SiPix Microcup Electrophoretic Epaper for Ebooks

Robert Sprague, SiPix Imaging Inc., Fremont CA

Abstract

SiPix micro cup electrophoretic electronic paper is designed for applications in ebooks. Such applications require high contrast, good whiteness, reasonable switching speed, freedom from ghost images, and long term bistability. This paper will describe the current status of this technology as available for black and white operation. Exciting opportunities also exist for future color embodiments which utilize a dual mode switching technology which offers good quality color with no compromise black and white performance.

Overview of Microcup Electrophoretic Media

Microcup electrophoretic media is one of the prime candidates for paperlike displays in ebooks. It is white, scatters light in a Lambertian fashion, switches in less than a second, holds an image for many hours without power applied, and provides high quality grey scale images. In this paper we will describe the basic principles of operation and show performance data.

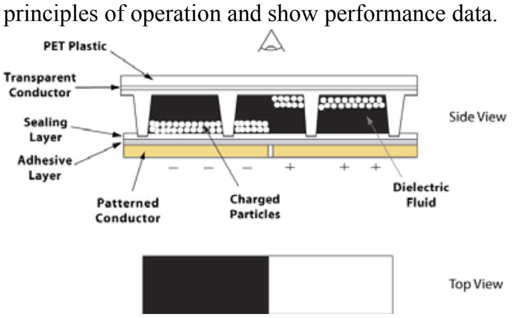


Figure 1: Cross Secion of Microcup Media

Figure 1 shows the cross section of a sheet of microcup electrophoretic media. The sheet consists of an embossed row of cells called microcups which contain an electrophoretic dispersion. This dispersion consists of a black (or colored) dielectric fluid containing a dispersion of white titanium dioxide particles. These particles are electrically charged so that they can move through the fluid under the influence of an applied field. When the particles are at the top of the dispersion, the paper appears white. When they are at the bottom, the paper appears black, or can appear colored if a colored fluid is used instead. The particles have a size of about .6 microns, so that the image resolution obtained is determined not by the microcup size but by the spatial resolution of the backplane driving it. As shown in Figure 1, the microcup media is laminated to a backplane which may be a printed circuit board with segmented electrode structure on it, or for an ebook, is an active matrix backplane with a matrix of pixels actively driven. If the applied field has a higher resolution than the microcup or the edge of one electrode is within the cup, the image switches at that location. The microcups are primarily for preventing movement of the particles across the display to provide long lifetime. In addition, they provide structure support for the media so that it is ideally suited for flexible operation.

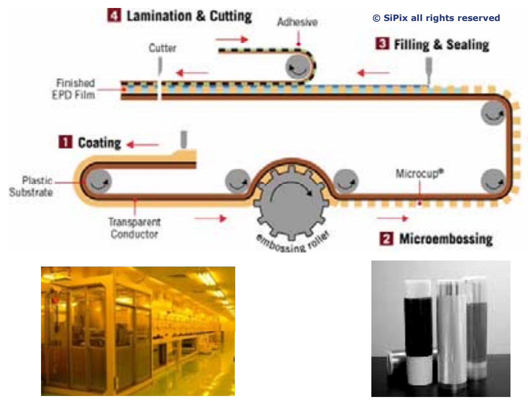
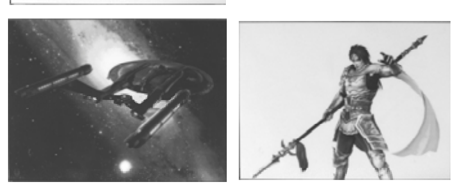


Figure 2: Roll-to-roll process

Figure 2 shows a diagram of the roll-to-roll process for making this microcup structure. A web of PET is coated with an embossing fluid. It then runs over an embossing roll to empress the microcup structure on to the film. The film is partially cured before it leaves the roll, offering a fully formed honeycomb structure. At the next step in the process, this microcup structure is filled by a doctor blade coater with the dispersion. A second coating is then applied on top which is a sealing fluid. This sealing fluid does not mix with the dispersion so that they phase separate, leaving the sealing on top of the microcup. It is cured in this location, producing a hermetic seal for each microcup. After the seal is formed, and adhesive layer is coated on top of the seal, it is laminated to a second sheet of PET with a release layer and formed into a roll of electronic paper. To build a display, this protective sheet is peeled off and the microcup media is laminated to an active matrix backplane to produce an active matrix display panel.

	eReader Media
Contrast	7:1
Whiteness	36%*
Optical Transition Time	250ms
Temperature	0ºC – 50ºC



SiPix active matrix display images

Figure 3: Photos of Displayed Images

Figure 3 shows some photographs of images generated with this media. It is driven with 16 levels of grey on the backplane, has a contrast of 9:1, a whiteness of 36%, and switches in approximately 250 milliseconds.

