of grey to be displayed by interspersing the black and white particles. Potentially, the particles in the microcapsules could be any two contrasting colours, allowing shades of a single colour, or one colour blending in to another.

Figure 3 shows E Ink sheets displaying text and graphics. Each microcapsule visible in these pictures is about 100 microns across, so the magnification is fairly high.

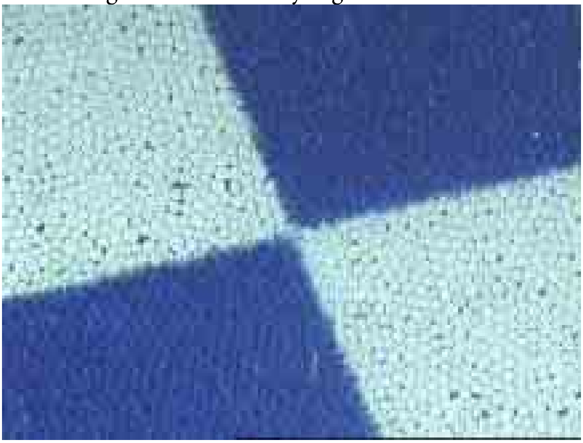

Figure 3: Source – E Ink Corporation

E Ink is bistable, hence it can display text and images without consuming any power.

E Ink is also developing a variation on the technology described above, which has charged white particles suspended in a black oil/ink mixture. Here, a charge is applied to move the white particles to the top or bottom of each microcapsule. When the white particles are at the top, the display appears white, and when the particles are at the bottom, the display takes on the colour of the base ink.

Here also, different combinations of coloured ink and particles can be combined to produce displays of two contrasting colours.

The life of an E Ink display is estimated to be in the order of millions of state changes or more. E Ink is expected to operate well between 10 and 60 degrees Celsius.

MANUFACTURE

The process of manufacturing E Ink is as follows. The microcapsules themselves are produced using proprietary batch chemical processes. The microcapsules are then suspended in a liquid 'carrier medium', a clear glue, and applied to an ITO-coated Mylar substrate. This constitutes the 'display' part of the E Ink technology, although a means of controlling the microcapsules is required.

The composite is then stuck to a layer of 'switches' used to control the display. This layer of switches is known as a Thin Film Transistor (TFT) substrate. The process uses the same equipment as LCD manufacture, yet requires far fewer process steps and material components. This leads to lower costs and higher yield.

This process is illustrated in Figure 4.

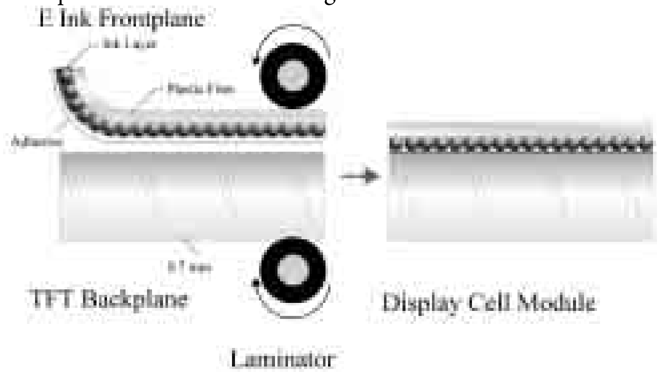

Figure 4: Source – E Ink Corporation

READABILITY

The E Ink display technology provides a paper white, reflective display. This display has many of the desirable characteristics of paper, while overcoming some of the major drawbacks of LCD technology. E Ink compares especially well to the displays found in the current generation of ebook readers.

The following table compares E Ink to common monochrome LCD displays and newsprint, in terms of white state reflectance and contrast ratio.

Display Technology	White State	Contrast

	Reflectance	Ratio
Transflective Mono STN LCD (common PDA with touchscreen)	4.2%	4.1
Transflective Mono TN LCD (common ebook with touchscreen)	4.0%	4.6
E Ink (with touchscreen)	26.6%	9.2
E Ink (no touchscreen)	38.1%	10.0
Wall Street Journal Newspaper	61.3%	5.3

Source: E Ink Corporation

The E Ink display has high contrast, in excess of that of LCD and newsprint. White state luminance for E Ink is in excess of LCD, approaching that of newsprint. LCD is also sensitive to the angle of illumination, that is, the angle at which light hits the display. This can be a problem when using an overhead reading light but is not a problem for reflective displays like E Ink.

POWER CONSUMPTION

The power consumption figures for E Ink are low for a number of reasons. A backlight is not required as the display is reflective. More importantly, because the display is bistable it only draws power when the display changes from one state to another. Hence the requirement for battery power is reduced – this means that the size and weight of required battery component of any device using this display type is also reduced. This makes the E Ink display technology particularly suitable for mobile applications and devices can be cheaper and lighter.

