E-Paper

By: Justin Falk

Robert Morris College - MIS 540

Table of Contents

Abstract

A new advancement in technology termed "electronic paper" is beginning to emerge on the market and will soon appear as a commercialized product. Electronic paper has been toted to have the possibility to change the world as we know it. This paper covers the basics of electronic paper including how it works, its advantages, its major applications, its future, and the prototypes of specific manufacturers. A small section is dedicated to the advancement of Chameleon Liquid, the newest discovery in electronic paper.

Introduction

E-paper, short for electronic paper, is reported to be a thin flexible display capable of presenting visual images or text which has the readability factor of traditional paper. Advances in optical display, power consumption, and network connectivity have greatly expanded the number of potential applications for e-paper. Originally thought to be a creation of science fiction e-paper has began to take the first steps in a market towards public commercialization.

Invention of E-Paper

Nick Sheridon believes in electronic paper (Lincoln, 2000). After inventing it in the 1970s at Xerox's Palo Alto Research Center, he was forced to stand by and watch his work reproduced and then advanced, 2,500 miles away at the MIT Media Lab. Now he’s back in the e-paper industry as head of research at Gyricon Media, a Xerox knock off. Gyricon is entering the signage market just as its only e-paper competitor, E Ink (inheritor of the MIT effort), disclosed it will stop manufacturing its Immedia retail signs and focus instead on developing displays for handheld devices. While Immedia was a relatively large (4'x6') department-level display, Gyricon hopes to sell stores hundreds or thousands of smaller (12"x12"), cheaper displays that allow retailers to update prices over a wireless network.

How It Works

Electronic paper consists of millions of micron-sized beads embedded in a sheet of clear plastic. E Ink and Gyricon use different kinds of beads. But both work on the same rule: a current changes the color of the beads, either by turning the bead or by moving particles within the bead. Perhaps e-paper's biggest request is that when the current switches off, the image remains fixed. This means e-paper displays can run for years off a single battery. To print an image on its electronic paper, Gyricon uses an active mold of transistors. The active mold displays each pixel with a separate transistor, which drives up the cost of production and limits the size of displays. Gyricon is also experimenting with passive mold addressing, which turns pixels on or off using one transistor for each row and each column. The problem is that the beads must be extremely uniform. What's more, both kinds of molds require a rigid circuit board, defeating one of the main advantages of paper: flexibility.

Major Uses of E-Paper

The overall usage or purpose of e-paper ranges from posters, point of purchases, and billboards to cell phone displays. When it comes to posters and message board displays there is a large possible market for electronic display devices that will change to the felt tip on cardboard, chalk on blackboard, or moveable magnetic character signs that are widely used in retail and service industries. With a wireless link such message boards or posters can be remotely changed and updated.

In the industry for supermarkets’, point-of-purchase displays are another early application for e-paper technology. Point-of-purchase display designers have long accepted the value of adding animation, but they faced difficult limitations in design, space, cost, and power. Now, with e-paper technology they can add a simple motion factor that builds the brand, integrates easily, and lasts for months on batteries. There are several advantages of this type of e-paper point-of-purchase displays. It has a paper-thin package and can animate continuously for up to 6 months using just two AA batteries. This means it can be used for high-impact point of purchase display signs in retail environments where access to power outlets are often limited. In addition these displays can be easily viewed from all angles and under virtually any lighting condition.

For music and movie billboards, the outdoor advertising industry worldwide is worth about $19 billion, of which in the US alone some $6 billion is spent on men with ladders, brushes and pots of glue. Electronic billboards that could be distantly changed or updated would not only save the industry a lot of money, but would also open up the opportunity of creating new advertising models, such as short term poster ads, or ads that change in accordance with changes in the weather or other market conditions. They could even respond to individual viewers, once location based wireless services are widely deployed. Electronic billboards constructed using light bulbs or LEDs have been around for a long time, but they are very expensive to buy and run and are only warranted in areas where there is high viewer traffic. Advertising rates are equally high. Billboards constructed using e-paper display technology can, however, be made at a much lower cost, and use a lot less power, thus making them an economic proposition in a far greater number of sites.

