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Assessment of E-Paper: Technological Approach, Challenges and Usefulness

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ABSTRACT
This study is an assessment of e-paper, a portable, reusable storage and display medium which looks like a paper but which can be repeatedly refreshed by electronic means in thousands or millions of times. Each electronic paper display is made up of millions of such capsules in a thin film, with the particles inside the capsules of different colors and different electric charges. The intent of this study is to examine the various technological approaches working towards the complete realization of E-paper concept. The findings show that, the application and mass adoption of E-paper technology has its own usefulness and constraints. It was discovered specifically that, the technology is not sufficiently capable to interchange paper. The paper recommends among other things that users should not be in a hurry to replace paper with the E-paper as this may have some negative effects.
Keywords: E-Paper, Technological Approach, microcapsules, Portable, Reusable Storage.

INTRODUCTION

Electronic paper can be traced to the 1970s by Nick Sheridon at Xerox's Palo Alto Research Centre Genuth and Iddo. The first electronic paper, called Gyricon, consist of tiny, statically charged balls that were black on one side and white on the other (Crowley *et al.*, 2002). The "text" of the paper was altered by the presence of an electric field, which turned the balls up or down. In the 1990s another type of electronic paper was invented by Joseph Jacobson, who later co-founded the corporation E Ink which formed a partnership with Philips Components two years later to develop and market the technology (Comskey *et al.*, 1998). As year passes by, development changes are occurring. It differs from other e-readers in having a replaceable battery, and a separate touch-screen color LCD below the main electronic paper reading screen.

E-paper (sometimes called radio paper or just electronic paper) is a portable, reusable storage and display medium that looks like paper but can be repeatedly refreshed by electronic means thousands or millions of times. It is a display technology using organic electronics designed to mimic the appearance of regular ink on paper. An Electronic Paper Display, also known as EPD, is a display device that possesses a paper-like high contrast appearance, ultra-low power consumption, and a thin, light form. It gives the viewer the experience of reading from paper, while having the power of updatable information (Genuth, 2007).

Unlike a conventional flat panel display, which uses a backlight to illuminate its pixels, electronic paper reflects light like ordinary paper and is capable of holding text and images indefinitely without drawing electricity or using processor power, while allowing the paper to be changed. One important feature is that the state of each pixel can be maintained without a constant supply of power (Wikipedia, 2018).

The basic material used in the electronic paper display is ELECTRONIC INK. Electronic ink is a proprietary material that is processed into a film for integration into electronic displays. Although revolutionary in concept, electronic ink is a straightforward fusion of chemistry, physics and electronics to create this new material. Applications of electronic visual displays include electronic pricing labels in

retail shops and digital signage, time tables at bus stations, electronic billboards, smartphone displays, and e-readers able to display digital versions of books and ideal e-paper display can be read in direct sunlight without the image appearing to fade. To build e-paper, several different technologies exist, some using plastic substrate and electronics so that the display is flexible. E-paper has the potential to be more comfortable to read than conventional displays (Sarno and Pham, 2010). This is due to the stable image, the wider viewing angle, and the fact that it reflects ambient light rather than emitting light in response to an electronic change, changing the page in much the same way that pixels change on a computer (Wikipedia 2018).

Electronic paper was developed in order to overcome some of the limitations of computer monitors. These limitations include the backlighting of monitors which is hard on the human eye, while electronic paper reflects light just like normal paper. In addition, e-paper is easier to read at an angle than flat screen monitors. Electronic paper also has the potential to be flexible because it is made of plastic. It is also light and potentially inexpensive (Wikipedia, 2018). The paper discusses the technology approach of e-paper and examines its advantages and disadvantages.

Technological Approach

The principal components of electronic ink are millions of tiny microcapsules, about the diameter of a human hair. In one incarnation, each microcapsule contains positively charged white particles and negatively charged black particles suspended in a clear fluid. When a negative electric field is applied, the white particles move to the top of the microcapsule where they become visible to the user. This makes the surface appear white at that spot. At the same time, an opposite electric field pulls the black particles to the bottom of the microcapsules where they are hidden. By reversing this process, the black particles appear at the top of the capsule, which now makes the surface appear dark at that spot (Rogers Etal, 2012). To form an E Ink electronic display, the ink is printed onto a sheet of plastic film that is laminated to a layer of circuitry (O'Brien and Terrence 2011).

