

## Displaying Digital Information on Paper-like Devices

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## **1. Executive Summary**

For almost three decades, digital paper (also referred to as electronic paper or e-paper) has been hypothesised as a way of combining digital information with the familiarity, quality and convenience of paper. Recently, technology has been developed which makes this a realisable goal. Of the products that are emerging, some enable digital information to be displayed on paper-like devices, while others use paper and ink as digital input devices. This report focuses on the former, and describes the efforts of two companies (Gyricon Media and E Ink Corporation [1,2]), who have been working to create their own versions of products which, until now, have been the stuff of science fiction.

So far, the companies have been using e-paper in manufacturing display signs for shops, but mobile devices with e-paper displays should begin appearing this year (mid-2003). Both companies believe that the same technology will soon be used to produce electronic books and newspapers.

Although there are doubts about how consumers will respond to such products, e-paper is low-cost and offers high quality, lightweight, flexible displays which consume relatively little power. Moreover, the contents of e-paper can be changed wirelessly and remotely, and the same set of physical pages can be used to read numerous different texts. This suggests a number of applications in higher and further education, including a second wave of electronic books and journals, new and innovative teaching methods, as well as digital notice boards, exam papers and timetables.

This Technology and Standards Watch report describes the technology and its emerging and future applications. Risks and benefits of e-paper are discussed, and its potential relevance to higher and further education is examined.

## **2. Keywords**

Electronic paper, electronic ink, digital paper, digital ink.

### 3. The Technology

The new millennium saw the first prototype digital paper and ink emerging from Gyricon Media and E Ink Corporation. Products from both companies consist of a layer of millions of tiny, black-and-white plastic spheres which, when a small electrical charge is applied, form a pattern of text and images. Once the content of the display has been formed, no further current is required until the page is updated. The overall effect is that of thin, flexible sheets that look and feel like ink on paper. Applications have included advertising signs for shops and displays for portable devices, but electronic books and newspapers incorporating the technology could soon be appearing on the market.

It is important to note that the terms "digital paper" and "digital ink" are also used to refer to another emerging technology which, rather than concentrating on the potential of e-paper as a medium for displaying information (a digital **output** device), attempts to use paper and ink as a digital **input** device (see, for example, products from Anoto [3]). Such products use completely different technologies, have different applications and, as yet, have not converged (for example, it is not possible to "write" on the e-paper under consideration here – it can only be used for display purposes). Therefore, they are outside the scope of this report.

"Electronic paper", "digital paper", "electronic ink", "digital ink", "e-paper" and "e-ink" can all be used to refer to the technology under consideration here. To avoid confusion, the term "e-paper" will be used throughout the report.

### 4. The Technology and Standards Watch Issue

E-paper has the potential to combine the advantages of the electronic medium (instant and remote delivery of learning resources) with those of the printed page (lightness, flexibility, legibility, typographical quality, and familiarity to the user). It is being considered here in order to identify key issues and explore its potential benefits to learning and teaching in further and higher education. This advances the JISC Strategy 2001-2005 [4], which outlines the aim "to help understand the benefits and problems of deploying innovative IT applications within further and higher education", and to ensure "that the sectors are fully aware of the opportunities of the Internet and emerging technologies and that staff and students are adequately prepared to exploit them".

### 5. Products

Nick Sheridan, a physicist at Xerox's Palo Alto Research Centre (PARC) has been credited as the first person to consider e-paper seriously [5]. In 1975, when he joined PARC, he observed how awkward and difficult it is to read from bulky, low contrast monitors, in comparison with reading from paper: "I thought, I guess, that instead of replacing paper with the monitor, it might be smarter to replace the monitor with paper" [6]. His solution to the problem was called "Gyricon": tiny coloured beads, sandwiched between very thin plastic sheets, which "gyrate" in response to an electrical current to present text and images.

He hoped the product would be ready for 1985, but encountered two major problems. First of all, he had difficulty in manufacturing the beads so that they were entirely uniform. Secondly, the circuit boards available at that time (such as those used in laptops) were stiff, inflexible and expensive, and therefore could not be used to produce paper-like products. The first prototype e-paper was far from Sheridan's original vision, and he subsequently postponed his research in this area.