Display Technology	Power Use 5' QVGA, 320x240 pixels	Power Use 8' SVGA, 800x600 pixels
Transmissive colour AMLCD (PDA)	1000 mW	3830 mW
Reflective monochrome STN LCD (PDA)	60 mW	n/a
Reflective colour AMLCD (common PDA)	25 mW	600 mW
Monochrome E Ink (one update per 10 secs)	0.7 mW	7.1 mW
Monochrome E Ink (one update per 60 secs)	0.1 mW	1.2 mW

The table above compares the power usage of E Ink displays to active and passive matrix LCD displays as used in Personal Digital Assistant (PDA) devices. As the table shows, E Ink displays use far less power than LCD displays of similar size.

FORM FACTOR

First generation E Ink displays (hybrid) will be half the weight and half the thickness of TFT LCD technology. This is because while the rigid glass backplane is still required, a sheet of E Ink replaces the front glass panel.

In addition to this, new backplane technology will allow flexible displays. These new backplanes are essentially active matrix drive circuits printed on thin flexible plastic substrates. These have been under development by Bell Labs/Lucent, and E Ink demonstrated a functional prototype of a flexible display based on this technology in November 2000.

E Ink estimates that flexible displays based on this type of technology will be available in 2004–5. A comparison of these different display types is shown in Figure 5.

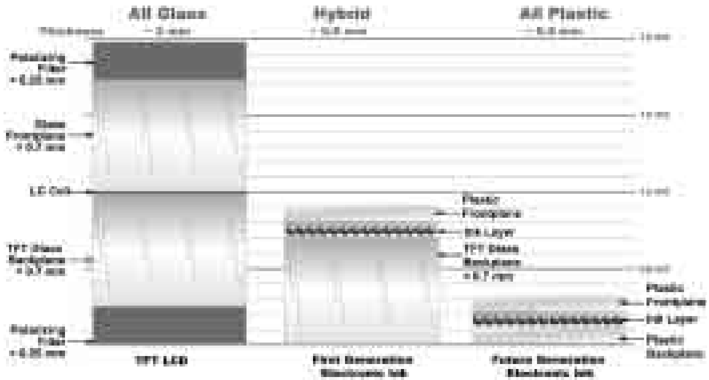

Figure 5: Source – E Ink Corporation

The printable transistors on these flexible substrates are made entirely of plastic materials and fabricated using a low cost printing process that utilises high-resolution rubber stamps. The switching properties of these backplanes are similar to TFT on glass, yet they provide a flexible, rugged and lightweight platform. Interestingly, this method of production has the advantage of being compatible with rapid reel-to-reel printing techniques, and transistors can be applied to large sheets of plastic in a single step.

The resulting display is as thin as 0.3 mm, providing a 75–85% reduction in the thickness of the display and an even greater percentage saving in terms of weight. These displays provide a uniform image, even when flexed.

MORE RECENTLY

The preceding text comprehensively describes the E Ink display technology. However, recent progress makes the E Ink display technology even more interesting as a candidate for use in ebook readers and other handheld devices.

High Resolution: In early 2001, E Ink announced that in partnership with IBM, they had created and demonstrated a high-resolution active matrix electronic ink display. This display measured 12.1 inches diagonally, and had the resolution of a 'typical laptop computer display', which would place it in the 80–100 PPI range. This high-resolution display was able to update the image on screen 10 times faster than the traditional E Ink display. Additionally the display had reduced power consumption.

Colour: A month later, E Ink announced that they had formed a strategic partnership with a Japanese company called Toppan in order to develop colour electronic ink displays. Toppan specialises in colour filter arrays for flat panel displays, and the technology that E Ink is proposing to use is exactly the technology used to provide colour in LCD displays. These displays will be colour, but have all the benefits of other E Ink displays, including being 20–50% thinner than traditional LCD.

At the Society for Information Display conference in 2001, E Ink demonstrated a prototype display capable of 80 PPI in full colour. As the underlying technology is the same as E Ink, this display would have been able to display 4096 distinct colours. This is interesting also because in order to display 80 PPI colour (with a colour filter) the underlying display had to be capable of 240 columns by 80 rows in each inch – meaning that transistor density for the driver layer is progressing well.

The addition of the colour filter does have some impact on the performance of the technology overall. Luminance (White State Reflectance) figures are slightly worse as there is no natural white state. White is a composite, derived by activating the red, green and blue pixels at the same time. The colour filter also absorbs some light causing luminance to drop off a little, although contrast is unaffected.

Also, power consumption increases slightly as there are more pixels to switch to achieve colour at the same resolution as a monochrome display. Manufacturing is more complicated as the colour filter is another layer that needs to be added to the display.

It is estimated that high-resolution colour displays will be commercially available from 2004.

