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New displays for e-readers

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Dec 10th 2009

Display technology: Readers of electronic books must choose between long battery life or vibrant, living colour. Could they have both?

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THE sudden surge in the popularity of e-readers—slate-like devices, such as Amazon's Kindle, on which electronic books can be read—has been one of the big surprises of 2009. Recessions are often a good time to launch new products, as old certainties are questioned and consumer tastes shift. The iPod made its debut in 2001 in the depths of America's recession, and e-readers may prove to be a similar success story this time. But today's e-readers, like that first iPod, are technologically quite simple. Most of them have a monochromatic screen to display text and black-and-white pictures, and none can handle video.

Even so, around 5m e-readers will be sold worldwide in 2009, according to iSuppli, a market-research firm, and a further 12m in 2010. The Kindle is by far the most popular e-reader, but there are many others. Sony has offered a range of e-readers for years, and has recently introduced several new models. Barnes & Noble, a bookstore chain, unveiled its own reader, the Nook, in October. Plastic Logic will unveil its QUE proReader in January at the annual Consumer Electronics Show in Las Vegas, which is likely to be a coming-out party of sorts for this new product category. Many other firms, including makers of laptops and flat-panel displays, are also entering the market. Apple may well upstage all of them by announcing its own tablet-like device in January.

Over 90% of existing e-readers use a display technology called E Ink, made by a firm of the same name that was spun out of the Massachusetts Institute of Technology in 1997. E Ink is based upon tiny capsules filled with positively charged white particles and negatively charged black ones, suspended in a clear liquid. Transparent electrodes above and below the layer of microcapsules create electric fields that, depending on their polarity, push either the black or the white particles to the surface in a particular region of the display.

This “electrophoretic” technology has several advantages, says Steve Haber, president of Sony's digital reading division. It is easy on the eye, does not need to be back-lit, can be read easily in bright sunlight, and requires very little battery power. (The image on the display remains in place, even when no power is applied, and energy is only expended when changing it.) There is clearly room for improvement, however. E Ink displays are relatively slow to update, which can irritate readers as they turn their digital pages. They cannot display colour images or video, unlike the liquid-crystal display (LCD) technology used in mobile phones and laptops. But LCDs are much more battery-hungry and are not so easy on the eye when reading for long periods. Another approach, organic light-emitting diode (OLED) technology, shows promise but is expensive and difficult to scale up.

Mirasol

A mirasol display

The ideal e-reader display, says Mr Haber, would combine excellent battery life, a paper-like reading experience, full colour and a response-time fast enough to support video—while also being affordable. Alas, such a technology is not yet available on the market. Some firms are responding by launching e-readers based on LCD technology. Apple's device is expected to use LCD, and Asus, a maker of small laptops, has developed an LCD-based e-reader. The Nook cleverly splits the difference: it has an E Ink screen to display text, and a smaller LCD touch-screen below it for navigation, which switches off when not in use to save energy.

E Ink and a handful of rivals, including SiPix and Bridgestone, are developing colour electrophoretic displays. This involves adding a layer of coloured filters above the black-and-white capsules, so that they can change colour. The difficulty lies in making the filters and their control systems small enough, and ensuring that the filters, which cut down on the light reflected by the capsules, do not make the resulting image look too dull. Sri Peruvemba, vice-president of E Ink, says the firm hopes to have solved these difficulties by the end of 2010. But video remains a problem. It currently takes about half a second to change the page on a Kindle. Getting an E Ink display to show video is theoretically possible, says Mr Peruvemba, but would involve changing the chemistry of the display.

So it will probably be some years before electrophoretic displays are capable of displaying video. Meanwhile, several emerging technologies are waiting in the wings to challenge the dominance of the electrophoretic approach.

Qualcomm, a maker of wireless chips used in mobile phones, has developed a display technology called mirasol that could prove to be ideally suited to e-readers. A mirasol display reflects ambient light like an E Ink display, but instead of being made of liquid-filled capsules it consists of tiny cavities between two layers of mirrors. The top layer of mirrors is designed to allow a small amount of ambient light to pass through it. The light then bounces off the bottom mirror, and then bounces again off the underside of the top mirror. As the light bounces back and forth, appropriate spacing of the mirrors amplifies a particular colour (wavelength) of light, while cancelling out others. A tiny electromechanical switch under the bottom mirror can also lift it up, adjusting the spacing and preventing it from reflecting any light at all.