It wasn't until the mid-1990s that progress resumed once more in the e-paper field, when Joseph Jacobson at MIT's Media Lab set about duplicating Sheridan's work. He found an alternative solution to the problem of manufacturing identical spheres and, in 1997, jointly founded E Ink Corporation, a company devoted to developing this technology. At the same time, Sheridan returned to his research into e-paper and was also able to refine the process of manufacturing perfect spheres.

The discovery, in the late 1990s, that plastic could conduct electricity, provided a solution to the second obstacle to the development of e-paper. Circuits could now be sprayed, printed or stamped onto rolls of plastic that were lighter, cheaper and more flexible than silicon or copper. Sheridan and E Ink realised the potential of this discovery for e-paper and, more than 20 years after the idea was conceived, were able to start creating workable models.

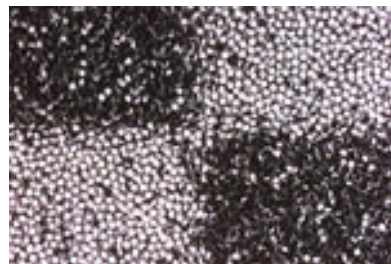
### 5.1 SmartPaper™

In 2000, as a result of Sheridan's work, Gyricon Media was founded as a spin-off from Xerox, to focus on the development of e-paper, or "SmartPaper™". A Research and Development team continue to work at PARC, while the corporate headquarters is in Ann Arbor, Michigan.

SmartPaper™ comprises millions of tiny beads trapped between two thin, flexible plastic sheets. The beads are 100 microns in diameter, smaller than grains of sand, and their hemispheres have different colours (e.g. black and white) and electrical charges (positive or negative).



**Figure 1.** SmartPaper™ beads: smaller than grains of sand<sup>1</sup>

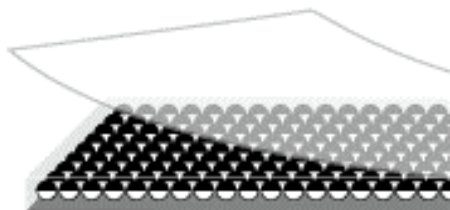


**Figure 2.** Dichromatic beads

Each bead occupies its own pocket between the plastic sheets, surrounded by oil so it can move freely. When an electrical charge (exceeding a set threshold) is applied to the surface, the beads flip to present just one hemisphere to the user.

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<sup>1</sup> All pictures of SmartPaper™ are used with permission from Gyricon Media



**Figure 3.** Plastic sheets embedded with beads



**Figure 4.** Roll of SmartPaper™

The voltage can be used to display text and images on the SmartPaper™ which are visible until another electrical charge is applied. The electrical signals can be applied to the “paper” through fixed surface electrodes or a moving stylus. No current is required to maintain the image. Images can be displayed with resolutions over 100 dpi, and Gyricon expect to improve this over time to 300 dpi.

For its first commercial application, SmartPaper™ is being combined with MaestroWare™ to produce MaestroSigns™, dubbed as “the next generation of retail communication” [7]. SmartPaper™ provides the hardware and MaestroWare™, another product from Gyricon Media, provides the software for these point-of-purchase displays for retail settings, which enable retailers to change the prices of products across all outlets at once. This saves stores the substantial costs of regularly updating paper signs. “The system could be controlled from corporate headquarters through a central computer via the Internet so stores could put on dynamic sales”, explained Bob Sprague, Gyricon’s interim CEO [8]. It made its debut in the children’s department of Macy’s department store in Bridgewater, New Jersey, in June 2001, with a dozen 11-by-14 inch displays.



**Figure 5.** SmartSign™ at Macy’s Department Store, Bridgewater

Gyricon believe that such store signs will provide a lucrative market for SmartPaper™: in April 2002 they launched a pilot program with Dow Jones & Co. to provide signs for news stands advertising *The Wall Street Journal* and other periodicals, highlighting the content of the paper each day, and they aim to manufacture up to a million signs in 2003. Only later will they look to using this technology for portable and wireless devices.

