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## E Ink and Digital Paper

Norman Desmarais

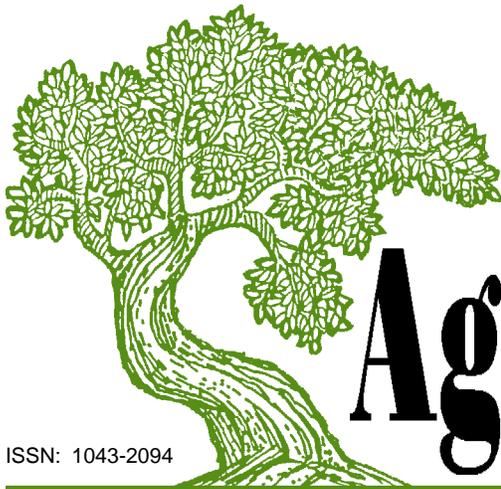
*Providence College*, normd@providence.edu

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# Against the Grain

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## Innovations Affecting Us — E Ink and Digital Paper

by **Norman Desmarais** (Acquisitions Librarian, Phillips Memorial Library, Providence College, Providence, RI 02918; Phone: 401-865-2241; Fax: 401-865-2823)  
<normd@postoffice.providence.edu>

The main objections people have to reading books and documents in electronic format have to do with comfort. The reading devices, whether computer monitors or dedicated devices, cause eye strain, are hard to read at various angles and under various lighting conditions, and lack paper's portability and ease of use. Two companies are working to change that. **E Ink** and **Gyricon Media** are working on digital paper technologies, hoping to make digital displays as easy and convenient to use as ink on paper.

**Xerox Palo Alto Research Center (PARC)** began work on electronic-ink or electronic reusable paper, depending on how you want to look at it, in 1975. It is this technology that underlies the efforts of both **E Ink** and **Gyricon Media**. It uses microscopic beads that change color under an electrical charge. **E Ink's** Electronic Ink uses millions of tiny “switchable” transparent polymer microcapsules — about 100,000 per square inch of inked area. These microcapsules, which are analogous to the microencapsulated coatings on business forms, contain microscopic white pigment spheres immersed in a dark dye. A positive charge attracts the white chips to the top of the sphere and a negative charge repels them to the bottom, where they are obscured by the dye, causing text to appear. Reversing the process produces white letters on a dark background. Once switched, they retain their setting with little or no additional power. These microcapsules can be sprayed or pressed onto a variety of materials, such as plastic, glass, and paper.

**Gyricon Media's SmartPaper** uses tiny solid beads suspended in pockets of oil fixed in a silicone rubber sheet. These beads, which are half black and half white, turn freely depending on their charge. The black side has a static charge, while the white side is neutral. These beads must be

embedded in their own silicone rubber sheet to function; but the silicone sheet could conceivably be applied to other surfaces.

### E-Ink

**Joseph Jacobson**, who was doing postdoctoral research in physics at **Stanford University** in 1995, turned to electrophoresis to develop his vision of an eBook that could be reconfigured electronically to display the text of any of hundreds of “books” stored in silicon memory in the book's spine. Electrophoresis uses an electric field to charge particles. **Jacobson** founded **E Ink Corp.** in 1997 which derives its name from the electrophoretic ink process.

**E Ink's** prototype displays use **E Ink's** electronic ink and Lucent's active-matrix drive circuits printed on thin, plastic film. The electronic ink has qualities similar to paper: extraordinary brightness and contrast under a wide range of lighting conditions and easy viewing from all angles. The plastic transistors have properties similar to those of silicon chip semiconductors; but they are flexible and can be printed.

The first flexible electronic-ink display was a five-by-five-inch screen with the consistency and thickness of a computer mouse pad. A partnership with **IBM Research** resulted in a flexible 12.1 inch diagonal (25 square inch area) display with the resolution of a typical laptop computer monitor (83 dpi). It is roughly one quarter the thickness and weight of a standard liquid crystal display (LCD) panel and can display both text and simple graphic images while being flexed. LCD is the most popular display technology, found in everything from digital watches and calculators to mobile phones, flat-screen televisions, and even microwave ovens.

The company's first product, called “**Immedia**,” was an indoor display board for **J.C.**

**Penney**. The large signs (44 inches by 15 inches) needed a very low resolution of only 2-3 dpi (dots per inch) and were a little more than 5mm thick. Computer monitors, by comparison, display at 70 dpi and most laser printers print at 600 dpi.) The company claims its electronic paper has a resolution of 200 dpi which can increase to 300 dpi with the use of 30-micron beads.