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Cavities with mirrors spaced specifically to amplify red, blue and green light are grouped in bunches of three, each of which corresponds to a single dot, or pixel, on the display. By adjusting the mirrors under each cavity, these pixels can be made to produce different colours. The mirrors can be switched fast enough to produce a range of colours, and to display video. The technology is already available in the form of small screens for use in mobile phones and satellite-navigation devices. These displays sip power, drawing just one milliwatt in a static state and 30 milliwatts when showing video. A comparably sized LCD would draw 240-700 milliwatts of power, depending on the image displayed. Jim Cathey of Qualcomm says e-reader screens based on mirasol will go into production in 2010.

The Nook

Another micro-electro-mechanical display comes from a start-up called Pixtronix. Instead of reflecting ambient light, its PerfectLight technology uses tiny shutters that open and close quickly to allow through light from a backlight composed of red, blue and green light-emitting diodes. LCD displays also use shutters, in effect, consisting of liquid-crystal elements whose polarisation can be changed to block light or let it pass. The trouble is that liquid-crystal shutters absorb over 90% of the light passing through them, even when they are open. PerfectLight's technology allows as much as 60% of the light through. And its shutters can switch fast enough (up to 1,000 times per second) for video.

While Qualcomm and Pixtronix are busy building tiny pixels that move, Philips has spun out a company called Liquavista that takes a much simpler approach. The pixels in Liquavista's displays consist of an insulating layer, an electrode, water and coloured oil. These layers are sandwiched between two sheets of glass or plastic. When no voltage is applied, the oil spreads out to cover the pixel, which is 200 microns on a side. This happens because the insulating layer is hydrophobic, meaning it tends to repel water. With the water pushed away, there is room for the oil to spread out. But when a voltage is applied the insulating layer instead attracts the water—a technique called electrowetting. This squeezes the coloured oil into a tiny droplet in the corner of the pixel, where it cannot be seen.

The oil can bead up in this way within 3 milliseconds, and it takes 9 milliseconds to spread out again once the power is turned off. But that is fast enough for video. A recent demonstration of a six-inch display shows impressive crispness in black-and-white. A prototype of a colour screen has respectable, but not spectacular, contrast.

Like E Ink and mirasol displays, electrowetting displays can reflect ambient light, simply by placing a mirror in the layer beneath the oil. But this layer can also be made transparent, so that the display can also be backlit and used in darkness. And by using a special type of reflector that lets the backlight through, but also reflects ambient light, an electrowetting display can have the best of both worlds.

Liquavista

Liquavista

Looking into the crystal ball

Now for a reality check: in the history of ingenious display technologies, only a handful have ever made it into mass production. So although there are many promising new technologies for next-generation e-readers, the technology arguably best positioned to take over from E Ink, at least in the near future, is a variant of LCD. Engineers have repeatedly shown that they can improve LCD technology when the market demands it. Such displays have wider viewing angles than they did just a few years ago. Fast motion, like a tennis serve, is no longer jerky. And large LCD panels have become much thinner and far more power-efficient.

There is already one LCD-based e-reader on the market. Fujitsu's FLEPia uses a so-called cholesteric LCD, which produces an image from reflected light. The crystals are bistable, which means that they can remain in either a reflective or non-reflective state without any power. Cholesteric LCDs do not require a backlight and lack many of the layers of a traditional LCD, which should make them easier to build. But the manufacturing process and materials differ enough to make cholesteric displays more expensive than standard LCDs—hence the FLEPia's high price (about $1,000). Moreover, despite having a colour display, the FLEPia takes two seconds to switch from one image to another, so video is out of the question, and even reading books can be painfully slow.

Pixel Qi, a start-up, believes that there is scope to tweak LCD technology within the constraints of standard manufacturing methods and materials. The firm's founder is Mary Lou Jepsen, the former technology chief of the One Laptop Per Child project, and the forthcoming displays bear a strong resemblance to those handed out in low-cost laptops to hundreds of thousands of children throughout the world. They have two modes: one that uses a backlight and is identical to a standard LCD when the light is low or when high colour contrast is desired, and a second, monochromatic mode in which the backlight is switched off. This second mode is suitable for reading or watching video in bright light, and can reduce power consumption by 80%.

Pixel Qi had to redesign every layer of a standard LCD to enable this dual-mode operation. The standard transparent layer between the backlight and the liquid-crystal shutters above it was replaced by a special aluminium layer that reflects ambient light from above, while also allowing light from below to pass through tiny pinholes. The liquid-crystal layer also had to be redesigned to allow light to pass through it in both directions.

This design can be used in low-power monochromatic mode for reading, but can also switch to backlit colour mode when needed. Pixel Qi expects to go into mass production with 10-inch displays by the end of 2009, targeting the netbook and e-reader markets. Just as the One Laptop Per Child scheme helped bring into being the low-cost laptop, or netbook, so Pixel Qi could prompt the LCD industry to switch its focus to developing new products suitable for use in e-readers. One way or another, inexpensive colour e-readers with video are on their way.