## 5.2 E Ink

E Ink Corporation, headquartered in Cambridge, Massachusetts, was founded in 1997 to create “the next medium for visual communications” [9]. The company develops “electronic ink”, a proprietary technology that “helps unleash the full power of our connected world by uniquely combining a paper-like reading experience with the ability to access information anytime, anywhere” [10].

E Ink’s technology is similar to that of Gyricon’s. Like SmartPaper™, electronic ink comprises millions of tiny microcapsules (beads), about the diameter of a human hair, and an electrical charge is applied to form text and images. However, rather than each hemisphere of the bead having a different colour and the bead turning to present one of those colours when a current is applied, E Ink’s beads contain a mixture of positively charged white particles and negatively charged black particles suspended in fluid. Upon the application of a negative electrical field, the white particles move to the surface of the bead and, when a positive electric field is applied, black particles rise to the surface.

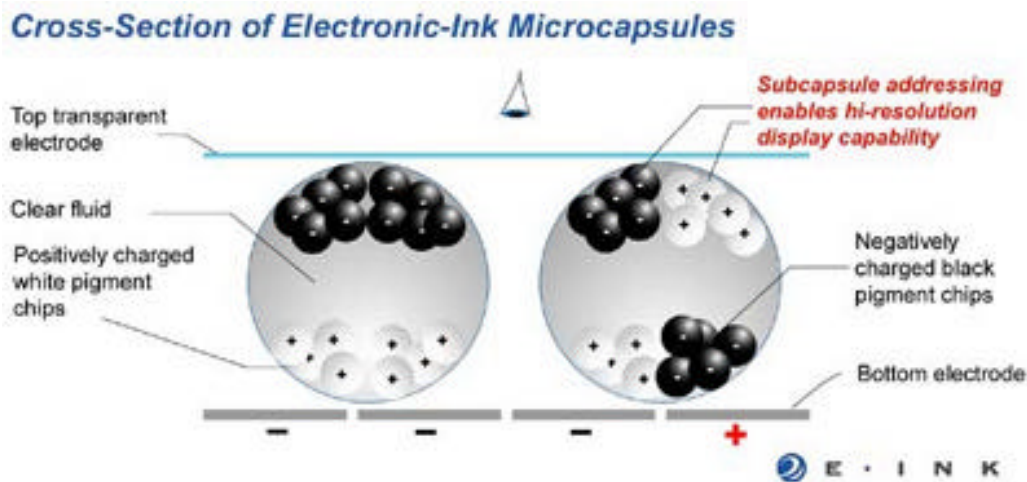


Figure 6. Cross-section of electronic ink<sup>2</sup>

To form a display, the ink is printed onto a plastic sheet which, in turn, is laminated to a layer of circuitry. The circuitry forms a pattern of pixels that can then be controlled by a display driver. The liquid in which the beads are suspended allows them to be printed onto almost any surface (plastic, glass, paper, and so on) using existing screen printing processes, ultimately “bringing information out of the confines of traditional devices and into the world around us” [11]. The display image is maintained with little or no additional power.

Like Gyricon Media, E Ink’s first commercial application of its technology was display signs for retail stores. Their product, called Immedia™, was first used to provide shoppers with continuously updated information about sales, special offers, and highlighted brands, in shops in Massachusetts, Dallas and Chicago during Summer 1999. Although demand for advertised products did not increase in this early implementation, the technology worked well, and E Ink continue to work on the displays. More recently, they have been developing Ink-In-Motion™, which claims to improve the promotional

<sup>2</sup> All diagrams and pictures of E Ink technology are used with permission from E Ink Corporation

effectiveness of display signs by combining the appeal of ink-on-paper with flashing text and images.

However, while Gyricon Media's main focus is on in-store displays, E Ink is now turning its attention to displays for smaller applications. The company is currently collaborating with Lucent Technology who have licensed Bell Labs' proprietary flexible transistor technology that can be printed on thin sheets of plastic. Lucent made a multi-million dollar investment in E Ink, and aim to produce ultra-thin, lightweight displays for mobile phones, PDAs and electronic books.

