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E-Paper Opportunities-2009

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Executive Summary

E-paper displays are reflective devices that deliver crisp text and images for very little power. They are also typically thin, lightweight, devices that are conducive to implementation on flexible substrates. Some, in addition, are printable, and many types of e-paper are bistable, that is, they can retain screen contents without consuming power. E-paper is, in short, very much like ink and paper, with high contrast ratio, outdoor readability (a major appeal of these reflective devices) and the potential for high resolution and low cost. Its value proposition is that it combines the benefits of paper with the dynamism of displays.

Today's e-paper contestants include: bistable TN (twisted nematic) LCDs (liquid-crystal displays) from such companies as Nemoptic and ZBD Displays Ltd.; Ch (cholesteric) LCDs from Kent Displays Inc., Fujitsu Frontech, Matsushita, Varitronix International and others; ECDs (electrochromic displays) from Acreo, Aveso and Ntera; and EPDs from E Ink Corp., SiPix Imaging Inc. and Bridgestone Corp. The line-up also includes a MEMS (micro-electro-mechanical-system) display entry called iMod™ (interferometric modulator) from Qualcomm MEMS Technologies Inc. (QMT), and EWDs (electrowetting displays) from Philips spinoff Liquavista.

The slate of e-paper contestants includes some unknown names, which do not represent the corporate clout that stands behind some of these companies. Behind the slate stands a long list of significant financial backers, technical collaborators, manufacturing partners, value-added resellers and marketing partners.

E.1 Summary of Market Opportunities

E-paper can be applied across a broad range of applications; some of these now rely on ink and paper, and some make use of established flat-panel-display (FPD) technologies. The main applications for e-paper today include electronic signage, portable electronics, information displays, advertising displays, gadgets and throwaways such as smartcards, novelties and smart packaging.

E-paper excels in providing a crisp, contrasty, monochrome display in a thin, lightweight format. Its strongest appeal is its low power requirement, which extends the battery life of handheld equipment and provides a "greener" (lower-power) solution for fixed installations. In addition, the outdoor readability enabled by reflective e-paper is well suited to portable electronics, now limited to indoor use by their transmissive or emissive displays.

There is a wide range of other applications to which e-paper is suited, including some very traditional display applications and other areas that have yet to incorporate an FPD. Simple e-paper devices provide the opportunity to deliver information in scenarios that were previously mute. In one real world application, a simple e-paper bar code now lets a USB memory stick tell the user its remaining capacity, without having to load it into a computer.

The possibilities for e-paper are particularly rich. The greeting card industry has vigorously applied the technology for singing/talking cards, using relatively unsophisticated electronics. Can e-paper—flat and flexible from the get go—be far behind? We're told that "digital bricks," wall material with integrated e-paper, will appear by the end of this year in Japan. For displays in well-lighted environments, e-paper has an opportunity to find a place, whether it's in office automation equipment, advertising displays or outdoor billboards. The list goes on.

Portable electronics provides huge opportunities for small- and medium-size e-paper screens. In small screens, targets include watches, smart graphics, and cell-phone main and sub displays; in medium size screens, they include PDAs, instruments, games, e-book readers, ultramobile PCs and portable terminals of all kinds.

E-paper is, further, perhaps the most promising display technology for disposable electronics. There is substantial pent-up demand for a simple alphanumeric function built into smartcards of various sorts, for example, for both informational and security reasons. E-paper will also be a contender for smart packaging applications, where it entices consumers to buy, or informs them about, the product inside the package.

E.1.1 Opportunities and Evolution in the E-Book Reader Market

Since our last report, e-book readers have firmly established themselves in the marketplace; according to the estimate of one stock analyst, the Amazon Kindle alone now accounts for 10 percent of all the books sold in the U.S., for example. E-book readers could use any display technology, but right now, they are e-paper's market to lose, but it is unlikely to lose out to any other technology in segments where sharp black and white text and long battery operation are prized. The E Ink EPDs that virtually own the e-reader space today will, however, find competition in other e-paper technologies, some of which have better speed and color capabilities.