**E Ink** allows an image to remain on the screen even after the power source is shut off. It enjoys low power consumption, drawing less than 1/1000th the power required by a standard notebook computer screen when used for normal reading. This results in longer battery life. Portable devices incorporating **E Ink** displays could have far smaller batteries, making them even less expensive and more portable.

The company claims that electronic ink displays are lighter, five times brighter, 30-percent thinner, and have a higher resolution than traditional LCD displays. They have a high contrast in daylight, improved by switching from blue to deep black ink with other two-color options available and full color possible. The bright paper-white background eliminates the need for a backlight in most applications. Because electronic ink displays read like ink on paper, they should cause less eyestrain than most other displays that typically emit or transmit light. They also allow a wide viewing angle.

While the **J.C. Penney** test proved the concept that electronic ink could be used on any surface where a display is needed, the company has withdrawn from the store market and turned its attention to the more lucrative handheld display market. It plans to develop high-resolution displays for portable devices, such as cellular phones, personal digital assistants (PDAs), and eBook reader devices with screens as easy to read as ink on paper.

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**Philips Components**, a division of **Royal Philips Electronics** in the Netherlands, teamed with **E Ink** to manufacture and sell display modules using **E Ink** technology for PDAs and electronic books, hoping to gain a competitive advantage in battery life for its handheld devices because electronic paper consumes as little as one hundredth the power of a comparable LCD screen.

**E Ink's** ultimate goal is to develop what it calls "radio paper" — flexible digital paper with high-resolution color and the capability of being reconfigured instantly via a computer, a wireless data network, or the Internet. It could be used both in computers and in ultra-thin, lightweight displays for portable information appliances. Radio paper could result in reprogrammable books, newspapers, billboards and other documents that need refreshing with the latest information, garments, and even wall-paper.

**E Ink** envisions its eBook to have "real pages that can be leafed through, thumbed over and read on the beach." The company also anticipates pages that will let a reader switch from the daily newspaper to a best-selling novel at the press of a button, achieving a cross between broadcast and print. Potential applications could range from reusable technical manuals to displays for handheld devices.

**E Ink** faces some stiff challenges. Competition will come from **Gyricon Media**, organic light-emitting diodes, and carbon-based compounds that are pliable and relatively energy-efficient and capable of producing light-emitting semiconductors.

### **Gyricon**

**Nicholas K. Sheridan** invented **Gyricon** which is Greek for "rotating image" when he was a senior research fellow at **Xerox Corp.'s Palo Alto Research Center** in California. He eventually formed **Gyricon Media** which became an independent venture in December, 2000. **Gyricon** or **Electric Paper** uses thousands of tiny plastic balls that act as pixels embedded in a silicone rubber sheet. Each sheet, including its plastic sheathing, is as thin as poster board and about as floppy. It can store digital images for months without power and can display those images powered only by two AA batteries which can last up to two years. The sheets can also refresh and update images much the way a monitor does.

The company's prototype product, called **SmartPaper** was initially intended for use as point-of-purchase displays in retail stores. It looks like an 11-by-14-inch panel on an aluminum stand. It has an array of electrodes along the edge that can update instantaneously the information displayed on the paper's flexible, rubbery surface. This allows retailers to control product pricing from a central location, changing prices electronically on the store floor and at the cash register at the same time.

**SmartPaper** is 12 to 15 mils thick while paper is only about four mils thick; so paper has an advantage for look and feel. However,

**Gyricon Media** envisions a paper substitute capable of printing itself that could serve to display up-to-the-minute news or feature stories. The computing power could reside either in a binder holding the sheets or in a wand or stylus device. Both devices are expected to receive data wirelessly and imprint text and images on the sheets, refreshing them as often as needed. The devices could eventually read the pages as well as write to them, making them two-way. **Electric Paper** could be almost as cheap and reader-friendly as paper and as spontaneous and rich as the Internet because the remote server and the wand or binder would concentrate all the power, weight, and cost.

Analysts expect **Xerox** to pursue the "magic wand" approach. The wand or stylus would contain an array of electric contacts and memory devices. The words and images would be updated by drawing the wand over the "paper," or pulling the "paper" through a slot in the wand. This approach has the advantage that it could become a portable printer, copier, fax, and scanner. But this makes **Electric Paper** little more than a photocopier with re-usable paper — an idea that had been tried before and had failed.

Sceptics are quick to point out that **Xerox** has a history of failing to commercialize great ideas developed inside **PARC**. The graphical user-interface popularized by **Apple's Macintosh** and **Microsoft's Windows**, drop-down menus, the computer mouse, and even **Ethernet** originated in **Xerox PARC's** labs to be ignored and developed and commercialized by other companies. **Gyricon** could end up following suit.