The circuitry forms a pattern of pixels that can then be controlled by a display driver (*Daviss and Bennett, 1999*). These microcapsules are suspended in a liquid "carrier medium" allowing them to be printed using existing screen printing processes onto virtually any surface, including glass, plastic, fabric and even paper. Ultimately electronic ink will permit most any surface to become a display, bringing information out of the confines of traditional devices and into the world around us. It is based on a thin sheet of flexible plastic containing a layer of tiny plastic beads each encapsulated in oil and it rotate freely. Each hemisphere of a bead has different colour and different electric charge. Electric field is applied the beads are rotate, create two-coloured pattern. Electronic ink can be applied to flexible or rigid materials. For flexible displays, the base requires a thin, flexible material tough enough to withstand considerable wear, such as extremely thin plastic(Otani, 2008). The method of how the inks are encapsulated and then applied to the substrate is what distinguishes each company from others. These processes are complex and are carefully guarded industry secrets. Nevertheless, making electronic paper is less complex and costly than LCDs. There are many approaches to electronic paper, with many companies developing technology in this area. This is company technological approach to electronic paper technology called the Electrophoretic display. Electrophoresis is a process, which enables separating molecules according to their size and electrical charge by applying an electric current. In an electrophoretic front plane, small charges submicron particles are suspended in a dielectric fluid that is enclosed into a sub-pixel size cell or microcapsule. When an electric filed is applied across the cell or capsule, the ink particles will move towards the electrode with the opposite charge. With a transparent electrode, the cell or capsule takes in the color of the ink when current is applied. The contrast is improved by using opposite colored particles such as black and white- and charging them with opposite polarities. When current is applied, all the black particles will migrate to one side, and all the white to the other. Switch the field, and the capsule will change color. This enables switching between all black particles and all white particles on the transparent front electrode of the cell or microcapsule. This is how the high contrast ratio of electrophoretic display is created (E-paper central, 2010). The electrophoretic technology used by E-ink is

the most widely known and used form of E-paper. Known as electronic ink, it is a proprietary material that is made into a film for incorporation ink a paper-like display.

Other technologies being applied to electronic paper include electrofluidic display which uses voltage to manipulate colored ink in much the same way that print heads operate in color printers. Jason Heikenfeld, a Professor of Electrical Engineering at the University of Cincinnati, formed Hamma Dynamics LLC in 2009 to create products based on his electrofluidic display technology. He and his colleagues are considering a wide range of applications from E-readers to E-windows to tunable casings for electronic devices (Kroeker, 2009).Other research efforts into E-paper involved using organic transistors embedded into flexible substrates (Huitema, et al., 2001 and Gelinck, 2004) including attempts to build them into conventional paper (Anderson, et al., 2002).The technological approach is not limited to the one mentioned in this research however, our interest is to bring the knowledge of technological approach.

