TABLETS, eREADERS, AND MUCH MORE

Information DISPLAY

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SOCIETY FOR INFORMATION DISPLAY

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February/March 2012
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What's Next for eReaders & Other Portable Applications

Plus, Principles of Holographic Displays and Stereoscopic Vision

AMERICA INVENTS ACT: WHAT YOU NEED TO KNOW

THE RISE OF THE ULTRABOOK

TOUCH TECHNOLOGY MEETS eREADERS

DISPLAY WEEK 2012-FIRST LOOKS AND HOT TOPICS

eREADERS FOR TEXTBOOKS: CAN IT WORK?

NEXT WAVE IN FOLDABLE DISPLAYS

Plus

Journal of the SID February/March Contents

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ON THE COVER: *Tablets and eReaders place display engineers in paradoxical situations that are full of trade-offs. They are, therefore, platforms for the introduction of new display technologies. This extremely rich area of display development will be relevant – and controversial – for a long time to come. One can easily argue that this sector of displays has the largest number of distinct technologies pitted against each other. How long will it last? Maybe until that ultimate full-color, video-rate, readable in all-lighting conditions, unbreakable, foldable, and energy-saving touch-driven display is developed. In the meantime, a few technologies have been carefully matched to the right applications, enabling early entry even without perfect screen performance. An example of this is E Ink's electrophorectic display made in a roll-to-roll processing plant in Massachusetts. In the photo, the latest geration of E Ink's display film is unrolled alongside the Charles River near Boston.*

Photo Credit: Gary Sloan
Cover Design: Acapella Studios, Inc.

Next Month in *Information Display*

SID 2012 Preview / Backlights
- Syposium Preview
- Honors and Awards
- LED and Backlighting Forecast
- Evolving LED-Based Edge-Lit Light Guides
- Monolithic Segmented Light Guides
- Part II of America Invents Overview

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contents

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editorial

The Progress of Portable Displays

by Stephen Atwood

This month, we take a look at the topic of tablets, ranging from eReaders to holographic displays, but I want to start with some observations on the topics of tablets, eReaders, and other portable displays. We asked guest editor Jason Heikenfeld, Associate Professor & Director for the Novel Devices Laboratory at the School of Electronic and Computing Systems at the University of Cincinnati, to help us understand the latest product trends, as well as how the new devices would be used, and what the future looked like for these types of products. Jason assembled a nice lineup of perspectives we are pleased to feature this month.

It is easy to be optimistic about this segment of the industry when you see the significant adoption of eReaders, tablets, smartphones, and other similar devices appearing everywhere. I am on an airplane as I write this, and everyone around me is peering into their tablet, smartphone, or eReader. I feel out of date with my traditional laptop computer and 15-in. screen as I click away on an almost full-sized keyboard, counting the precious minutes until that dreaded pop-up flag alerts me to an empty battery. (I might also acknowledge that I feel pretty cramped too and will soon shut this down and grab my Kindle.) My fellow travelers are enjoying state-of-the-art touch screens and almost unending battery life with much more space on their tray tables. There has clearly been a revolution in personal-computing technology.

However, as much as it seems that the frontier of personal-computing devices has been conquered, some functionality still appears to be missing. For example, all of the devices I can buy today use fixed, flat, rigid displays. The display dictates the physical outline of the device and displays larger than about 5 in. on the diagonal relegate the device to a bag or purse for transport.

The entire time I have been working with *ID* magazine, we have been publishing articles on flexible displays and trying to keep a balanced view between the hype of "just around the corner" and the pessimism of "that will never happen." We have published numerous articles on the underlying technologies for flexible displays, carried various accounts about the supply chain and manufacturing technologies required, talked at length about the uncountable advantages of a display that can bend or fold, and in some cases noted the loss of early-entry developers who tried and failed to achieve the goal. Most of these perspectives have been positive, but none have demonstrated the proof that rollable or foldable displays are soon to be in our hands in any mass-market application. The wait has been long.

