Magnetically Written Electrophoretic Display

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Keywords: E Ink; microcapsules; electrophoretic display; magnetic, e-paper, flexible, JustWrite™.

ABSTRACT

A new magnetically written electrophoretic display technology (MEPD) has been demonstrated that requires no TFT backplane to image. MEPD maintains the essential paper-like characteristics of ePaper. It has the reflective "paperlike" look, and is readable in direct sunlight. Moreover no power is required for static image. It has the flexibility suitable for bendable, rollable, or foldable applications. MEPD has been coated in a roll-to-roll production line, and is especially applicable for no-lag stylus input and/or large format applications.

1 INTRODUCTION

Writing or drawing is an essential part of paper, which comes naturally and effortlessly. In many ways electrophoretic displays look and perform like paper. Because they are Lambertian reflectors of ambient light with excellent contrast ratios both indoors as well as in direct sunlight, they provide a paper-like reading and viewing experience. Writing, however, has not come naturally. Because image refresh and rendering by the controller can take certain amount of time, there is a latency between the act of writing and the appearance of an image on the display, which can be on the order of 50 – 100 milliseconds (note that even an Apple pencil writing on an iPad has a latency of about 20 milliseconds) [1].

E Ink has developed a new magnetically-written electrophoretic display in which the charged black pigment particles used in conventional electronic paper displays have been replaced by charged ferromagnetic, black particles. Similar types of engineered polymeric surface coatings to those used on a standard black electrophoretic pigments have been applied to the magnetic black pigment. This results in pigment particles that are responsive to both electric and magnetic fields [2]..

2 MEPD FILM AND ITS ELECTRO-OPTICAL PERFORMANCE

The new magneto-electrophoretic (MEP) composition containing magnetic black particles can be switched electrically in the same way as a conventional electrophoretic display: i.e., between white and black states with the capability of also attaining stable intermediate states of gray. When addressed with a magnetic stylus, the fluid exhibits a gray state that is intermediate in optical density between the extreme electrophoretic white and black states. Thus, starting from a white state, the magnetic stylus can produce a relatively dark image, while starting from the black state a lighter image can be formed.

The experience of writing with a magnetic stylus onto E Ink's magnetically-sensitive ink is very similar to that of writing with a pen or pencil on paper because it has no visible latency and no parallax since it does not required a thick layer for protection. The new MEP material, trade named JustWrite™, has now been produced at manufacturing scale on roll-to-roll equipment.

The basic structure of the MEP film is shown in cross-section (not to scale) in Figure 1. Microcompartments, which may be microcapsules, microcups, or polymer-dispersed droplets, are located between two electrodes, at least one of which is transparent. A segmented or TFT backplane can be also be used to add more versatility in displaying printed and graphic information.

The magnetic stylus can be either a permanent magnet or an electromagnet. In either case, the magnetic field produced by the stylus interacts with the magnetic black pigment particles in colloidal suspension, causing them to form chains that are aligned in the magnetic field direction [3][4]. The magnetic particles can be ferromagnetic or superparamagnetic [5].

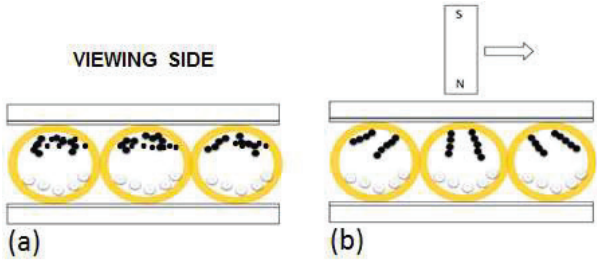

Fig. 1 Schematic, cross-sectional drawing of E Ink MEP film. (a) Dark state switched electrically; (b) Magnetically-written gray state with chained ferromagnetic black pigment particles

The magnetically written image can be erased globally by application of an electric field.

The response time of the magnetically-written film is so fast that no visible latency can be detected when writing with a stylus that produces magnetic fields of at least about 30 Gauss at the active layer at speeds of up to 200 mm/second.

The effect of writing speed on contrast ratio was measured with a magnetic ink with the electrically-driven white and dark states of 78.4 L* and 15.6 L*, respectively, giving a contrast ratio of 27:1. The effect on contrast ratio of writing with a magnetic stylus at various speeds is shown in Figure 2. It can be seen that at very high magnetic stylus speeds the contrast ratio decreases, but these are at speeds higher than those required for normal writing.

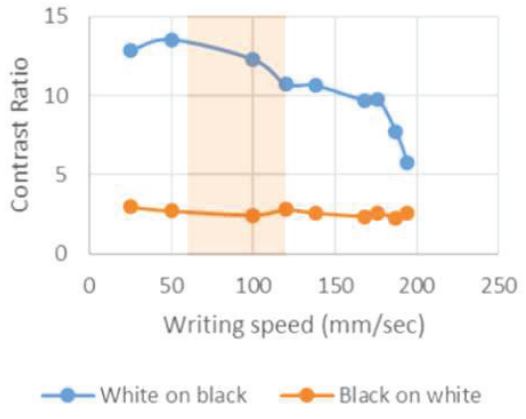

Fig. 2 Effect of writing speed on contrast ratio with magnetic ink giving electrically-driven white and dark states of 78.4 and 15.6 L*, respectively. Normal writing speed shown by shaded region. This ink formulation was optimized for white writing on a black background.