The success of devices like the Blackberry and the iPod has demonstrated that there are large potential markets for specialist portable data devices. Philips has already produced prototype designs for an e-paper display based e-mail and business information system with a built in mobile phone link, much like the Blackberry, and for a similar e-paper based portable GPS and map system. Other mobile data devices using roll-up or even wearable flexible screens are being developed for military applications.

An E-Paper Alternative: Chameleon Liquid

Yadong Yin and the Department of Chemistry at University of California Riverside created a new "chameleon" liquid by using a unique polymer suspended in a water mixture. The polymer contains small iron oxide particles coated with plastic. The plastic coating creates a highly charged surface for each particle, and because each particle has the same charge they naturally repel each other in the water solution. However, due to the iron, a magnetic metal, the iron oxide particles will attract each other when exposed to a magnetic field.

How It Works

Electrostatic repulsion and magnetic attraction will result in the free floating particles arranging themselves into an ordered structure known as a colloidal "photonic crystal" (Physorg.com, 2007). The colloidal crystal structure creates spaces between particles which will reflect a certain wavelength of light. Changing the space will result in the changing of wavelength of light. This is similar to the numerous types of crystals present in many known minerals. Each type of crystal, such as amethyst, opal, etc, results in a unique color. However, in this situation the spaces in the colloidal structure can be easily be changed by changing the degree of strength of the magnetic field applied to the particles in the solution. These spaces freely bound within the liquid are able to be changed extremely quickly and precisely. In other words, by simply changing the magnetic field one could easily change the color of the liquid solution.

Capability

The distance of a simple magnet can even make a significant difference to the color of the liquid. Originally a brown-like substance the solution can exhibit all the colors of the visible spectrum in order of their frequencies. For example as the magnet is rather distant the solution is red. As the magnet moves closer and closer the solution will change respectively to orange, yellow, green, blue, indigo, and violet. “This chameleon liquid is the first report of a photonic crystal that is fully tunable in the visible range of the electromagnetic spectrum” (Dume, 2007).

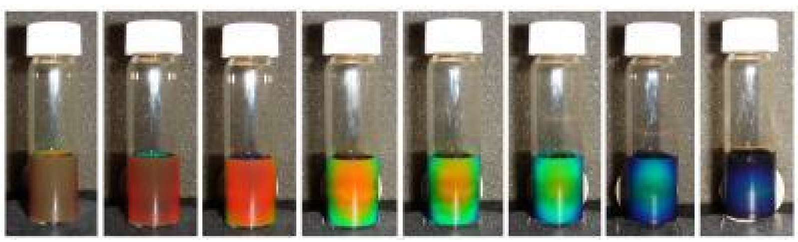

Figure 1: Chameleon Liquid

Uses

Fortunately the solution is cheap and easy to produce making it a great candidate for use in flexible, reusable, electronic paper by jamming the crystal structures between two plastic sheets. A simple magnet in the form of a pen could be used to write on the rewriteable paper. Pens that could vary strength would be capable of writing in all colors. The solution also could be used in signal sensors, optical switches, visible color displays, posters, billboards, and other forms of optoelectronic devices used in telecommunications. Due to the color being created by the reflection of light the solution makes for great outdoor usage. This is unlike current LCD displays and monitors which perform poorly in sunlight. The ability to make a color display based on a single material would be greatly cost efficient. Experts responsible for creating the desired material estimate the technology to use the liquid could possibly be available within two years.

Future of E-Paper

Paper continues to be the primary method of distributing and viewing textual content. It is lightweight, easy to read, requires no power source, and is very durable. The only problem is that it is static. In order for e-paper to have a future it must be able to match all these characteristics plus be dynamic. In addition to this it must be affordable and easy to use. According to senior marketing manager of E-Ink, this new generation of paper must first become thin, light, rugged, and shatterproof. The next challenge is then to develop this medium to be curved and comfortable. Lastly, this medium must flexible, and be capable of taking a certain amount of flex.

Experts estimate that flexible electronic paper will be arriving within the next decade, however, new developments could bring it into our daily lives much sooner.

