Advances in Microencapsulated Electrophoretic Ink for Flexible Electronic Paper Displays

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Abstract

True electronic paper displays are being enabled by the development of two core technologies – plastic electronics for display backplanes and electrophoretic ink for use as the imaging layer. Electrophoretic ink developed by E Ink Corporation continues to advance performance along with parallel technology breakthroughs in flexible TFT backplanes. An overview of these advances in the ink imaging material will be discussed with special emphasis of the expected impact on the emerging flexible display applications.

1. Introduction

Early demonstrations of microencapsulated electrophoretic ink showed promise for the future of ultra low power, thin, lightweight, paper-like displays [1]. The technology has now advanced to roll-to-roll production status for use with flexible segmented displays and rigid glass TFT displays. Both types of displays are highly readable and consume very low power due to the multi-stable properties of the pigments [2]. Microencapsulated electrophoretic inks are ideally suited as an early-adoption platform for flexible and rollable TFT displays for a variety of reasons discussed below.

First, the microcapsules provide an intrinsic inter-substrate spacer layer, thereby eliminating the need for additional spacers. Second, the lambertian reflective pigment characteristics give a uniform image even with bent displays where the viewing angle varies due to the curvature of the display.

Electrophoretic displays have been demonstrated on amorphous and poly silicon transistor backplanes for both plastic and stainless steel substrates [3-4]. Relaxed TFT performance requirements such as low mobilities and low current have enabled the use of emerging organic TFT technology [5-7]. Continued advances in ink performance research such as improved white state, address time, and environmental operational ranges show promise for continuing improvements for future generation products into the future.

2. Ink Performance

Advances in ink materials and design have allowed the demonstration of electrophoretic displays with significantly improved brightness, contrast ratio, and response times. These laboratory demonstrations are compared in Table 1 to the commercial ink now in production.

Parameter	**In Production (since 2004)**	**Research Demonstrations**
WS / CR	35% / 10:1 (Lambertian)	>50% / 20:1 (Lambertian)
Address Time @ 15 V (B<->W)	500 ms	60 ms
Lowest Voltage @ 500 ms	15V	< 5V
Functional T	-10 deg C	-40 deg C
Mechanical Robustness	passes 15 cm Ball Drop	> 115 cm Ball Drop
Flexibility (FPL thickness)	Semi-Flexible (> 200 mm)	Very Flexible (< 65 mm)
Viewability	dim indoor to bright sun	very dim indoor to bright sun full dark with frontlight
Backplane Types	Si TFT on glass	Si TFT on glass, plastic, steel Organic TFT on plastic
B&W / color	2 bit gray scale color overlays	4 bit gray scale full color (CFA) RGB pigments

Table 1. Ink performance is given for new ink formulations as compared to the current commercialized ink product.

For the newest inks, contrast ratios exceed, and reflectance approaches the value of those for popular newspapers (Figure 1a). Outdoor readability in bright sunlight is a significant challenge for typical backlit or emissive displays. Figure 1b demonstrates the readability E Ink electrophoretic displays in office lighting and full sunlight. A low power LED backlight was also demonstrated for applications such as cell phones where readability in complete darkness is required.

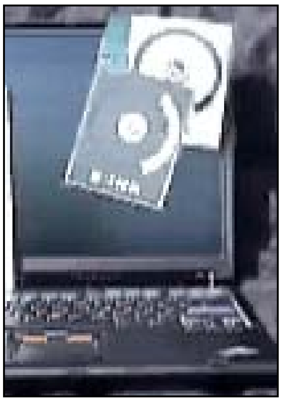

Figure 1a (left). An E Ink flexible segmented display on PET is compared to a newspaper in office light.

Figure 1b (right). An E Ink flexible segmented display in full sunlight is compared to an IBM R40 computer in the full backlight brightness position. The computer image could not be read under full sunlight conditions.

The time required to change from white state to black state is dependent on the driving impulse, that is the voltage times the duration of application of the voltage across the ink. New inks have been demonstrated that can be driven at voltages as low as ± 5V at 500 ms, or as fast as 17 fps at ± 15V for a black to white or white to black state transition.

Extremely robust electrophoretic inks have also been demonstrated that can survive a hammer blow with minimal damage using no mechanical protection layers. These ink designs will be especially important for ultra-thin displays that will be rolled and unrolled after each use.

3. Conclusions

Microencapsulated electrophoretic inks are an ideal frontplane for conformable, flexible, and rollable electronic paper displays due to their inherently flexible form, angular independence to lighting and viewing angle, readability under a broad range of lighting conditions, and compatibility with a variety of flexible TFT backplanes.

4. References

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