This month, we offer another optimistic view in our Frontline Technology feature, "The Future of Displays is Foldable," by author Edzer Huitema from Polymer Vision. Edzer's view is that most of the underlying technology is indeed in place today, with well-understood manufacturing processes and ever-improving substrate materials. The challenge, in part, will be to merge the "foldable" part of the effort with new display technologies such as OLED and electrowetting to move beyond the limited range of performance currently available from electrophoretic. Between now and then – and Edzer's view is that "then" means another 3–5 years – we will need to see if the chicken-and-egg cycle of consumer acceptance can fuel any more product development to spur better volumes and hence generate enough revenue and profit to see any rollable or foldable electrophoretic offerings become mainstream.

(continued on page 44)

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industry news

2011 Holiday Sales Highlights

According to the National Retail Federation, U.S. retail industry sales for the 2011 holiday season were up 4.1%, year-over-year, with total sales of $471.5 billion between November 1 and December 31.[1] This positive news is somewhat tempered by data from the United States Department of Commerce, which, while acknowledging that consumer spending picked up at the end of the year, notes that sales of automobiles and the higher price of gasoline may have had more to do with the upturn than widespread consumer confidence.[2] As it turns out, retail holiday sales are difficult to track. Strong Black Friday and Cyber Monday sales do not necessarily equate to stronger sales during the rest of the season, and what with returned merchandise and gift cards still to be redeemed, it may be a few months more before we have a definitive number. In the meantime, here are some interesting facts about sales relating to the display industry.

Amazon does not release sales figures, but has divulged that 2011 was the best year to date for sales of its Kindle products. Throughout December, customers purchased well over 1 million Kindle devices per week. The $199 Kindle Fire (with an IPS LCD rather than an electrophoretic display) was the number one selling item on Amazon.com for the 12 weeks leading up to Christmas.[3]

According to a recent Pew Internet report,[4] tablet and eBook-reader ownership increased spectacularly over the 2011/2012 holiday gift-giving period, with the share of adults in the United States owning tablet computers nearly doubling from 10 to 19% between mid-December and early January. eReader owners also jumped from 10 to 19% over the same time period.

The report noted that prior to the holiday season, from mid-2011 into the fall, there had not been much change in the ownership numbers for tablets and eBook readers. The authors surmize that Amazon's new low-priced tablet, the Kindle Fire, and Barnes & Noble's Nook Tablet, which were introduced at considerably cheaper prices than other tablets, may have spurred spending. In addition, the introduction of sub-$100 Nook and Kindle eReaders very likely made it easier for consumers to take the eReader plunge.

GameStop Corp. reported that holiday sales increased only slightly, as sales of new video game software from PlayStation 3 and Xbox 360 titles such as "Call of Duty 3" and "Elder Scrolls V" offset a 20% drop in hardware sales. According to Reuters, sales of traditional video game products such as consoles have been struggling worldwide as gamers have turned to online gaming as well as gaming on tablets and phones.[5]

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Flexible Technology Update: ITRI Develops Rewritable Paper

Taiwan's Industrial Technology Research Institute (ITRI) recently introduced its i2R technology, electronic paper that is both re-writable and re-usable. To use it, you send an image to a thermal printer, which transfers the one-color image to the electronic paper (Fig. 1). The e-paper can be cleared and reprinted numerous times. "We've rewritten it close to 300 times with our homemade equipment in the lab," says Janglin Chen, General Director of ITRI's Display Technology Center, "and there's no reason why it couldn't be done 500 or 1000 times."