First Generation E Ink Products: Philips Components partnered with E Ink in early 2001 in order to develop and commercialise high-resolution, active matrix electronic ink displays for use in handheld devices. As part of this deal, Philips secured exclusive rights on the manufacture and sale of display modules for PDAs and ebook readers 'for a select period.' It's not clear how long this exclusivity lasts, but the deal is significant nonetheless.

In mid 2001, Philips and E Ink demonstrated a 13cm diagonal, high-resolution electronic ink display prototype capable of displaying monochrome or greyscale text and images at 80 PPI. Broad commercialisation in of displays based on this technology is planned for 2003.

Preliminary specifications for these first generation E Ink displays are as follows:

First Generation E Ink Displays Preliminary Specifications	
Display Size Resolution	7–20cm diagonal 125+ PPI
Colour Greyscale	Black and White 2–4 bits
Reflectivity Contrast Ratio	40% 10:1
Viewing Angle Response Time	Unlimited 150 msec

Source: E Ink Corporation

In its first, high resolution, rigid backplane incarnation E Ink is expected to be price competitive with Active Matrix LCD. This price is likely to change over time as flexible TFT technology evolves. E Ink has stated that when the product is released it will be released globally, including Australia.

Recent conversations with E Ink have indicated that their technological research is progressing well and that displays exceeding some of the specifications of the Philips display are already feasible.

E Ink has already demonstrated displays with the required 150 ms response time. This means that the display can be changed seven times per second, the minimum requirement for acceptable text scrolling. Higher refresh rates are something the company is aiming for, but the 30 ms response time required for displaying video is some time off.

In terms of resolution, monochrome displays capable of greater than 140 PPI are feasible. The limiting factor here is the density of the transistors on the TFT backplane. IBM has demonstrated rigid TFT backplanes capable of driving 200 PPI displays in their *Roentgen* high-resolution LCD prototype, though these are likely to be expensive.

The Future: By 2003, E Ink expects a new generation of ebook readers that use E Ink displays to emerge. These devices will be the same size as a paperback book although they will weigh less and be just over a centimetre thick. They will have low power consumption, and be able to display around 10,000 pages of text and images from a pair of AA batteries (or a rechargeable three volt power source). E Ink predicts that devices like this may eventually cost less that US$199 – a price point that E Ink expects will be necessary to create significant market interest for ebook readers.

By 2004–5 a flexible page version might make it to market. A lightweight, updateable single page like this will also be useful for many other applications outside of the ebook reader market. The outstanding challenge, especially for reading applications, is the availability and cost of flexible transistor layers capable of driving high-resolution displays in this time frame.

E Ink have stated their intention to develop RadioPaper™, a flexible electronic ink page with a flexible computer, power supply and wireless networking functionality embedded in the page. E Ink expect all the components required to realise RadioPaper™ will be in place by 2005, about the same time they expect large format, high-resolution displays to be feasible.

The performance and features of E Ink are difficult to predict beyond this point. However, the price of flexible sheets of E Ink will drop over time, and by 2010 E Ink expect a multi-page (20-40) reading device to be commercially feasible. In light of this, it is interesting to note that E Ink holds a patent (US Patent No.

6,124,851) for an 'Electronic book with multiple page displays' – so the incentive for them to commercialise this type of product is high.

SMARTPAPER™

The company with the longest history in the area of electronic ink is Xerox.[12] In 1975, Nicholas Sheridon, a research scientist at the Xerox PARC research facility predicted that the future of electronic documents lay not in screen-based reading, but in paper-like electronic devices that had the portability and resolution of paper. While a working prototype was constructed, the project was abandoned after Xerox moved the scientist in order to have him focus on technology more closely related to their core business.

Work only resumed on the technology in 1991 when the patents granted in 1976 were in need of renewal. A number of related devices were also patented during this process: a high-speed desktop 'printer', a wand capable of erasing and rewriting a sheet of electronic paper in a swipe and a stylus which allows the electronic paper to record hand writing. Xerox partnered with 3M in 1999 to refine the process of producing electronic paper.

Gyricon Media[13] was borne from Xerox PARC in late 2000 in an attempt to commercialise their electronic paper technology. The core Xerox technology was called Gyricon – literally 'rotating image'. The technology now goes under the name, SmartPaper™.

Similar to E Ink, Gyricon Media has a retail signage product, called MaestroSign. This product is a wireless signage product that can be remotely updated. Gyricon Media have stated that they will bring their MaestroSign product to market in early 2002.

HOW IT WORKS

Nicholas Sheridon's original design from 1975 is still the basis of SmartPaper™ today. SmartPaper™ consists of millions of randomly positioned, oil filled bubbles in a sheet of rubber. Each bubble contains a solid bi-coloured ball of contrasting colours where, for example, one half of the ball is black and the other half is white.

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[12] http://www.parc.xerox.com
[13] http://www.gyriconmedia.com

These balls have a diameter of 100 microns or less. A protective plastic coating is applied to each side of the rubber sheet.