As e-readers evolve, some will specialize in providing a low-cost reading function, while others will come to resemble personal terminals or "e-platforms" as they incorporate more and more functionality. The Amazon Kindle, for one, provides wireless communications, an integrated keyboard and web browsing capability, so it's far more than just a reader. Those with larger screens may come to resemble full-fledged tablet computers or portable offices over time to compete with conventional portable computers that have an e-reader function on-board.

Larger screens will expand the market segments that e-readers can attack. Today's 6-inch-diagonal screens are suitable as e-book readers for consumers used to reading paperback books. Ten-inch and larger screens open the way to e-newspaper readers, as well as to e-document readers for professional users used to juggling reams of information on paper at their desks and on the road. Larger-screen e-readers will help spread the base of users into the professional realm, with their ability to effectively present more complicated documentation, akin to the document formats common to paper and computer screens today.

From the perspective of e-paper opportunities, the big question is whether there is room in the market for materials other than the electrophoretic film supplied by E Ink. Almost every book reader on the market at the present time uses this material; the Amazon Kindle and the Sony book reader certainly do, as do the upcoming offerings from Plastic Logic and Polymer Vision. It is hard to believe that E Ink will effectively hold a 100-percent share of this market forever or that, more generally, electrophoretic technology will; in our forecasts, we have shown other technologies taking a share of the e-book reader. At the same time, it is unclear where the competition will be coming from.

In particular, because of Amazon's hard to compete with library of e-books, the Kindle seems likely to set the pace for the industry for years to come. Kindle could sell as many as 800,000 to one million units in 2009 and the Kindle 2, which began shipping early in 2009, is said to be selling at roughly twice the rate of the original unit. Helping sales will be the new larger-format Kindle DX. It seems unlikely that either Amazon (or for that matter Polymer Vision, Sony or Plastic Logic) are going to switch core materials/technologies/suppliers at this point, so any real opportunities for suppliers of materials or technologies in this space depend on the emergence of other high-volume suppliers of e-book readers.

With this in mind, one should note that Fujitsu has released a color e-reader in Japan, while Samsung plans to unveil an e-reader with touch-screen capability in South Korea this year. In Europe, iRex Technologies makes a versatile line of e-readers with touch screens and Wi-Fi. That two leading Asian consumer electronics firms are getting into the e-paper business suggests that Amazon could ultimately lose some market share. While Amazon's rivals may not have the access to content that Amazon does, they may be able to compete using larger/flexible displays, touch screens, color, more sophisticated text management and even video. Most of these additional features should be fairly easy to offer in an e-paper environment, at least eventually. Also, one should remember that Amazon is not as strong in other parts of the world as it is in the U.S.

The opportunity for e-book readers and the e-paper materials and components that go into them will also depend on how far the e-book can be expanded into new markets. At the present time, most of the buyers are likely to be tech-savvy book enthusiasts and there are just so many of those; around 14.9 million U.S. households regularly buy books online. One hope of the book reader industry is to expand its sales into educational markets (students who don't want to carry around books, for example). However, expanding e-book reader functionality does not necessarily mean that e-paper sales will expand. Amazon is, for example, expanding Kindle capabilities to the iPhone, which will not grow the market for e-paper at all.

E.1.2 E-Signage Opportunities for E-Paper

Electronic signage is a huge, mostly untapped arena that's extremely fragmented and wide open for new technologies to have an impact. The e-signage market covers a range of products from simple electronic shelf labels (ESLs) and pricing tags through flashy advertising signs all the way up to large public information displays and huge outdoor billboards. E-paper is unusually scalable across this range.