E Ink have formed an agreement with Philips Components to develop electronic ink sheets which Philips will integrate with their own display technology. The eventual aim of this partnership is to launch a joint Philips/E Ink display module product for new mobile communication devices in mid-2003.

In June 2002 the company demonstrated the world's thinnest active-matrix display: steel foil coated in electronic ink technology, less than half the thickness of a credit card. Shortly after, they demonstrated a colour display (see Figure 7), using a custom colour filter array produced by Toppan, another partner in E Ink.



Figure 7. Active-matrix colour display

## 6. Developments

### 6.1 Potential future applications

Looking further into the future, e-paper has the potential to be used in much more imaginative ways than for store signs or mobile device displays. Perhaps the most obvious applications involve exploiting the paper-like quality of the technology by replacing traditional paper-based products such as books, newspapers and magazines. This is the ultimate goal of E Ink Corporation, to produce RadioPaper™, "a display with the readability of ink on paper but with the added benefit of digital technology to download newspaper headlines or a best-selling novel at the user's command" [12]. An investor in E Ink is publisher Gannett, which owns 110 daily newspapers, including *USA Today*, and they hope to be producing such displays in two to three years.

Electronic books could take on a whole new identity when combined with e-paper technology. Currently, electronic books can be read on PCs, PDAs or specially designed handheld devices, sometimes using special software, but always the reader has to negotiate an environment that is less intuitive and read from screens with lower resolution than paper. By "binding" together many sheets in one volume, e-paper has the potential to improve electronic book technology by bringing back much-loved features of paper books which have been lost due to the limitations of traditional display technology. With electronic books made from e-paper, readers would be able to:

- pick up their electronic book and start reading straight away, without having to turn on a device and wait for the book to appear;
- turn pages without having to use buttons or dials;
- quickly “flick” through pages when searching for information, just like they do with paper books; and
- navigate an electronic book by remembering the physical arrangement of pages and passages of text.

Moreover, books made from e-paper would be more durable than many current PDAs or dedicated reading devices, with displays made of flexible plastic rather than glass.

However, although e-paper requires relatively little power and does not have the same requirements for long-lasting batteries as other devices, some kind of power supply will still be necessary. Therefore, despite the fact that e-paper technology is lightweight, its dependency on a battery may bring the weight of its products in line with devices employing more traditional displays. Indeed, a prototype dedicated reading device demonstrated by E Ink at the NIST eBook 2001 conference in Washington weighed 9oz which, although considerably lighter than RCA’s REBs [13], is actually heavier than some competing products, such as the hiebook (8.8 oz) [14], eBookMan (7oz) [15] and Sony CLIE (7oz) [16]. Of course, it may well weigh less when brought to market and, to put the issue in context, 9oz is lighter than the average paperback and so potential customers may not be deterred.

Although electronic books which retain many of the features of paper are a real possibility, neither E Ink nor Gyricon Media are developing technology which enables their e-paper to be “written” on and used for digital input and, until it is possible to mark the e-paper with annotations which are displayed each time the relevant book is in use, the experience of reading an electronic book will not truly be like that of reading a paper book. It is likely that the companies will integrate e-paper with other technologies to enable functionality such as annotating and highlighting, but that some other input mechanism will be used, such as a keyboard or stylus and writing area. The vision of a product which can be used just like paper may still be a long way from realisation.

Other suggested applications of e-paper include maps, wallpaper and price tags [17]. Kahney notes that economies of scale may make e-paper displays ubiquitous, allowing them to be built into clothes and footwear, food and drink containers, coffee cups, and new electronic gadgets [18].

## **6.2 Likely relevance to HE and FE**

In terms of its relevance in a higher or further education setting, e-paper could potentially have an impact on any situation in which paper is currently used. Perhaps the greatest change will be in the delivery of books and journals. As discussed above, a student could possess a single electronic book made from e-paper and read all of his or her material for a course or semester on the same set of pages.