Figure 6 shows a magnified view of a piece of SmartPaper™, with some balls in the white state and others in the black state.

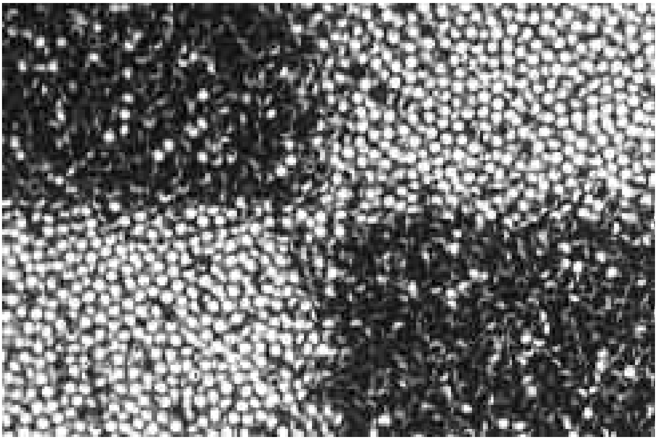

Figure 6: Xerox PARC

Each ball carries an electric charge, where one hemisphere is positively charged and the other is negatively charged. When an electric field is applied to the plastic sheet, the balls rotate and display one either one colour or the other. Using low voltage, partial rotation can also be achieved to display black, white and three shades of grey. This technique can be used to display text and graphics on the plastic sheet.

Figure 7 illustrates the principle of ball rotation.

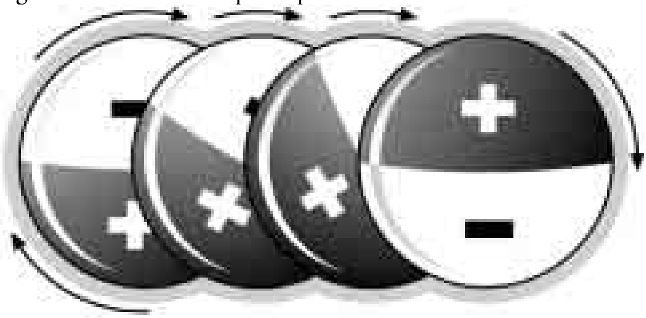

Figure 7: Source – Gyricon Media (adapted to show charge in initial and intermediate stages)

The SmartPaper™ display technology is bistable, that is, once an image is displayed it is retained without drawing any power. Adhesive forces between the ball and bubble wall require an electrical threshold to be exceeded before the ball will rotate. This means, as with E Ink, power is only consumed when the image is changed – making power consumption very good.

Gyricon Media stated that they are using a 'scanned array' (most likely similar to passive matrix as used in LCD) to activate the balls in the rubber layer. This technology allows SmartPaper to achieve a higher resolution than currently possible with TFT backplane technology. The limiting factor is the size of the balls able to embedded in the rubber layer. One drawback of this technology is display refresh speed – currently it takes two seconds to change the image on a SmartPaper display.

The product literature states that the display can undergo at least five million image changes without malfunction or fading. The display works optimally in the 0 to 50 degrees Celsius range. Gyricon Media provide no information on the manufacture of SmartPaper.

READABILITY

SmartPaper™ is a fully reflective display technology and has paper-like appearance and readability. The viewing angle of a SmartPaper™ display is equivalent to paper.

Display Technology	White State Reflectance	Contrast Ratio
Gyricon (Black/White)	24%	>10
Gyricon (Blue/White)	34%	>10

Source: Gyricon Media

Currently, the resolution of a SmartPaper™ display is in excess of 100 PPI. Hundreds of balls make up each dot (or pixel) and images are likely to benefit from the smoothing effects of electric fields from the display driver.

Gyricon Media have stated that they expect to improve the image quality over time to at least 300 PPI. This performance is dependant on the size of the balls embedded in the rubber layer. Their literature, mentions a ball density of about 250,000 per square inch, indicating a high theoretical maximum resolution.

POWER CONSUMPTION

As SmartPaper™ only consumes power when the display is changing, power consumption is very good. Gyricon Media provide an example of the battery life of their MaestroSign.

A MaestroSign will run for up to two years on three AA batteries. It is stated in their literature that in this case the power is almost completely consumed by the radio communications system and the in-built computer required that updates the display. While the frequency or number of display updates is not mentioned in these figures it is still somewhat indicative of power consumption

FORM FACTOR

'Unhoused' SmartPaper™ is less that 2.5 mm thick including the driver layer, and 0.5 mm without. Gyricon Media indicated that they are not currently using TFT as a driver layer, but that it could be used in combination with Gyricon sheets. They are 'actively studying' their options at the moment with respect to flexible transistor backplane technology.

Figure 8 shows the structure of SmartPaper™.