Outdoor displays: The use of e-paper in large outdoor displays/billboards is something of a niche opportunity. In this area, e-paper will be capitalizing on the rise of digital signage, a market with a long way to go; in the U.S., for example, there are about a half-million billboards, but only a few hundred that are digital. E-paper does not seem to be a complete slam-dunk for outdoor displays, especially with the lack of color. However, at least one company, Magink Display Technologies, seems to have focused on this area and is pushing its ChLCDs as the green alternative to LEDs for billboards. Another selling feature of e-paper in this segment is its ability to be read in bright sunlight. Magink has already had some substantial success in this area. Following a 2008 that included such high-profile installation sites as the New England Patriots' Stadium and Hall of Fame, Magink has had a number of significant announcements and installations already in 2009. These include a billboard design win at Sign and Vision Limited, a leading outdoor advertising company based in Austria, and a showcase "animated façade" installation at the Barbizon Lighting Company in New York. NanoMarkets believes that other firms may follow in this Magink's footsteps.

Indoor information and advertising displays: Another niche opportunity for e-paper is to be found in indoor information and advertising displays. Again, the absence of color may be an issue here and it is unlikely that e-paper will take over this sector. It is also true that e-paper's ability to be read in bright sunlight is not that important for indoor environments. On the other hand, the crisp sharp text associated with e-paper may be an advantage for certain information displays. Some firms are already entering this space with clever ideas such as Fujitsu Frontech's 12-inch information "tiles." Both Fujitsu Frontech and Magink have been installing various types of display systems for several years in airports, stadiums and hospitals. Nemoptic has found some success in exhibition signs, and says that it expects to compete across the signage space from price tags to signs containing product information, transportation information and advertising. Toppan is also known to be developing products for the advertising market using E Ink technology.

ESLs: Although we have downgraded our numbers for electronic shelf labels (ESLs), this sector has by far the largest potential of any of the signage areas in which e-paper is likely to compete. Most ESLs today are small LCD segmented displays and e-paper can improve on what's on offer by easily adding dot-matrix graphics capabilities, while preserving (or perhaps even improving on) the long life of the battery. E-paper ESLs also seem to be capable of displaying barcodes. E-paper may also be have an advantage in its potential flexibility; real labels are, after all, flexible. And from a supply standpoint, small electronic labels are a fairly easy entry point for e-paper makers when one compares it to the huge marketing infrastructure that needs to be built around new e-book readers and the technical problems associated with making large displays.

E-paper is already having a major impact in ESLs in particular, where it is fueling a movement beyond simple segmented pricing signs to dot-matrix signs that can handle more (and more complex) information. Also, it appears that ESLs are continuing on an upswing, despite poor economic conditions. Or perhaps the poor conditions are fueling the movement to this proven contributor to cost savings, where the money (or credit) to invest in technology is available. While the e-book reader

market is already dominated by a couple of large players and the other parts of the signage market are very niche like, the ESL market is still open territory in which several e-paper makers are serious players, but in which opportunities can still abound. E-paper firms active in this space include Nemoptic, SiPix and Bridgestone to name just three.

E.2 Firms and Technologies to Watch

E.2.1 Frontplanes Meet Backplanes

The coming activity in e-paper will be spread across the range of technologies and companies. In the e-paper space, it is hard to get away from E Ink, which has become—as it were—the Microsoft of e-paper. E Ink's pending acquisition by Prime View International (PVI) essentially creates a power house that will be capable of supplying the display industry with combined frontplane and backplane expertise for the first time. This obviously makes operational sense and is perhaps no surprise given that backplane and frontplane technology are now relatively mature. In the past, keeping these two areas separate made sense because the relatively small firms involved in the e-paper space needed to focus on one thing at a time.

The combination of E Ink and PVI is about more than just operational efficiency, however. It also brings together the industry-leading e-paper frontplane technology with the industry leading e-paper backplane technology. Although it has not received the notoriety that E Ink has, PVI is a central player in a number of these technologies and NanoMarkets believes it will continue to be in the forefront, until perhaps some firm beats it with an innovative flexible backplane technology. PVI was the first to work with E Ink to supply EPD modules, and it is the foundry partner for QMT and its MEMS displays. It is also working with Liquavista on active matrix (AM) versions of that company's EWDs.