Emergence of E-Paper

Xerox PARCH researchers call their e-paper Gyricon, and it consists of a thin layer of transparent plastic full of millions of small black and white or red and white beads. These beads are similar to toner particles and contained in an oil-filled cavity. When electronic voltage is applied, the beads rotate to show the color on the viewable side of the plastic.

Gyricon is electrically writeable and erasable, can operate on very low power, and can be used thousands of times over. In addition Gyricon does not require any backlighting or refreshing and is brighter than any flat displays available now.

Lucent has developed a prototype which they call E Ink, and it consists of electronic ink drive circuits printed on plastic all contains within a thin 25 inch square display. Transistors in the display's circuits are made of low cost plastic. The electronic ink is capable of being viewed from all angles.

LG Phillips has announced its development of their 14.1 inch LCD E-paper color display. This display is supposed to replace the size of a regular 8.5X11 sheet of paper. The ink used is the E-Ink developed by Lucent. It is capable of displaying 4,096 colors and can be viewed from 180 degrees. The image is reported to appear crisp even when bent.

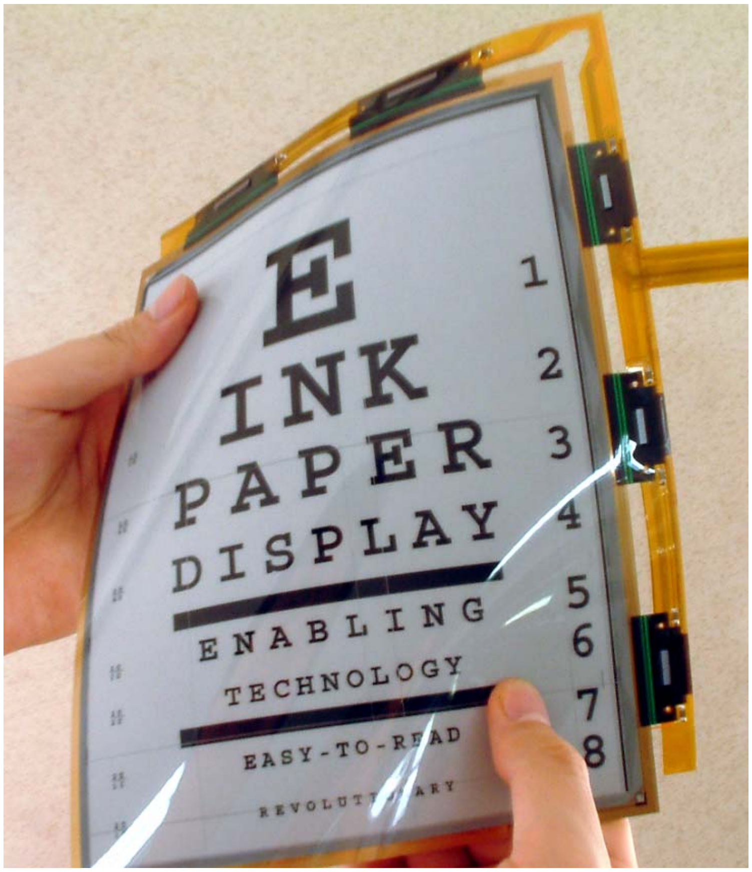

Figure 2: LG. Phillips E-Paper LCD

Figure 3: LG. Phillips E-Paper LCD

Quantam Paper has developed a way to partner with e-paper's emergence into the market. They have found a way to apply thin flexible electronic displays to paper and other common substrates using a lithographic or flexographic press. Possibilities for this process include inserting media advertisements in magazines, newspapers, etc. This may open the doors for commercial printing companies to share the expected enrichment of e-paper advancement.