Possible applications include tickets for events and transportation, ID badges, and signage. Chen notes that the technology is ideal for temporary IDs, as well as for airline boarding passes and other documents that are significant to security but are not meant to last.

i2R is made of ITO-coated PET (polyethylene terephthalate) that is 125 µm thick. Atop the ITO is a cholesteric liquid-crystal material dispersed in gelatin. "It's kind of a thick syrup," explains Chen. The "syrup" is then coated with a layer of pigment, and on top of this pigment layer another layer of electrodes is placed. "The structure is simple and elegant," says Chen. Apparently members of the press think so; the i2R e-paper won a 2011 Wall Street Journal Technology Innovation Award.

At this point, says Chen, e-paper is basically ready for use by interested manufacturers. "We are not going to replace paper," he says, "but we offer options. We want people to consider it for applications that require a frequent update. Then bistable is perfect because it only requires power when it changes."

Flexible Technology Update: Liquavista Becomes Samsung's R&D Center

Back in December 2010, Samsung Electronics Co., Ltd., acquired Liquavista, based in Eindhoven, the Netherlands. Liquavista, founded in 2006 as a spin-off from Philips Research Labs, is the developer of an electrowetting technology for applications in eReaders, mobile phones, media players, and other mobile devices. This technology, which operates in transmissive, reflective, transparent,

(continued on page 45)

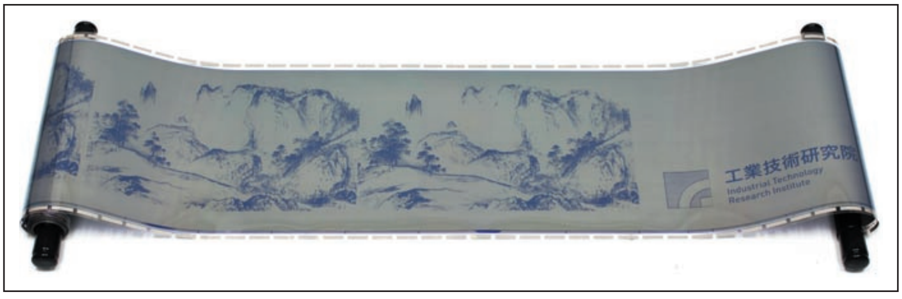

***Fig. 1:** ITRI's rewritable e-paper allows text and graphics to be printed and then erased, making it possible to reuse the paper hundreds of times. Image courtesy ITRI.*

guest editorial

Tables and eReaders: Fertile Ground for Display Innovations

by Jason Heikenfeld

I am not an early adopter of technology. Over a year ago, my wife and I finally purchased a reflective Kindle using an E Ink screen, and it quickly became the dominant way books are read in our home. Just this past year, I purchased an iPad, with some reluctance due to my impression that it was just a toy. I now have the iPad tablet synced to cloud document storage and have found it indispensable for my numerous work hours outside the physical office. This year my three children (Luke, Will, and Jack) are now all at the same school, where each member of grades 6–8 is assigned his or her own tablet for use in nearly all classroom learning activities. Five years ago, we would have been talking about use of laptops at best. These personal examples represent a tiny part of how many of us are using tablets and eReaders. Credit innovators such as Amazon and Apple for envisioning bold new consumer products – products that are centrally reliant on advanced screens created by our display community.

This Tablet and eReader Applications issue of *Information Display* touches on one of the most exciting, controversial, and technology-diverse areas of display development. We have selected a set of authors and articles that cover only a few applications, but which communicate a great breadth of market opportunity. These opportunities also impose challenging requirements for displays. For example, weight is a major concern, much more so than with laptops that you can rest on a table or smartphones that have relatively small screens. This, in turn, imposes limits on battery size and increases the need for very low display power consumption. Also, these devices often leave the home or the office and find themselves in direct sunlight, where color gamut and contrast ratio collapse for a conventional LCD panel. Furthermore, while we love portability, especially when we can store the device in our pocket, there is always the desire for a much-larger-sized display.