Delivery models for electronic journals may change: rather than reading articles online or printing them out, students and lecturers may choose to download them to e-paper instead. Alternatively, subscribers to a particular journal may possess one sheaf of e-paper pages devoted to that journal on which it is possible to read the contents of any issue. Whenever a new issue is published, the table of contents would be updated automatically.

Moreover, the delivery of lecture notes and even lectures themselves may change with the introduction of e-paper. Just as advertising displays can be updated across all stores at once, it will be possible for lecturers to control the release of written information to students, and to reach all students simultaneously. Thus, e-paper could be used in a classroom or distance learning environment, in which notes are distributed to students at the appropriate moments during a lecture; this could be helpful for teaching that involves step-by-step instructions or explanations, for example, experiments or formulae.

Overall, the flexibility of e-paper, in terms of the number and variety of situations in which it can be used, suggests it will be adaptable to a further education environment, in which the ability of technology to adapt to the requirements of a heterogeneous population of staff and part-time, distance or mature learners is key. Together with its paper-like qualities, this technology could enable students with poor IT skills or a dislike of technology to benefit from digital learning and teaching resources, leading to greater equality of access throughout the education system. Further, lecturers may feel more confident about producing digital content for this new but more familiar medium.

E-paper could also provide some administrative functions in an educational setting. Notice boards incorporating the technology, for example, could inform students of upcoming events and campus news, while e-paper timetables could ensure that all students are kept up-to-date with changes to lecture times and rooms. Exam papers made from e-paper would enable last-minute corrections to be made to all papers at once and, by withholding the distribution of content until shortly before the start of an exam, worries about secure storage of the papers would be diminished.

On a practical level, if e-paper proves popular, the incorporation of wireless networks throughout universities and colleges will become more urgent. It is possible that demand for printing facilities will fall, as e-paper should provide a more comfortable reading environment than that provided by current display technology, offering an alternative to printing out documents to read on paper.

## 7. Assessment

When used for display purposes, e-paper, as developed by Gyricon Media and E Ink, potentially offers many benefits, in terms of combining the advantages of traditional paper with those of modern technology. However, its success in the marketplace has yet to be tested, and there are several factors which may impede its advancement. Outlined below are the potential benefits of e-paper, and the risks to its development.

### 7.1 Potential benefits

E-paper offers the following advantages:

- **High quality displays**  
The quality of e-paper is better than that of traditional LCDs; its resolution is higher and its contrast is close to that of paper, making it much more readable. The displays are clearly visible in direct sunlight and legible from a much wider angle. Moreover, e-paper can be read more easily in poor lighting conditions and, therefore, does not require a backlight.
- **Low costs**  
E-paper is made from inexpensive materials, and the manufacturing process is cheaper than that for LCDs. If produced in large quantities, the costs will become much lower, so that several hundred sheets wired together into a book could cost less than a laptop screen [19]. In addition, each sheet can be erased and filled

repeatedly with text more than a million times, so that a single book of e-paper would meet the most ferocious reader's needs over a lifetime.

- **Low power consumption**  
Unlike LCD displays, text is effectively "printed" on e-paper and will remain there, with no need for a power supply, until the next time the pages are changed or updated. Therefore, e-paper requires relatively little power (E Ink claims that less than 1% of the power used by a standard notebook computer screen is required by its e-paper).
- **Lightweight products**  
Not only is e-paper efficient to use, but also it is independent of a heavy, bulky power supply: once the text is on the paper, it can operate with no further current. Furthermore, power to support backlighting is not required. Combined with the fact that e-paper technology itself is thin and light, this makes for sleeker, lighter products
- **Flexibility**  
The developers aim eventually to produce e-paper that is truly paper-like in that it can be rolled up or folded. This would indicate a level of flexibility, robustness and mobility that surpasses that of other digital displays.
- **Wireless updating**  
The text and pictures displayed on e-paper can be changed wirelessly. This makes possible rapid and seamless dissemination of news and other information which changes frequently.