Ink formulations and the stylus design can be optimized to maximize contrast ratios when writing from the dark or white states, as shown in Figure 3.

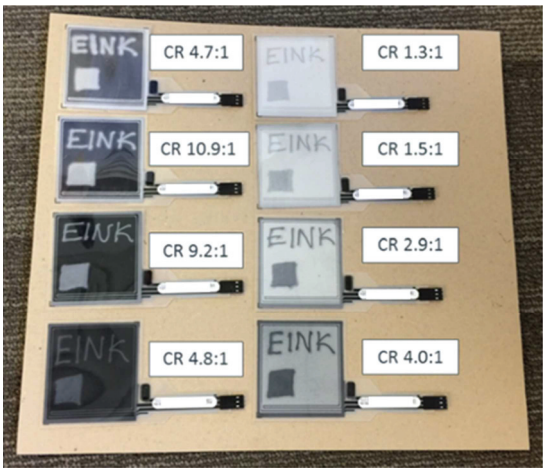

Fig. 3 The effect of different ink compositions on contrast ratio with magnetic stylus writing from dark and white states.

As mentioned above, the stylus used for writing onto E Ink's MEP film can be either a permanent magnet or an electromagnet. The use of an electromagnetic stylus gives the opportunity to change the applied magnetic field dynamically. Simply changing the frequency of alternating current supplied to an electromagnetic writing head can change the image appearance. Figure 4 shows this effect, together with a demonstration of writing lines close to the width of a single microcapsule, using an electromagnetic writing head that in this case was located adjacent to the underside of the writable film. A linear or two-dimensional multi-pixel array magnetic print head could be used to write high resolution images onto a magnetically sensitive electrophoretic film without the need of adding the cost of a TFT or multi-segmented backplane.

While there are many product options for this new MEP film, probably the lowest cost and simplest products will be the use of a simple permanent magnet incorporated into a stylus with the form factor of a conventional pen, pencil, or marker. This has the advantage of retaining the natural feel of familiar writing tools and does not require a battery except to erase an image. Figure 5 shows writing with a magnetic stylus with the form actor of a pencil. Stylus design can control the width of lines and other aesthetic writing.

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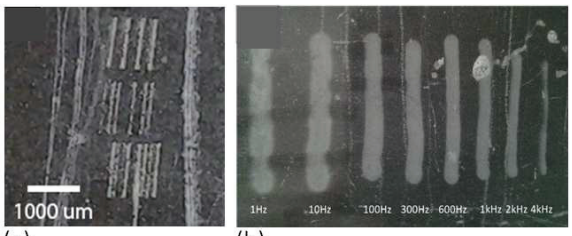

Fig. 4 Writing onto magnetic film with electromagnetic head. (a) High-resolution lines (width ~100 microns); (b) changing line width by adjusting the frequency of AC current supplied to the electromagnet at a constant voltage.

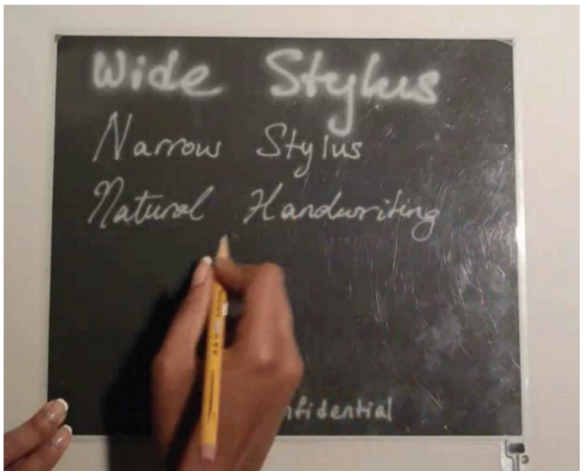

Fig. 5 Natural writing with a pencil-like stylus

MEPD is well suited for large area writable/erasable smart surface applications for both kids and adults. In the education space, MEPD can replace blackboards (or whiteboards) and "writable" films and paints. Unlike the conventional blackboards or whiteboards, MEPD has no chalk or marker dust mess. It is non-toxic, and erasable with one button. Other potential applications can include healthcare board for planning, communication, or patient information, office collaboration board, writable desks or tables, etc. Fig. 6 shows a children's desk – Draw, Learn, and Play

Fig. 6 Children's Desk – Draw, Learn, and Play
These images are actual drawings on JustWrite™ displays.

3 CONCLUSIONS

Magnetically written electrophoretic display (JustWrite™) has been demonstrated to exhibit excellent writing capability with no visible latency, and require no patterned backplane to image, while maintaining the essential paper-like characteristics of the e-paper. MEPD has been coated in a roll-to-roll production line, and is well suited for the large area applications such as eBlackboard, Healthcare board, writable desks or tables, etc.

4 ACKNOWLEDGEMENTS

The valuable contributions of Richard J. Paolini, Jr. and Stephen J. Telfer to this work are much appreciated.

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