With the marriage of frontplane and backplane in the e-paper space upon us, two other firms that are worthy of attention are Plastic Logic and Polymer Vision. These were both once primarily backplane firms that used organic TFTs (OTFTs) in their products. However, they are now more and less than they used to be. They have both remade themselves as e-book reader firms, which gives them access to a much larger revenue stream than they once would have commanded, but is a much more demanding strategy in terms of capital and the need to build infrastructure than their original strategy. It remains to be seen whether these relatively small firms (when compared to Amazon or the large Asian consumer electronics firms) will be successful in this field. At the same time, Polymer Vision and especially Plastic Logic are downplaying one of the main supposed advantages of their OTFT technology—namely flexibility. The first Plastic Logic product is not flexible, and instead emphasizes touch screen capability. The Polymer Vision product is more foldable than flexible.

E.2.2 Moving Beyond EPDs?

The casual inquirer into e-paper technology could be forgiven for assuming that all e-paper was electrophoretic. This is largely because of the impact of mindshare leader E Ink, rather than because electrophoretics is superior to any other e-paper technology. But nothing succeeds like success and it

seems likely that the already present hint that electrophoretic technology is an "industry standard" will help other firms with EPD. SiPix is one firm that is already making EPDs and has been for some time, although it does not seem to have achieved the fame of E Ink. Meanwhile, Bridgestone has become a player with a high-speed variation that makes an AM backplane unnecessary in many applications. NEC is expected to join Prime View International and LG Electronics as a manufacturer of E Ink EPD modules.

But no one should discount other technologies that may have technical advantages or may get to color faster than EPD. (With this in mind it is notable that Amazon has said that it does not expect to have color e-book readers available for many years.) Finally, it is possible that at some time in the future, some non-EPD technology may receive a boost the way that EPD has from an adoption by a powerful company; obviously, however, the who or what of such an adoption is mere speculation at this point in time.

That said, e-paper using some kind of liquid crystal technology seems like a good bet for future success. After all, LCD is truly an industry standard for displays and cholesteric liquid-crystal displays were the first e-paper to reach the market. This type of liquid crystal display is also moving on several fronts. With its new manufacturing line for flexible ChLCDs in place, Kent Displays is pushing hard at the low end, while Fujitsu Frontech is vying for indoor information displays with 12-inch "tiles" and for personal information terminals with its pricey FLEPia device. Magink Display Technologies, meanwhile, is pushing ChLCDs as the green alternative to LEDs for billboards.

The other LCD technology being used in e-paper is based on bistable TN LCDs. Here several companies are fielding variations on the conventional passive matrix (PM) TN LCDs. These variations incorporate proprietary mechanisms into an otherwise conventional display to give it bistability and, thus, improve viewing characteristics and enable larger pixel counts. Nemoptic has granted Seiko Instruments a license to manufacture its bistable TN LCDs.

There are other kinds of e-paper technology, of course, including some that are barely out of the lab. Two that impress us are electrowetting and MEMS. The electrowetting display technology of Liquavista BV, a 2006 spinout of Philips Research Labs, is an intriguing technology with lots of application potential. Its fate will depend on the success (and speed) of the company's AM development activities. Meanwhile, one type of reflective micro-electro-mechanical-system display, the DMD (digital micromirror device) of Texas Instruments, has had a major impact on electronic projectors. Now a Qualcomm subsidiary named Qualcomm MEMS Technologies Inc. hopes to revolutionize handheld equipment with its version of the reflective MEMS—the iMod (interferometric modulator) display. First products are small monochrome displays, but the company has larger things in mind, as well as multicolor devices capable of displaying video. A new factory for second-generation devices went on line in May 2009.

Finally, there are electrochromic (or electrochemical) displays. These are lower quality—and potentially less expensive—technology than the other varieties of e-paper display. However, they

provide an attractive alternative to PM LCDs for simple segmented applications. Aveso Inc., a 2004 spinout of Dow Chemical, leads the pack. While ECDs are unlikely to ever compete with EPDs in higher end applications such as e-book readers, they are well suited to a particular large and growing segment of the e-paper market, namely smartcards.