**Gyricon** faces several challenges, such as increasing resolution, improving the whiteness from the current LCD gray, developing full color, making the sheets fully erasable, and shielding them from electrical interference. **Sheridan** already has a patent to use transparent **Gyricon** beads with thin disks of color filter material. These cyan, magenta, and yellow beads would each be addressable by different voltage levels to produce color.

### **Cholesteric Liquid Crystal Display**

While digital ink and electronic paper hold much promise, they do not seem to pose a viable threat to LCDs. **Kent Displays** and **Hewlett-Packard** are both working on LCDs that are as bi-stable and reflective as electronic paper. There is also competition from organic light-emitting diodes.

**Kent Displays Inc.** is focusing on cholesteric liquid crystal displays that are beginning to emerge from laboratories. **Dr. J. William Doane** created a technology called "cholesteric" liquid crystal displays (Ch-LCD) which uses liquid-crystal material made from cholesterol. The Ch-LCD is chemically altered so that it is bi-stable making it reflective or non-reflective, depending on the direction of the electric current applied to its surface.

Unlike standard LCDs, Ch-LCDs can be read from large angles and retain the full image when power is removed from the display. They can also be used in a variety of lighting conditions, including direct sunlight, because the display reflects light instead of emitting it. Not only do Ch-LCDs reflect light, they can reflect it near

infrared, making it usable at night with night vision goggles which interests the U.S. military's eBook effort.

The cholesteric-LCD requires the electric current to reach a certain threshold before it works. That results in little "cross-talk" between neighboring elements in the display, allowing for much simpler and cheaper wiring to switch the pixels on and off. Even though the cholesteric display is only 1.5mm thick, it still needs a rigid plastic surface. That means it cannot be folded or even furled. Although Ch-LCD has great potential for devices like PDAs and eBooks, it is out of the running as an alternative to newsprint.

**Hewlett-Packard** is experimenting with slightly elastic liquid-crystal materials that consist of molecules that can be stable in two different orientations. This approach does not need energy to maintain the display. Meanwhile, **Microsoft Corp.** is working on a project called "ClearType."

### **The Myth of the Paperless Office**

These electronic ink or digital paper technologies aim for universal display applications, ranging from desktop computers to PDAs, telephones, wristwatches, etc. The devices will probably weigh less and use less power than existing devices. They promise much easier reading with text easily viewable under varied lighting conditions and from a wide range of reading angles. They target applications that have conventionally used paper, such as billboards, in-store displays, newspapers, wallpaper, shelf price tags, and other applications where the content is subject to change.

While the technology shows promise for improving readability over existing devices, it remains anchored in the ink on paper or book metaphors. The publishing industry is undergoing a paradigm shift; but the metaphors still describe innovations in terms of what they replace rather than the new reality. The principal concept underlying the electronic book remains the book rather than the improved functionality. The book, until now, designated a format — a group of pages of paper or other material bound together; but the electronic book neither looks nor feels anything like a book. The concept of the electronic book has shifted from the form to the content, referring to the information content rather than the format or playback device.

New technologies usually introduce new capabilities or do something more efficiently. These characteristics, rather than the delivery medium, should drive the use of the metaphors. Paper is superior to digital technology as a communications and storage medium in a number of ways. It is cheaper, more portable, flexible, light, foldable, and is more easily replaced than anything digital. Paper has good contrast as well as has high and even reflectivity. It is readable in a variety of lighting conditions and from a wide range of angles. Paper use is intuitive: it is humanly readable and requires no training or special viewers that need electrical power or batteries; and magnetic fields won't corrupt its content. Nor does it have to be "refreshed" periodically or converted to other media or formats every ten years or so. However, ink on paper cannot be erased instantaneously and reused millions of times without wearing out.

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Some pundits have used the phrase “the paperless office” to predict paper’s rapid demise. But the paperless office is a myth. It will occur only after the paperless bathroom. Other technologies touted as instruments to bring about the paperless office have contributed to the consumption of even more paper.

Electronic ink and digital paper technologies may do little to bring about the paperless office

because they are display technologies, not storage technologies. On the other hand, digital paper will certainly displace its share of paper, just as email and electronic forms have replaced paper-based memos and internal report documents, if it is capable of storing book length documents. Electronic books might eventually drive the creation of Internet-based “book of the month”-type subscription services. However, as long as the technologists resort to paradigms of ink-on-paper to define its functionality, no digital medium will become recognized as a true paradigm shift. 

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 • Information about Electronic Reusable Paper is available on the Xerox PARC Website at [www.parc.xerox.com/dhl/projects/gyricon/](http://www.parc.xerox.com/dhl/projects/gyricon/).  
 • Information about SmartPaper is available on the Gyricon Media Website at [www.gyriconmedia.com/smartpaper/index.asp](http://www.gyriconmedia.com/smartpaper/index.asp).

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