## 7.2 Risks

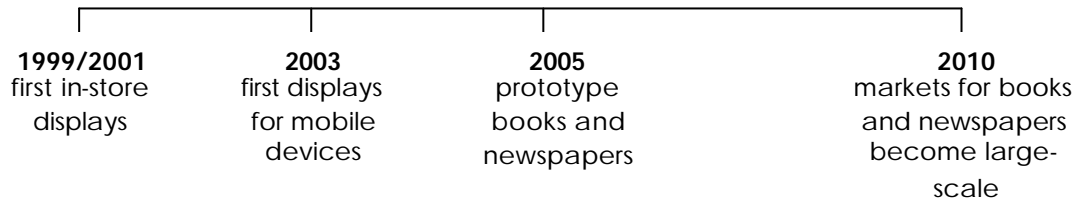
However, there are several potential problems which must be overcome in order to ensure the future success of e-paper:

- **Lack of up-take by manufacturers**  
Although Philips Components have an agreement with E Ink, other manufacturers of PDAs and mobile devices may not be keen to invest until products incorporating the technology have been tested in the marketplace. Nokia and IBM, for example, are still very much focused on improving LCD technology [20].
- **Life-span**  
E-paper displays currently last between 10,000 and 30,000 hours, compared with 100,000 for a PC monitor [21]. The lifespan of e-paper has to improve so that it is competitive with other display technologies.
- **Batteries**  
As noted in section 6.1 above, although e-paper is lightweight and consumes little power, some form of power supply will be required, and this may prove a barrier to developing truly paper-like products.
- **Consumer response**  
It seems likely that consumers will be attracted by the notion of e-paper, however it is uncertain whether their response will be positive in the long-term. Target markets should be defined and researched, in order to meet requirements and expectations. For e-paper to realise its full potential, a "killer application" should be developed which shows off all of its benefits and attracts a substantial market. It is unclear who this market will be: people who love paper but don't like technology, or gadget lovers?

## 7.3 Timescales for development

As shown in Figure 8, Gyricon Media and E Ink have been focusing on in-store displays since 1999-2001. Both companies continue to develop these products, but E Ink are also working on displays for mobile devices, and hope to have a product available for mid-2003. It has been predicted that the products discussed in section 6.1 above, such as

electronic newspapers and books made from e-paper, will be a commercial reality by 2005, with markets becoming large-scale by 2010 [22, 23].



**Figure 8.** Timescales for development

#### 7.4 Conclusion

When applied in a learning environment, e-paper has the potential to overcome two current obstacles to the use of electronic educational material, identified by the EBONI Project [24], namely, that students and teachers want to read from screens that:

- are both portable and large enough to read comfortably; and
- are of a higher quality (in terms of resolution, contrast and glare) than is possible with current display technology. Indeed, it has been calculated that people read 25% slower from screens than from paper [25].

Moreover, the flexibility of e-paper makes it robust, and it consumes less power than current display technology.

As discussed in section 5 above, the technology to make the companies' goals realisable is already available in its initial form. Whether e-paper will become a commercial reality in the timeframes proposed by Gyricon Media and E Ink will depend on the developers' ability to scale down the technology to the sizes needed to make useful e-paper [26]. The rapid rate at which the technology is developing suggests that this is feasible.

However, that markets for books and newspapers made from e-paper will be large-scale by 2010 is less certain. When making such predictions it should be borne in mind that, historically, attempts to replace paper have failed [27]. This is partly because there's not much wrong with traditional paper. It is totally intuitive to use, its design has evolved over thousands of years, it's cheap, and it can be written on using a number of materials. Not only that, but many people also enjoy the sensory experiences associated with paper – its feel, its smell, and the look of bookcases full of paperbacks and hardbacks.

People are creatures of habit and, for many, there would have to be some very compelling reasons to switch to e-paper. Products combining the familiarity and usability of paper with the functionality of the digital medium may well provide those reasons, and have the potential to appeal to diverse markets. It is this issue, of whether e-paper meets the futuristic expectations implied by its name, that will determine its ultimate popularity and success.