E.2.3 The Color Story

There can be little doubt that the main problem with e-paper at the present time is its lack of color. It is obvious that for most applications, color is now a requirement for any new technology and in our view any e-paper firm that can provide a stable high-quality color technology at a reasonable cost will have a lot going for it. Color can be reasonably easy to achieve with color filters, however, this tends to compromise reflectivity and brightness and the goal is to create e-paper technologies in which color is intrinsic. Color e-paper of this kind is now available, but there have yet to be any real breakthroughs and typically color e-paper is either not very good as far as the quality goes or there is a significant penalty in adopting color in terms of speed or cost. E-paper will not be able to penetrate the cell phone/mobile computing market, which we believe will represent a huge market for e-paper once color appears, until these tradeoffs disappear.

There is also the question of "color" versus multicolor. Some e-paper technologies are inherently bi-color. EPDs could easily be red and green, rather than black and white. It's just that black and white ones are more appropriate in most applications. It is possible to extend some e-paper technologies to include more than two colors. Thus, some e-paper vendors offer interesting color combinations: white plus red, green, blue, gold or black for SiPix EPDs, for example, and blue/white, red/amber, yellow/green, pink/peach and orange/yellow for Varitronix's ChLCDs. For its part, Liquavista EWDs come in green, red, purple and two shades of blue, but the company can custom blend colors for customers to "match their corporate colors to enhance branding."

However, getting to full color is much more challenging and it is a goal that is still quite some way from achievement. Between the extremes of monochrome and full color lie several levels of multicolor, and there are several alternative paths to achieving them. The default technique for bistable LCDs and EPDs has been traditional RGB (red, green, blue) color filters like those used by conventional LCDs. Using conventional color filters allows vendors to come to market quickly with multi-color e-paper, leveraging the established LCD manufacturing base. But as we have already noted, color filters are limiting technologically.

There are yet other conventional colorization techniques, including temporal schemes (for technologies that are fast enough to fool the eye), which sequentially display R, G and B fields. More common, though, are so-called "stacked" displays. These are typically constructed as a sandwich of three displays dedicated to three primary colors, usually CMY (cyan, magenta, yellow) in a subtractive color scheme.

Not surprisingly, each of the different e-paper technologies has its own advantages and challenges when it comes to color. Thus, Fujitsu Frontech claims that stacking monochrome ChLCDs to create

multi-color displays yields an additive reflective effect that greatly improves color quality. EPDs seem particularly conducive to alternative colorization schemes. Mixing particles of three primary colors, which respond to different drive voltage characteristics, for example, seems intuitive but also necessitates a more complex drive scheme with more complex drive electronics.

E.2.4 Flexibility

E-paper has become increasingly identified with "flexible" displays, in part because e-paper is "paper like" and paper is inherently flexible, so intuitively e-paper should be too. This is certainly the direction that e-paper product makers would like to see things develop technologically, but most e-paper products to date have not been flexible. However, prototypes of flexible displays have been shown for at least 10 years and progress toward commercialization is being made.

First, it is worth noting that the industry leading frontplane technology supplied by E Ink is printed on a flexible substrate, but so far all the widely available e-book readers using this technology have been rigid, although this could change quite soon. Polymer Vision plans to release a "flexible" display later this year, although this seems to be more foldable than flexible for the time being. Meanwhile, at the end of 2008, Kent Display installed and began operating a flexible-ChLCD manufacturing line, running the company's proprietary in-line process called polymer-induced phase separation (PIPS) for a simple display product. Fujitsu has also recently introduced flexible e-paper technology. Plastic Logic's first product will be a Kindle-like e-book reader with touch-screen capability rather than flexibility. However, Plastic Logic has been such an advocate of flexible displays over the years that it is hard to believe that this company will not also move in the direction of flexible displays in the not too distant future.

