Ink gets an upgrade

Gary Legg, Executive Editor

THE LATEST INKS ARE ELECTRICALLY ALTERABLE AT THE PIXEL LEVEL. TO CHANGE YOUR PRINTED COPY OF *EDN* TO *PLAYBOY*, PRESS THIS BUTTON.

DOESN'T WORK? OH, SORRY. Actually, we're not yet using the latest ink for printing *EDN*. We're still using Ink 1.0, which the Egyptians introduced some 3000 years ago. It's essentially a ROM technology; you can read it forever, but you can't alter it after you write it. Ink 2.0 is coming, though, and it's a RAM technology. You might soon be able to alter the entire contents of a printed page in a fraction of a second. With only one physical book or magazine, you'll be able to view and read the contents of many.

You can coat electronic ink, or e-ink, onto virtually any surface, including paper or plastic (photo courtesy E-Ink Corp).

Microcapsules serve as e-ink's pixels. The microcapsules shown here are 250 μm in diameter, corresponding to an image resolution of 100 pixels/in. E-ink now has microcapsules smaller than 100 μm (photo courtesy E-Ink Corp).

In reality, programmable books and magazines probably won't exist for a while—maybe three years or more, say researchers. But electronic ink, or e-ink, is already working in the laboratory, and it's demonstrating huge potential for eliminating many of the differences that exist between hard copy and soft copy. Eventually, it might give us the best of both worlds.

Consider what e-ink is capable of. Like regular ink, you can print it on paper, on film, and even on curved, molded surfaces. When it's printed on paper or film, you can flex it and even roll it up like a newspaper (although you can't fold or crease it). You can change the contents of an e-ink display quickly and with minimal power, and the new image then remains in place for weeks without additional power. An e-ink display needs no backlight, and its viewing properties are excellent. And it's cheap. Eventually, an e-ink display might well cost only a tiny fraction of a glass LCD's price.

So what's the catch? None, really, except that e-ink is still a new and unproven technology. Also, it's limited for now to large, low-resolution, monochrome displays, and it can't yet change images fast enough to be useful for video. But e-ink is suitable today for many applications, say its inventors at E-Ink Corp (Cam-

bridge, MA, www.eink.com). A pilot project is already starting to use e-ink for electronically updatable price markers on store shelves. Other possible near-term applications for e-ink include scoreboards, traffic warning signs, and programmable storefront banners. Longer term uses include displays for personal digital assistants, pagers, and computers.

THE SECRET IS OUT

The secret behind e-ink is a microcapsule that's electrically alterable to show one of two colors, typically black and white. Microcapsules aren't new; they've been used in "scratch-'n'-sniff" applications for years. Nor are color-changing microcapsules new; Xerox's Palo Alto Research Center created a version years ago (www.parc.xerox.com/parc-go.html). Researchers at E-Ink claim that their e-ink is an improvement over other displays, however. For example, E-Ink claims that its microcapsules are easier to manufacture and that its e-ink retains images better and longer.

Microcapsules from E-Ink take either of two forms. One type contains pigment chips of two colors, typically black and white, in a fluid (**Figure 1**). The other type contains pigment chips of one color in a liquid dye of a contrasting color. In either case, applying a voltage across a microcapsule moves pigment chips of a particular type toward one of two transparent electrodes. If you view the microcapsule from the position of one electrode, you see the pigment chips of one color; if your view is from the other direction, you see the dye or pigment chips of the other color.

MILLIONS AND MILLIONS

E-ink contains millions of microcapsules suspended in a liquid medium. The medium, like that of ordinary ink, allows the ink to stick to the surface it's printed on. On a printed surface, microcapsules form a virtually continuous array of pixels, each capable of changing from one color to another. Currently, e-ink's microcapsules can be as small as 100 μm in diameter, corresponding to about 250 pixels/in. Individually addressing such small pixels is still a daunting problem, however, which is why high-resolution e-ink displays are still in the future.

E-ink's optical performance varies with its electrical parameters. For example, an e-ink display shows very high contrast when a 90V source polarizes the pigment chips but low contrast with a 10V source. Similarly, better contrast results from a longer application of the voltage. The contrast is high when switching between the two colors occurs at a rate of 10 Hz or slower but low at a switching rate of 100 Hz. E-Ink researchers are working to decrease both the switching voltage and the switching time, primarily by creating smaller microcapsules.

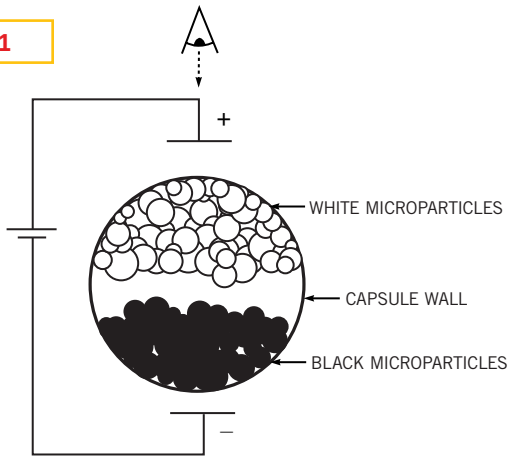
A big plus for e-ink is its power consumption—low during programming and nonexistent otherwise. Current draw during programming varies with pixel size, but is on the order of 500 nA per pixel. Eventually, according to E-Ink founder Joseph Jacobson, a 12.1-in. display will consume only about 12 mW of power.

Use of e-ink displays for computer monitors will have to wait on further technology developments, however. Current schemes for addressing pixels fall short when microcapsules are small enough and packed closely enough together to form a medium- to high-resolution display. With a passive-matrix addressing scheme, consisting of an x-y grid of select lines, currents in the lines affect not just an addressed microcapsule, but other microcapsules in its vicinity. An active-matrix scheme, on the other hand, requires fabricating an array of transistors on a flexible substrate that the e-ink is printed on. Both technical and cost issues hinder this approach, although researchers are making progress on both fronts.

A BIG PLUS FOR E-INK IS ITS POWER CONSUMPTION.

E-Ink expects active-matrix drive circuitry on flexible materials to be economically feasible within the next few years, enabling what Jacobson calls "the last book"—a single book that can change its content to be any book (**Reference 1**). And maybe you'll be able to roll up an interactive *EDN* and carry it in your coat pocket. □

Figure 1



Application of a voltage causes a microcapsule to change color by moving pigment chips within the microcapsule toward a transparent electrode.

Reference

1. Jacobson, J, B Comiskey, C Turner, J Albert, and P Tsao, "The last book," *IBM Systems Journal*, Vol 36, Nov 3, 1997, www.almaden.ibm.com/journal/sj363/jacobson.html.