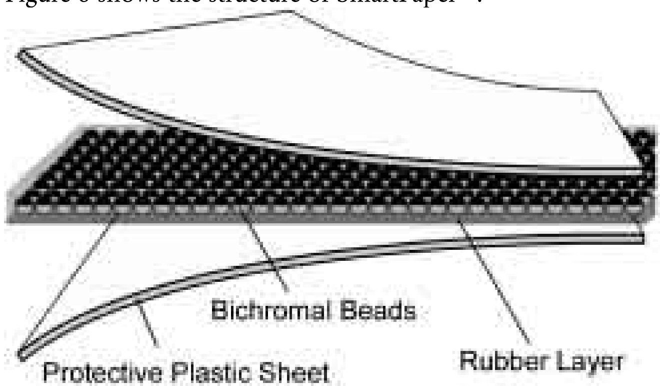

Figure 8: Source – Gyricon Media (adapted to include labels)

The 100 micron balls are packed very tightly in a sheet of SmartPaper™ – a 27 cm by 28 cm sheet contains 30 million Gyricon balls. SmartPaper™ is currently available in sheets sized between 8 cm by 12 cm and 120 cm by 120 cm.

MORE RECENTLY

We contacted Gyricon Media and attempted to clarify the development path they have been pursuing for SmartPaper (Sheridon 2001). While they have a roadmap for the technology, they are not able to disclose it. However, in answering some specific questions, some details were revealed, which we can relate here.

We were able to ascertain that they still have a working relationship with 3M and that a number of interesting developments have occurred in their labs. They have been able to improve resolution beyond 100 PPI by using smaller diameter balls. With 50 micron balls they have been able to achieve 200 PPI and with 30 micron balls they expect to get 300 PPI.

The refresh rate of Gyricon technology is also improving. Currently their displays are able to change the entire image in two seconds, with an individual ball rotation time of about 100 milliseconds. Recent research work has been able to get ball rotation time down to four milliseconds in some conditions. This suggests that it is feasible to get the display working fast enough to get the image to change more than seven times a second – adequate for scrolling text.

Interestingly, Gyricon Media stated that they would probably use the Power Paper flexible battery technology as it becomes available. However, they also stated that at present they see wireless capability mainly in retail signs and that they have no plans to sell SmartPaper, except as integrated into systems. This suggests they see some place for self-contained SmartPaper in the future, but seem focused on their retail sign business for now.

They do see a big market for high-resolution, low cost, electronic paper though. Especially for office use and use in electronic newspapers and the like. Currently, the material cost for a US Letter sized (22cm x 28cm) piece of SmartPaper is US$1 – what this means in terms of the price of this technology when commercialised is hard to say. However, it does mean that a component that was once a major cost is now almost negligible.

Gyricon Media estimates that bound volumes of SmartPaper are two to three years off, depending on the willingness of investors to move the technology in this direction. At present Gyricon Media cannot discuss plans for distribution of their products outside of the US. Xerox holds a number of patents around the Gyricon technology. One set of patents relates to colour Gyricon displays. A number of models for colour production have been proposed.

The first model involves Gyricon balls that act as 'colour valves' revealing or obscuring coloured dots on a rear layer. The second is an additive colour system that involves red, green and blue Gyricon balls embedded in one rubber sheet. These two methods are impractical, as the cost of manufacturing increases with the precise alignment required to activate the correct balls at the correct time.

A third proposed system has three layered Gyricon sheets, with each containing red, green and blue balls respectively. This system is easier to manufacture, but may suffer from some colour and image quality problems.

Some other patents pertain to devices that would imprint images on these displays. Figure 9 shows a SmartPaper™ display being written on with a 'stylus'. In this case, the stylus is a pencil with the lead carrying an electronic charge from an electrode connected to the other end. However, a self-contained stylus that performs the same job is trivial to make.

Figure 9: Xerox PARC

OTHER DISPLAY TECHNOLOGIES

A number of other display technologies are being developed that may also prove useful as alternatives to traditional LCD displays. These display technologies will be touched on briefly here.

oLED/LEP

One such interesting technology is Organic Light Emitting Diode (oLED). In its polymer-based incarnation it is also known as Light Emitting Polymer (LEP). oLED is an emissive display type – the display itself produces its own light, no backlight is required. This display type is full colour, high-resolution (greater that 200 PPI), flexible, has a wide viewing angle and has a fast response time, making it suitable for video. It exhibits low power consumption, at roughly half that of traditional LCD displays, and is cheap to produce.

There are two modes of manufacturing oLED (Jorgensen 2000), with the majority of patents held by Kodak (Polymer) and Cambridge Display Technologies (Molecular) respectively. Currently, these displays are in production in the micro display format, but the technology is expected to scale easily and large format displays are not far behind.

One major difference between this type of display and the electronic ink display described above is that it is not bistable, meaning it requires power at all times to display an image.