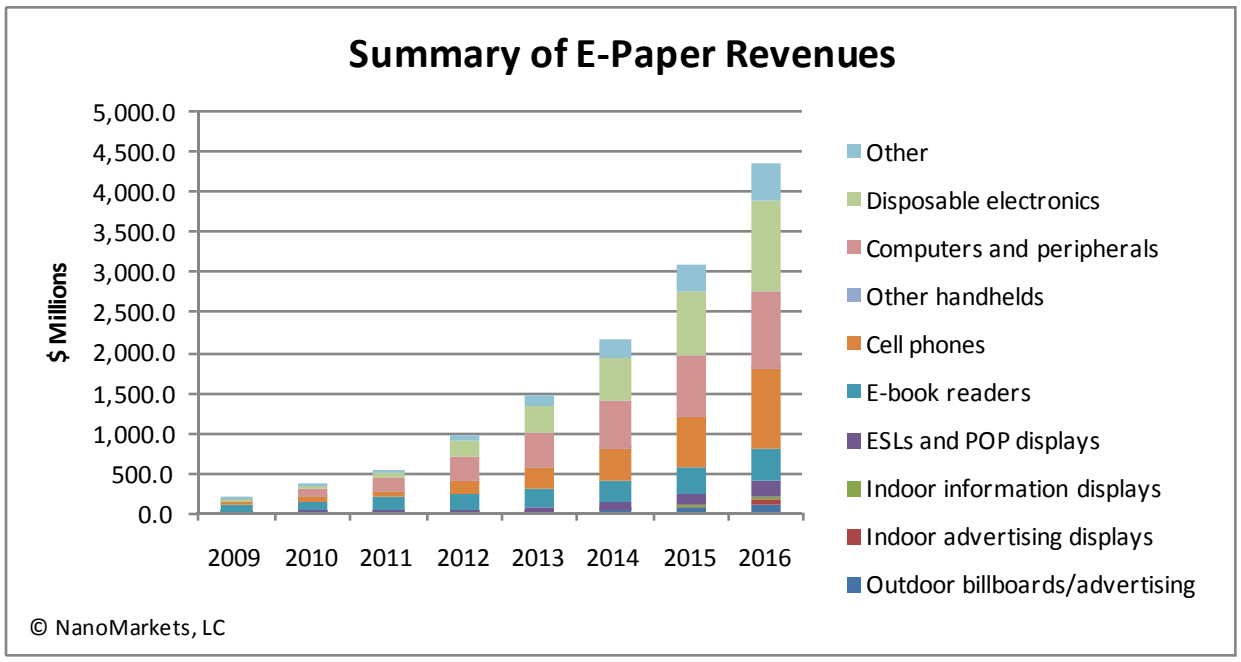
In fact, serious moves toward flexible products are taking place in almost all the e-paper technology areas. Both the major manufactures of bistable TN LCDs—ZBD and Nemoptic—have demonstrated flexible products. Kent Displays and Fujitsu, as mentioned above, are representatives of the Cholesteric LCD camp with flexible products in early commercialization phase. In the ECD space, Aveso's product is already a flexible offering and Ntera has a flexible prototype. And finally in the dominant EPD sector, all the leading players have flexible displays in at least prototype form. Qualcomm's MEMS display does not seem to have a flexible version yet, however.

