

## e-Paper

a report by

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The concept of 'electronic paper', or e-paper, goes back to the early 1970s, when Nicholas K Sheridon, now Research Director of Gyricon Media, was looking for an electronic display medium that was better than the rather dim cathode ray tubes available at the time:

*"I wanted to find a display material with as many of the properties of paper as possible. Finding a paper substitute was not my main motivation."*

A paper substitute is exactly what is on people's minds, but different developers of e-paper differ widely in how literally they take the paper metaphor. E Ink Corporation is the most visible developer of 'paper-like displays', and the company's demonstration of its latest generation of black-and-white and colour display prototypes at the Society for Information Display SID 2002 conference left most observers impressed. E Ink uses electrophoresis – the characteristic of charged particles to migrate through a fluid under the influence of an electric field – to attract light or dark particles close to the viewing surface to create an image. A great deal of research was undertaken on electrophoretic displays in the late 1970s and early 1980s, but problems converging around agglomeration – clumping together – of the particles slowed development, and the rapid progress of liquid crystal displays (LCDs) made that technology more attractive. E Ink puts the electrophoretic particles into microcapsules, which solves not only the agglomeration problem, but also vastly simplifies fabrication because the microcapsules can be screen-printed onto a substrate.

E Ink currently has a development agreement with Toppan Printing for colour filters, and with Philips for active-matrix (AM) back-planes. The three partners demonstrated the first colour AM 'electronic ink' display with reasonably high resolution (80 pixels per inch (ppi)) at SID 2002, but some observers were more impressed with the simpler black-on-white display, which delivered remarkable, almost print-like, contrast.

Receiving attention at SID 2002 was the 'Stingray' (see *Figure 1*). Built on a steel-foil substrate, the Stingray was billed, at 0.3 millimetres (mm) thick, as

the world's thinnest AM display. Commercialisation of the Stingray and the colour AM display is slated for 2004/2005.

To make such displays 'paper-like', they should ideally possess the following characteristics:

- thin, light and perhaps flexible;
- high in contrast, with true and intense blacks and bright, neutral whites;
- a low-glare surface that mimics the look of matt paper;
- able to present an image that is subjectively close to or 'on' the surface;
- reflective, as paper is; and
- bi-stable, so that once an image is written to the display, it holds that image without any additional use of power.

Pixel density is often not part of the e-paper discussion, but if people are to relate to a displayed image as they do to a printed magazine page, the display must present about 200ppi. e-Paper displays, and displays that have been used for commercial 'e-book' applications, are still a long way from 200ppi, which the author believes is one of the reasons that e-books have not taken off as their developers had hoped.

The only other e-paper candidate that adopts the paper metaphor more literally than E Ink is Gyricon (see *Figure 2*), which also uses small particles but, instead of using electrophoresis, it rotates the spherical particles under the influence of an electric field. Since each half of each sphere is a different colour, it is possible to make monochrome, multicolour or full-colour displays. Gyricon calls their particles 'bichromal microbeads'.

Until it was spun off late in 2000, Gyricon was part of Xerox, who may have applied the paper metaphor too literally, promoting it as 'electronic reusable paper' and designing a sheet-fed printer that would



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erase the old image and print a new one. The new company's first press release was already taking a different tack and promising to use the power of electronic reusable paper to provide networked, reusable retail signs that can be updated with the

**Figure 1: The Stingray Electrophoretic Display by E Ink Corporation – just 0.3mm thick**



**Figure 2: Gyricon's Paper-like Displays use Bichromal Microbeads**



click of a mouse, which is the marketing thrust the company continues to pursue today.

Another bi-stable technology is the cholesteric LCD (Ch-LCD) developed by Kent Displays, Inc. Ch-LCD is distinguished from the preceding technologies by actually having standard monochrome products on the market. Attractive colour prototypes have been shown. The technology is compatible with flexible substrates and reasonably high-resolution prototypes have been shown, but standard products are currently on glass substrates and are of fairly low resolution for simple signs and similar applications.

The point has been made that reflective LCDs with various structures can have very low power consumption, have demonstrated higher pixel densities and fare faster refresh times than the bi-stable technologies.<sup>1</sup> They have an established infrastructure that will make them very difficult to beat on price. At the moment, the trade-off is in the matt surface and the broad viewing angles possessed by paper and the non-LCD bi-stable technologies.

Individual definitions of e-paper may vary considerably, depending on the application and the display characteristics that are valued most. If the 'look' and wide viewing angle of paper is paramount, E Ink and Gyricon Media products will probably be of most interest. If the ability to remove power after addressing is what a customer requires, Ch-LCD can be added, which also has a wide viewing angle. For viewing text and images while expending little power, reflective or perhaps even transfective LCDs can be added. Interferometric, bi-stable, reflective colour displays are currently under development by Iridigm Display Corporation, although these require the application of a constant bias voltage.

Perhaps e-paper is better defined by application rather than by technology. We want to be able to read text and view graphic information as effortlessly from our displays as we do from paper. There will certainly be many applications in which real paper and ink will be the preferred display medium in the future, but there are others that are demanding an acceptable e-paper now. Looking around, we see people squinting at their mobile phones and personal digital assistants and almost nobody attempts to use their notebook personal computers out of doors on sunny days, which provides an idea of how great the possibilities are. This is without considering Gyricon's networked paper-like signs, Kent's concept of flexible, dynamic one-sheet newspapers and the many applications that will only arise once imaginative product designers are able to explore the possibilities of e-paper displays. ■

1. J H Morrissy (Three-Five Systems) and Yoshiharu Nakajima (Association of Super-Advanced Electronic Technologies).