CHOLESTERIC LCD

This technology is also an interesting alternative to electronic ink. Cholesteric LCD is a bistable display type, with the associated low power consumption. Additionally, they are fully reflective, requiring no backlight, and have a wide viewing angle and good readability in full sunlight.

A company called Kent Displays Incorporated, in conjunction with Honeywell, are producing a colour ebook readers for military use.[14] Their current generation Cholesteric LCD displays have a resolution of 130 PPI.

[14] http://www.kentdisplays.com

THE SUPPORTING CAST – PRINT IS DEAD, LONG LIVE PRINT

If companies like E Ink and Gyricon Media are to realise their respective dreams of flexible RadioPaper™ and SmartPaper™, there are a number of additional technologies that will be necessary in the final design. The great irony in all of this is that many of the new technologies that could go towards making electronic paper work rely on high tech print technologies. Techniques such as silk-screening, lithographic printing, high-resolution stamping and high-resolution ink jet printing are used to deposit these special inks with unique properties onto a range of rigid and flexible substrates.

Also, many of these new technologies are polymer based, or organic in nature. Almost all do away with the high temperature techniques required for the fabrication of current generation devices. This allows these new materials to be applied to old and familiar surfaces. It may be that electronic ink is ultimately 'printed' onto a specially coated paper or cloth substrates – very strange hybrids indeed.

The following sections provide a brief look at the technologies that might help to make electronic paper a reality.

PRINTABLE TRANSISTORS

Printable transistors are one of the more exciting developments of recent years. This technology allows electronic circuitry to be printed onto flexible plastic cheaply, quickly and with relative ease. Traditionally, the production of microprocessors is a very time-consuming process requiring a number of expensive and exotic ingredients and processes. The end result is a rigid device attached to an equally rigid circuit board – not ideal for many applications, especially flexible electronic paper.

Figure 10 shows a flexible printed circuit produced at MIT.

Printable transistor technology can potentially replace TFT on glass for display driver applications and circuit boards that normally power all manner of portable and desktop devices. It can also provide wireless capability in printable form. With this technology, a piece of electronic paper becomes a lightweight, flexible, wireless computing device. A device that can network with other devices, dynamically update its content, enable communication and collaborative work and eventually, take the place of the computer entirely.

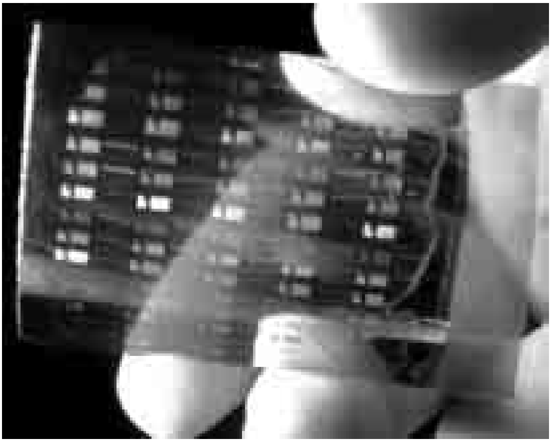

Figure10: Source – MIT NanoMedia

At the moment, printable transistors only run fast enough to act as the TFT layer for displays. As transistor mobility improves (i.e., the operating speed of the transistors), these printed transistors can be used in place of rigid circuit boards. The introduction of new materials and processes are necessary to drive increases in transistor mobility.

A number of companies are actively doing research and development with these printable transistors. Lucent developed the first printable transistor in 1997, using a silk screening process to print electronic circuits onto flexible plastic substrates. Other groups such as the NanoMedia group at MIT[15], Rolltronics[16] (a Hewlett Packard spin-off) and PlasticLogic[17] (a Cambridge University spin-off) have all developed printable transistors and are actively improving them.

These companies are also using processes such as high-resolution ink jet printing and rubber-stamping (Rodgers, Bao et al. 2001) to manufacture these circuits. In many cases the production process

[15] http://www.media.mit.edu/nanomedia/
[16] http://www.rolltronics.com
[17] http://www.plasticlogic.com

utilises traditional reel-to-reel printing techniques, allowing cheap high volume production (Levi 2001).

Recently, the NanoMedia group at MIT stated that they expect to be able to produce a simple printed microprocessor by late 2001 or early 2002 (Mihm 2000).

PRINTABLE BATTERIES

Another technology that brings RadioPaper™ and SmartPaper™ closer to reality is printable batteries. One example of this new technology is a product called Power Paper[18]. This allows a battery to be printed, pasted or laminated onto plastic or paper. The battery is 'open' and requires no casing, and is non-toxic and non-corrosive.

The resulting power source is 0.5 mm thick, flexible, environmentally friendly and inexpensive to produce. There are some caveats of course – this technology cannot yet be used to produce rechargeable batteries, this is expected by late 2002. Also, real world performance has not yet been demonstrated in consumer electronics applications, such as ebook readers or palm top devices.

A printable battery is composed of three separate printed layers, as illustrated in the Figure 11.