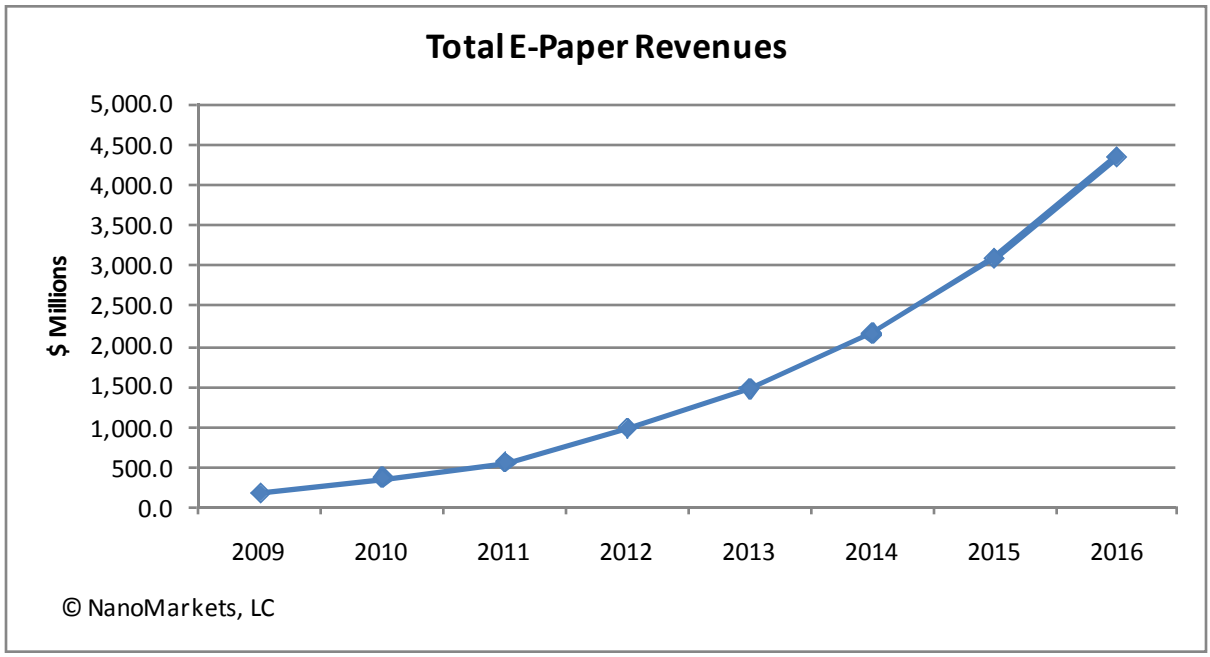
That flexible displays are taking such a long time to appear—certainly longer than NanoMarkets originally expected—is an issue. However, we believe that the industry indications suggest that they are making steady (if slow) progress. In addition, there seems to be some good demand-side reasons for thinking they will take off. In particular, for e-book readers we believe that the market would like to see larger screens for readability issues, but at the same time would like e-book readers to remain compact. Flexible displays solve that problem. In addition, flexible ESLs would make these devices more label like, perhaps making them easier to install and potentially helping to extend the concept of electronic labels to smart packaging. Finally, it is important to recognize that—despite initial appearances—the flexible display "movement" is larger than just e-paper. There are efforts to make

OLED displays flexible and (to a limited extent) even conventional LCD displays. Flexible e-paper displays will benefit from developments in these sectors too.

E.3 Summary of Forecasts: The Potential in Cell Phones and Smartcards

Exhibit E-1 summarizes NanoMarkets forecasts for the e-paper sector over the next eight years. Much more detailed forecasts are contained in the main body of the report. The reader should note that the values represent the value of the e-paper itself, that is, the display frontplane. This year (2009) is the first year that the e-paper market is expected to achieve over $100 million in sales and it will do so primarily because of the sudden success of e-book readers and the Amazon Kindle especially.





However, there are limits, we believe, to how far one can expand a display product aimed at people who want/need mobile access to lots of textual material and for Amazon the real goal is to sell more books not to sell Kindles (certainly not to sell more e-paper). We think that, the perspective of the e-paper maker, the e-book market will likely be eventually over taken by the cell phone market and the smartcard market. In both cases there are huge addressable markets and very clear advantages to using e-paper. In the cell-phone market, e-paper could better provide readability in sunlight (especially important in subdisplays, where e-paper can expect immediate implementation) and integrated e-book capabilities; the big downside for using e-paper in cell phones is the current lack of color capability. The initial draw for using e-paper in smartcards is that e-paper seems to be well suited to providing OTP capabilities, with other functionality likely in the future.

For additional information about this and other NanoMarkets' reports, please contact us at (804) 360-2967 or via email at sales@nanomarkets.net or visit us at www.nanomarkets.net.