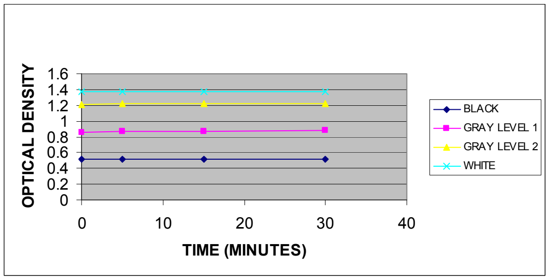


Figure 4: Bistabilty Data

Figure 4 shows some examples of the bistability achieved with such film. Although this data shows the stability out to 30 minutes, this bistabiltiy is very long term so that images have been stored on such panels for years without any notable degradation.

Figure 5a shows a measured grey level vs. drive time. To achieve good grey level performance, a lookup table of waveform lengths is used to produce the grey scale response curve in Figure 5b.

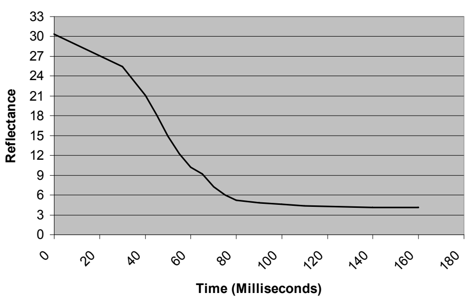


Figure 5a. Media Response vs. Drive Time

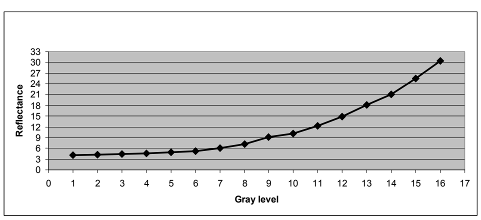


Figure 5b: Grey Scale Response

Improving the whiteness of reflective displays to be suitable for ebooks has been one of the challenges of all reflective display technologies.

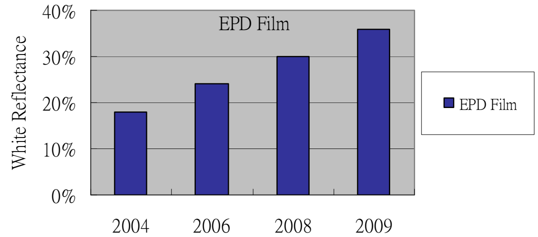


Figure 6: Whiteness History

Figure 6 shows the history of this development for microcup electrophoretic media. The improvements are a result of many technology advances including changes in the dispersion and the particles, optimization of the size and shape of the microcup, optimization of the conductive and reflective layers, and so on. These advances have now taken this to a suitable level to achieve excellent readability as shown in the recently publicly shown ebook in Figure 7.

Figure 7: Ebooks Using Microcup Media

This is by no means the limit of the technology, however. A recent advance which has taken this whiteness as high as 48% in demonstration vehicles is shown in Figure 8.

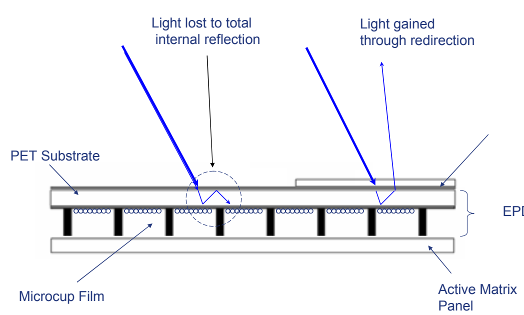


Figure 8: Principle of Light Boost™ Technology

In using what we call SiPix Light Boost^{TM} technology, an enhancement microstructured film is laminated to the top of the media. The purpose of this film is to redirect rays which would have been totally internally reflected at the top PET/air interface so that they are redirected toward the reader. Since as much as 40% of the light can be lost to total internal reflection, this can make a significant difference in brightness. In addition to this, the film redirects some light which would have been scattered in unusable directions towards the reader.

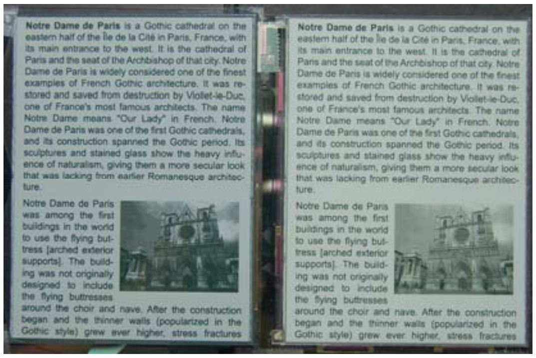


Figure 9: Images with And Without Light Boost^{T}

^{M}Figure 9 shows a photograph of media with enhanced brightness compared to a normal ebook brightness. The enhancement on the right is almost 50%, and although it does not show well in the photo, the contrast is also enhanced.

Conclusion

In this paper we have tried to describe the current status of microcup electrophoretic media for ebook application. Future advances will include higher whiteness, higher speed, and full color.