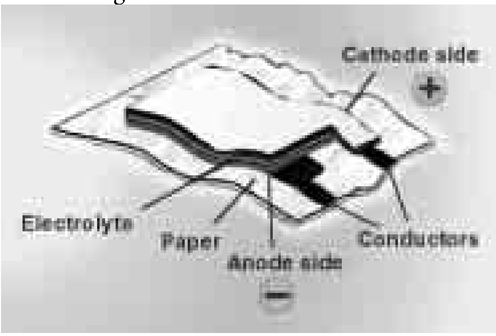

Figure 11: Power Paper

Based on the data on the Power Paper web site, a printable battery the size of an A4 page (about $600cm^2$ or $250in^2$) would have performance in the same category as an AA battery. A second layer (making the total thickness of the battery 1mm), connected in serial

[18] http://www.powerpaper.com

would provide three volts – enough to drive the new generation of ebook readers that E Ink and others expect to appear in 2003.

Both manufacturers of electronic ink have expressed interest in this technology. Gyricon Media (Eisenberg 2001) stated their interest in 'thin, flexible batteries with paper-like appearance and behaviour.' E Ink are a little more cautious (Wilcox 2001), citing the potential of this technology when used in appropriate applications, but underscoring the affordability of existing, standard battery technologies.

TECHNOLOGY TIMELINE

It is difficult to estimate exactly when this disparate set of new technologies will be ready for commercial use. The companies and research groups involved can only guess at when these new technologies will be ready for market. Some timeframes are based around the engineering effort needed to refine existing technologies, while others require the development of new techniques and materials. A number of companies contacted for this chapter were reluctant to supply any information, as it is too commercially sensitive.

Electronic ink display technologies seem to be quite advanced in all cases – the core display component is ready today. Rigid versions can be manufactured now, with TFT backplane technology being the main impediment to resolutions above 150 PPI. As colour solutions, such as those provided by Toppan for E Ink, are the same as those used for LCD displays, the problem of providing colour electronic ink is essentially solved. Again, the limiting factor for high-resolution colour is the TFT backplane technology.

Companies working on printable transistors are also making progress. Development here relies on the refinement of techniques for applying the special inks to flexible substrates. Once these matters of resolution (transistor density) are overcome they will be able to replace rigid TFT backplanes. Mass production via reel to reel printing techniques looks quite feasible in this case, making them quite cheap to manufacture.

However, with printable transistors, the issue of transistor mobility (operating speed) is proving to be a serious one. New techniques and materials will need to be developed to produce printable, flexible circuits that will replace the chips and rigid circuit boards that currently control computing devices. Many companies are working on this problem, and prototypes are looking promising. When these flexible circuits are finally produced, radio communications can easily be built in.

Printable batteries are well advanced and already working for some small-scale applications. Some improvements need to be made, especially with rechargeable versions, but the companies involved seem confident of achieving this by the end of 2002.

Issues of cost are crucial, and will determine whether these technologies are appropriate for use in handheld devices. While none of the companies are at the point where they can give detailed pricing, production techniques and materials involved will be relatively cheap when compared to the technologies that they might replace.

NEW TECHNOLOGY ENABLING NEW DEVICES

So if RadioPaper™ and wireless SmartPaper™ are coming, what are the implications? Some authors have somewhat melodramatically announced the death of the book (Jacobson, Comiskey et al. 1997). Still others have proclaimed that the book is with us for good, and that technological embellishments of the act of reading are simply going to be ignored by those who read. We are facing the inevitable standoff between bibliophiles and technologists, with their irreconcilable views about the future of books and the future of reading.

It does seem that the potential for electronic paper as a material alone is great. While designers are going to experiment with the forms that electronic paper can take and the designs that it can be integrated into, there is a need to reflect on how this is approached. Some authors have suggested that we need to take the time to look at how the book is woven into the fabric of our culture, in order to understand what form 'new reading' might take (Duguid 1996). Duguid talks in particular about our predilection for characterising traditional artefacts such as books as old and simple, when they are in fact very complex and our ways of interacting with them resonate deeply within us.

In order to begin understanding this from a design perspective, IBM and the German design studio Better Design, built a non-working prototype called the *eNewspaper (IDSA 1999)*. To understand what a device like this should look like, they performed a number of ethnographic studies and interviews to see how people actually used and related to newspapers. They found that the dimensions of the paper as well as the amount of information represented at the one time were important.

The physicality of the newspaper was important at a number of levels. People liked that a newspaper could be folded and carried around under their arm. Being able to leaf back and forward through the paper in order to get the 'big picture' view and then to use that spatial memory to return to articles of interest was also valued.

The way in which stories were arranged in relation to each other on the page also mattered. People enjoyed, even relied on the *serendipity* inherent in reading newspapers. An article they may not have known was of interest was often located near another they were reading.