## 8. Glossary

Immedia™	Wireless in-store display with the capability to change its content instantly. From E Ink Corporation.
Ink-in-Motion™	Dynamic wireless in-store display which enables continually flashing images. From E Ink Corporation.
LCD	Liquid Crystal Display.
MaestroSigns™	Retail signs incorporating SmartPaper™ technology.
MaestroWare™	Client-server software for designing and wirelessly transmitting screen displays. From Gyricon Media.
PDA	Personal Digital Assistant.
RadioPaper™	E Ink's name for a future product: a dynamic, high-resolution electronic display which can be used to create an electronic book or newspaper.
SmartPaper™	Electronic paper product from Gyricon Media.

## 9. References

- [1] Gyricon Media, <http://www.gyriconmedia.com/>
- [2] E Ink Corporation, <http://www.eink.com/>
- [3] Anoto, <http://www.anoto.com/>
- [4] JISC Five Year Strategy 2001-2005, [http://www.jisc.ac.uk/pub01/strat\\_01\\_05/exec.html](http://www.jisc.ac.uk/pub01/strat_01_05/exec.html)
- [5] Charles C. Mann. Electronic paper turns the page. *Technology Review*, March 2001, <http://www.technologyreview.com/articles/mann0301.asp>
- [6] *ibid.*
- [7] Gyricon Media. MaestroSign™, <http://www.gyriconmedia.com/maestrosign/index.asp>
- [8] Jim Battey. Electronic paper gets its bearing. *InfoWorld*, 13 April 2001, <http://www.infoworld.com/articles/hn/xml/01/04/16/010416hnetrend.xml>
- [9] E Ink Corporation. Press release: E Ink CEO to keynote digital publishing conference, <http://www.eink.com/news/releases/pr31.html>
- [10] E Ink Corporation. About E Ink, <http://www.eink.com/company/index.html>
- [11] E Ink Corporation. Technology, <http://www.eink.com/technology/>
- [12] E Ink Corporation. Future products, <http://www.eink.com/company/future.html>
- [13] RCA's REBs, <http://www.rca.com/product/viewproductcategory/0.2590.C1100005.00.htm?>
- [14] Korea ebook Inc. hiebook, <http://english.hiebook.com/>
- [15] Franklin Electronic Publishers. eBookMan, <http://www.franklin.com/ebookman/>
- [16] Sony. CLIE, <http://sonyelectronics.sonystyle.com/micros/clie/>
- [17] Battey, *op. cit.*
- [18] Leander Kahney. E-paper closer to delivery. *Wired*, 12 October 1999, <http://www.wired.com/news/print/0.1294.31877.00.html>
- [19] Mann, *op. cit.*
- [20] Olga Kharif. Tomorrow's paper-thin screen gems. *Business Week Online*, 18 June 2002, [http://www.businessweek.com/technology/content/jun2002/tc20020617\\_5587.htm](http://www.businessweek.com/technology/content/jun2002/tc20020617_5587.htm)
- [21] Kharif, *ibid.*

[22] Steve Ditlea. The electronic paper chase. *Scientific American*, November 2001,

<http://www.sciam.com/article.cfm?articleID=0004C2D2-B938-1CD6-B4A8809FC588FEEDF&pageNumber=1&catID=2>

[23] Naoki Tanaka. Market growth hoped for organic EL, e-paper displays. *AsiaBizTech*,

September 2001, [http://www.asiabiztech.com/nea/200109/peri\\_139989.html](http://www.asiabiztech.com/nea/200109/peri_139989.html)

[24] Electronic Books ON -screen Interface (EBONI) Project,

<http://ebooks.strath.ac.uk/eboni/>

[25] Jakob Nielsen. Alertbox, 15 March 1997, <http://www.useit.com/alertbox/9703.html>

[26] Ivan Noble. E-paper moves a step nearer. *BBC News Online*, 23 April 2001,

<http://news.bbc.co.uk/1/hi/sci/tech/1292852.stm>

[27] Eric Schonfield. Are we ready for digital paper? *ZDNet*, 11 March 2002,

<http://zdnet.com.com/2100-1107-856627.html>