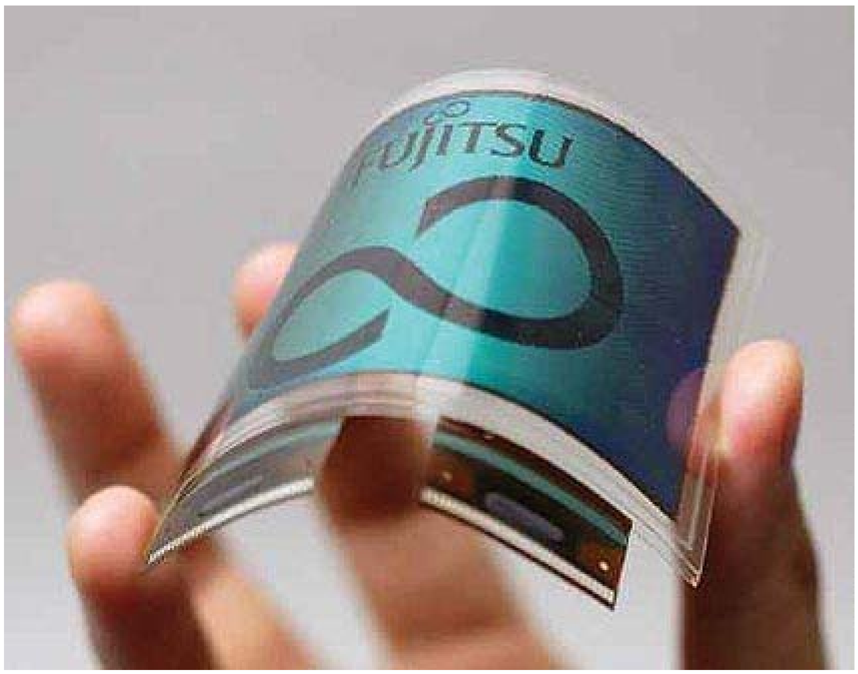

Figure 4: E-paper Display by Fujitsu

Fujitsu has developed an e-paper film that can receive and display data from an outside communications source. This film can update and gather data from the internet via a wireless technology. It can also adjust to ambient light without requiring a constant electrical charge. Fujitsu is developing the film to respond to voice commands so that traditional writing or external keyboards will not be needed to manually update it.

Combining these technologies allows for many unthinkable possibilities. For example, Citizen's is able to produce one lightweight, flexible, low-power clock that is capable of synchronizing the time through its wireless connectivity.

Figure 5: Citizen's electronic ink, bendable clock

Figure 6: Seiko's e-paper display watch

There are many other ideas for e-paper such as a consumer's newspapers or brochures that will update themselves automatically when the content has changed. A scenario such as a person shopping for automotives which brings a brochure home on a prospective car will be updated to new options or features when they become available through the manufacturer. The user will be updated by flashing paper or possibly even a sound alarm. Other scenarios such as subscriptions to magazines and newspapers will allow the user to keep one permanent copy that will update daily or monthly with new content. Markets in Europe and some U.S. papers including the New York Times have already begun evaluating the technology using test segments.

Unaware to many individuals is the current use of e-paper RFID tags in retail establishments. Pricing and other tag information is capable of being updated rather than reprinted and attached to various items. Sony has already prototyped an e-book reader which will be sold in Borders bookstores. Simply updating the e-book reader with new content will allow users to read any book, similar to the concept of tuning into a radio frequency channel, provided the user pays for the book.

The next greatest step for e-paper is the emergence of color. Many prototypes have been developed for full scale color displays, such as the LG Phillips LCD, however none of them have yet been able to be fully commercialized. Currently all commercial e-paper products are monochrome, and some capable of displaying multitudes of grey. Color stands as the biggest hindrance of e-paper entering the mobile display market. Chameleon liquid may serve as the biggest help to commercializing a color display.

Conclusion

In the next decade e-paper has a strong possibility to revolutionize digital books, newspapers, magazines, brochures, portable displays, organizational documents, RFID tags, and numerous other applications. As e-paper emerges it will bring a new realm of possibilities, some not even fathomed yet. E-paper has strong advantages of being thin, flexible, having minimal power consumption, wireless connectivity, and great readability from many angles including superior performance in outdoor light. Chameleon liquid may help with the commercialization of color e-paper, leading to strong possibilities to enter mobile display markets such as PDAs and iPods. E-paper could be able to deliver more customized content, save many industries millions of dollars, open up a new way of advertising, and it is only just a short electromagnetic step away.

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