As a result of this research, the *eNewspaper* prototype was created. It was made up of eight double-sided 21cm by 28cm sheets of electronic paper bound together at the spine with a slender piece of aluminium that contained networking hardware and storage facilities. Such a device would be able to receive news updates and dynamically present information in a familiar format.

When the Industrial Designers Society of America awarded the eNewspaper a gold award for design exploration in 1999 they said that:

> The truth is, we understand more about technology than people, but it's people who use this stuff. Effectively linking past, present and future, the Electronic Newspaper is smart, fully technological and yet has the feel of a familiar object.

Reading devices like the eNewspaper are *transitional objects* – reflecting and preserving long-practiced rituals and ways of interacting with texts. They are not exactly like newspapers, yet they are not exactly like the ebook readers of today. They are something in-between, offering us access to new ways of reading without discarding the old.

Some authors have recognised that a useful way of understanding the book is to look at the many manifestations it has, and to think about these manifestations as metaphors (Bellamy, Burrows et al. 2001). The metaphors explored in this work allow a text to be characterised variously as a page, book, artefact, container or service. These are equally about granularity of content, concrete and abstract conceptions of a text and the physical forms a text can take.

When considered in terms of form, ebook readers offer both a page and book metaphor for an electronic work. Text is commonly presented one page at a time, providing the facility to 'turn' pages to move forwards or backwards through the text. However, this really is just a way of viewing a stream of text through a page-sized window. The book metaphor is weaker still, offering little of the physicality of a book beyond size.

Electronic paper allows us to explore designs that employ richer page and book metaphors. Many of the activities we indulge in while reading books supplement and enrich our relationship with the text. We thumb through books to get an overview of material, rapidly navigating to focus on sections that may interest us. We use spatial and motor memory to locate and inter-relate material – skills that permit a very nonlinear reading of linear texts.

Current generation ebook readers do not support these types of physical interactions, allowing only shallow, linear interaction with the text. Future ebook reader designs, including bound volumes of electronic paper, have the potential to support the familiar physical interactions we have with books. This support for modes of reading does not just facilitate the functional – it also preserves the continuity of the *affective discourse* we have with the book as artefact.

Electronic paper will facilitate designs that allow traditional modes of reading text on electronic devices. It has to be acknowledged that many people are perfectly familiar with electronically mediated text. Experiences of reading have changed, and the book is currently just one of the many relationships we have with text. Rich Gold (Gold 2000) writes about the ubiquity of text, of how we are surrounded by it, even immersed in it. Mobile, hand held, laptop and desktop devices all have a cultural currency of their own – we don't just have *new reading*, we have *new readers.*

Designs for the next generation of reading device need to take our newer relationships with text into account as well. A malleable, hyperlinked, annotated, multiply-authored, navigable textual world cannot be ignored. A subtle transformation takes place when book is spelt with an 'e'. Gold writes about ebook readers moving books from the domain of the permanent to the domain of the *ephemeral.*

Books take their place in a larger information space and cannot help but take on the properties of the medium.

Designing for the activities that emerge around books in this context is crucial. It requires an understanding of how the reading device can reach deep into and across bodies of text – tightly integrating the physicality of the book and the abstract nature of the information space. An electronic book reader needs to be more than a simulacrum of a book. It needs to leverage the metaphors of book and page while acting as a dynamic and tangible physical interface.

CONCLUDING REMARKS

When talking about these new technologies, some authors are prone to making melodramatic proclamations about 'The Last Book' (Jacobson, Comiskey et al. 1997). It's true that these new technologies facilitate a range of book-like designs, but it remains to be seen what impact these new types of reading devices will have. More interesting, is the potential for a range completely novel designs that reflect to us the ways in which our relationships with text have changed.

There is also great potential for designs to extend beyond the physical aspects of the book and encompass and embody some of the more abstract ways in which we relate to texts and information generally. If the ways we navigate, visualise and manipulate information can be properly understood, these practices and modes of interaction can be supported or even augmented by the device. Reading devices with some degree of network connectivity also create opportunities for content creators to foster one-to-one interaction with, or even amongst readers. In this environment, content publishers can find new roles for themselves by providing services for both authors and readers.

While the compelling design of devices for reading is crucial, there are still important issues of Digital Rights Management (DRM) and distribution that are yet to be resolved. This chapter hasn't attempted to deal with those issues, but they are central to the development of a market for ebooks and ebook readers. This goes beyond ideas of protecting revenue while ensuring reliable and universal content delivery. Rights management must be instituted in a way that respects the rights of the publishers and authors while supporting the practices of communities of readers.

Moreover, books need to be understood as 'crucial agents in the cycle of production, distribution and consumption'(Duguid 1996). Should a change in reading practices occur, and a shift towards ebook readers and digital texts commence, the effects will be profound. The emergence of this significant new market around ebooks and ebook readers will have an impact on all aspects of the printing and publishing industries.

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