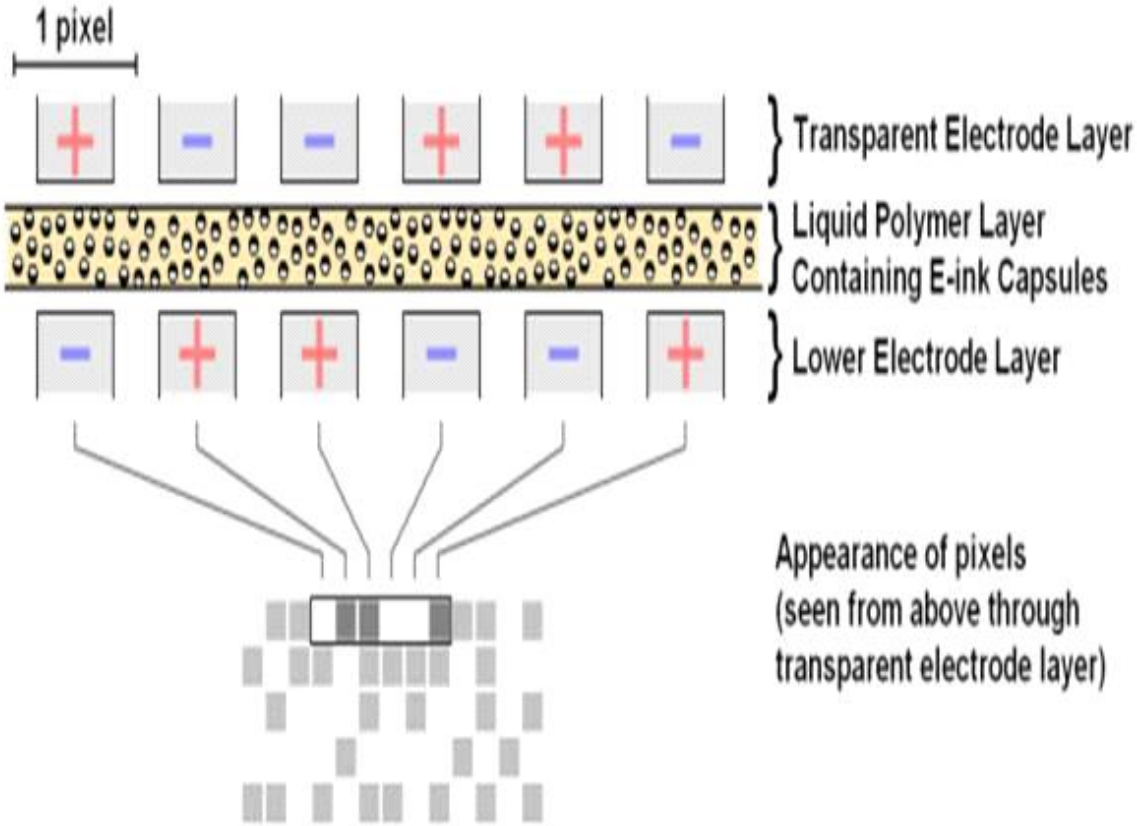

Fig 1.1 Diagram: of E-paper, Source: Wikipedia 2018.

How to use E-Paper Technology

E-paper comprises two different parts: the first is electronic ink, sometimes referred to as the "front plane"; and the second is the electronics required to generate the pattern of text and images on the e-ink page, called the "backplane". Over the years, a number of methods for creating e-ink have been developed. On a thin sheet of flexible plastic containing a layer of tiny plastic beads, each encapsulated in a little pocket of oil and thus able to freely rotate within the plastic sheet. Each hemisphere of a bead has a different color and a different electrical charge. When an electric field is applied by the backplane, the

beads rotate, creating a two-colored pattern. This method of creating e-ink was dubbed bichromal front plane. Originally, bichromal front plane had a number of limitations, including relatively low brightness and resolution and a lack of color. Although these issues are still being tackled, other forms of e-ink, with improved properties compared to the original Gyricon, have been developed over the years. One such technology is electrophoretic front plane, developed by the E Ink Corporation Electrophoretic front plane consists of millions of tiny microcapsules, each approximately 100 microns in diameter—about as wide as a human hair. Each microcapsule is filled with a clear fluid containing positively charged white particles and negatively charged black particles. When a negative electric field is applied, the white particles move to the top of the microcapsule, causing the area to appear to the viewer as a white dot, while the black particles move to the bottom of the capsule and are thus

- **Comparison of E-paper & LCD Electronic ink display Liquid Crystal Displays**: Wide viewing angle Best image only from one position Black on paper white Gray on gray Readable in sunlight Can be difficult to see Holds image without power drain Required power to hold images Plastic or Glass only Light Weight Power supply and glass make LCDs relatively heavy. Nevertheless, making electronic paper is less complex and costly than LCDs. An electronic ink display module is thinner, lighter weight, and more robust than conventional LCD's.

Challenges of E-Paper

The biggest technological difficulty facing E-paper is the fact that E-paper color displays is too expensive to be commercially feasible. There also exist some obstacles facing the mass adoption of E-paper technology. First, the technology is sufficiently not capable to interchange paper, that is, a display medium that is thin, flexible, capable of strong readable images without power consumption, highly readable in ambient light and has good resolution, high whiteness, good contrast and is pretty cheap that can completely replace paper technology is still developing. Again, one of the major obstacles is price. Research shows that the price of E-paper must fall below $1000 before a significant percentage of population will buy one. Another obstacle is availability of suitable technology since the technology has not reached equilibrium.

Advantages of E-Paper

- They are persistent without power, drawing current only when they change, which means low power consumption therefore batteries can be smaller and last longer. An electronic ink display module is thinner, lighter weight, and more robust than conventional LCD's.
- Electronic Paper is highly flexible and it is able to be twisted or bended into different curvatures. The Electronic Paper can be applied to different shapes of products, without being limited to being bonded to flat display panels. The manufacturing process is carried out using a roll- to-roll method, similar to printing paper, by injecting dielectric fluid and charged particles into the layer of capsules, and then sealing the top layer.
- The production is performed continuously at high speed. Conventional displays have a number of disadvantages in this application. They may be too expensive, too power consuming, or too hard to see when affixed to a shelf. On the other hand, e- paper can produce small, battery-operated, flexible displays.
- E-paper's potential flexibility can also be an advantage when affixing displays to shelves.
- **Readable E-Paper:** are easily readable even in direct sunlight because E-Paper displays reflect light like ordinary paper. An E-paper display has the appearance of ordinary ink on paper for it reflects light like ordinary paper. Unlike conventional LCD displays, which emit lights, the E-paper display is highly readable, not only indoors but also in direct sunlight, and the image on it is clear and modest, without flickering, and the viewing angle is near 180°.
- **Rugged E-Paper**: They are flexible, lightweight, durable and reliable. Compared to LCD displays, the E-paper displays have obvious advantage in thickness and weight, and due to the polymer film based structure, it's flexible in shape and size. What's more, E-paper is durable and reliable. The

flexibility feature of E-paper enables its various applications even for some extreme requirements that other types of display technology cannot meet. Based on the ultra-thin and flexible feature, the E-paper can be used on the smart card as a display showing balance and transaction record information.

- **Displays embedded in smart cards**
  Flexible display cards enable financial payment cardholders to generate a one-time password to reduce online banking and transaction fraud. Electronic paper offers a flat and thin alternative to existing key fob tokens for data security. The world's first ISO compliant smart card with an embedded display was developed by Innovative Card Technologies and nCryptone. The cards were manufactured by Nagra ID. Status displays

USB flash drive with E Ink-implemented capacity meter of available flash memory

Some devices, like USB flash drives, have used electronic paper to display status information, such as available storage space. Once the image on the electronic paper has been set, it requires no power to maintain, so the readout can be seen even when the flash drive is not plugged in.(Wikipedia 2018).

Disadvantages

- **It has very low refresh rate**: A notable disadvantage of electrophoretic display and electronic ink display is that it has very low refresh rate when compared to LCD IPS technology and AMOLED display technology this is also true for other electronic paper display technologies. This prevents manufacturers for using this display technology in electronic devices that have high degree of user interactivity. Note that user interactivity is high in devices such as smartphones and tablet computers.
- **Ghosting effect**: Electrophoretic display and electronic ink display are prone to ghosting effect. A shadow of an image may be visible after refreshing parts of the screen. This ghosting effect is due to the low refresh rate and the fact that the display technology works by moving charged pigment particles. Some particles end up stuck in the visible surface of a microcapsule.
- **High market competition:** Another disadvantage of electrophoretic display and electronic ink display is that it competes with existing display technologies that have become industry standards. Note that IPS displays and AMOLED displays have become very popular in smartphones and tablet computers, as well as in large screens such as televisions and computer monitors. Advancements in IPS and AMOLED display technologies have addressed issues concerning power consumption or energy efficiency, display longevity, and pixel density capacity, among others.
- **It Is Difficult To Read When There Is Darkness**: One of the advantages of reflective displays is their reliance on ambient light. E-paper is still less attractive to technologies such as LED or LCD, because it still unable to reproduce animations and it is difficult to read when there's no light. Thus,

unless the room is not bright enough, employees in an organization will have a very hard time reading the e-paper.

This means less power consumption form backlighting. However, devices that use this display technology still need some light source such as backlighting in order to be usable when in the dark.

- **Complex To Use And Cost Ineffective**: Publishing departments may have a bad time adapting to this new technology because it is still complex to use. Organizations still have manufacturing costs that were higher than expected, and some companies had trouble programming signs in their stores. Hence, companies are still reluctant to use this technology because it is more complex than paper.

RECOMMENDATION

E-paper has been traced to 1970s with different evolution, "Though new technologies are misperceived as total replacements for old ones, when in fact, the introduction of a new technology can simulate a synergy between old and new (Liu and Stork, 2000), we should reconsider the argument to completely replace all paper documents with electronic documents, and consequently, we predict a co-existence between paper and E-paper" (Akwukwuma and Chete. 2012). But we argue that as processes of development continue, E-paper could make paper technological absolute. Look at the evolution stages, **E ink**: E Ink Corporation's 1st generation technology, also known as E Ink Vizplex. Although "e-Ink" may be used to talk about all electronic paper displays, "e-Ink" and "E Ink" are trademarked by E Ink, which provides the majority of the electronic paper displays used in devices.

CONCLUSION

E-paper is a portable, reusable storage and display medium that looks like paper but can be repeatedly refreshed by electronic means in thousands or millions of times. Each electronic paper display is made up of millions of such capsules in a thin film, with the particles inside the capsules of different colors and different electric charges. Electrodes are placed above and below the capsule film. If we could replace all paper newspapers with E-Newspapers tomorrow, it would save 95 million trees which could remove 98 million tons of greenhouse gas each year. The E-paper display is energy efficient due to two advantages it has. Firstly, it doesn't use a back light which consume most power, but rather, it mimics the picture by reflecting ambient light. Secondly, it's bi-stable, which means no power is needed to hold a static picture. This makes the E-paper display consume much less power than conventional displays, such as LCD displays. We know that less power consumption means longer lasting battery life. Therefore, E-paper displays are highly suitable for the products which are limited to the size or require extreme battery condition. The bi-stable E-paper display is so low that it can be powered by a solar cell battery. The unique technology results in a compact & lightweight from factor allowing it to be ideal for highly portable applications. .

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