Tablets and eReaders place display engineers in paradoxical situations that are full of trade-offs. They are, therefore, ripe platforms for the introduction of new display technologies. This extremely rich area of display development will be relevant – and controversial – for a long time. One can easily argue that this sector of displays has the largest number of distinct technologies pitted against each other. How long will it last? Maybe until we develop that ultimate full-color, video-rate, all-lighting, readable, unbreakable, foldable, and energy-saving touch-driven display. In the meantime, a few technologies have been carefully matched to the right applications, enabling early entry even without perfect screen performance.

Two articles in this issue approach portable devices from an applications perspective, which in most cases will determine the future winners and losers. E Ink presents a piece on the potentially huge new market sector of electronic textbooks, and a re-invigorated Polymer Vision reminds us that there is pent-up demand for and a large technology push in foldable/rollable displays.

A more technology-based contribution comes in the form of a piece from industry analyst Geoff Walker, who writes about the different forms of touch currently used by eReaders. Last, DisplaySearch describes the spectacular growth of the tablet market and discusses "Ultrabooks," a new notebook category designed to compete with tablets.

(continued on page 45)

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The Future of Displays Is Foldable

Growth in mobile data consumption has pushed mobile-display sizes beyond 4 in., creating a potential market for foldable displays that enable further enlargement of the display without increasing the mobile-device size and weight. The applications, alternatives, and status of the technology for foldable displays will be discussed.

by Edzer Huitema

MOBILE data consumption has grown enormously over the past 5 years, with a worldwide growth rate of 159% in 2010 and a predicted annual growth rate of 92% until 2015, according to the Cisco Visual Networking Index. This growth was enabled on the one hand by the increasing availability of faster 3G networks, but also by the evolution of mobile-phone hardware, for which battery capacity, processing power, and graphics capabilities have all improved. A crucial aspect of this evolution is the display, which has increased in size dramatically with the introduction of the iPhone in 2007, with an on-screen touch interface replacing all of the buttons that were present 10 years ago. The display is now the dominant face of most mobile phones.

With the start of the roll-out of faster 4G networks, the pressure on display sizes is increasing, while the form factor of the mobile phone is limited; users have to be able to carry the devices all day. With the latest announcements of, for example, the HTC Titan with a 4.7-in. display and the Samsung Galaxy Note with a 5.3-in. display, the limits of mobile-device size have been reached and even exceeded for most consumers.

On the other side of the spectrum, tablets have emerged as the portable alternative for laptops, netbooks, and eReaders as a new portable dedicated reading device. Tablets and eReaders offer a display size of up to 10 in. and can be carried around. The fact that they are about five times the size and weight of smartphones and do not fit into a pocket limits the current sales volumes of tablets and eReaders to about 5% of smartphone sales.

A solution for enabling even larger displays in truly mobile devices would be to replace the glass display with a larger, lightweight display that can be bent to a shape that fits the pocket when the device is not in use. Although the first application areas of foldable displays will be pocket-sized eReaders and mobile phones, other markets, such as tablets, laptops, and eventually monitors and TVs, might also benefit from the use of these displays.

Flexible and Foldable Displays

The term flexible display is used to cover all displays that are intrinsically flexible, as opposed to glass-based displays that are rigid in nature. A more quantitative definition that is commonly used is that a flexible display is able to be bent at least once to a radius smaller than 50 cm (20 in.). Flexible displays mainly use plastic substrates instead of glass, but thin steel or thin glass substrates can be used. The latter two have the advantage of being able to withstand higher processing temperatures, while plastic substrates are more flexible, lower in weight, and more robust. The use of plastic substrates restricts the temperature range during processing to a maximum of 130–200°C, depending on the type of plastic used. The typical thickness of a flexible display is 0.2–1.0 mm.

Additional potential advantages for flexible displays include weight and thickness reduction and a reduced chance in breakage, which is a problem for larger-sized glass displays. They also enable products in which the display is used in a curved position, such as for advertisement or in-car displays.

Companies that have demonstrated flexible-display prototypes recently include Samsung,[6] LG,[7] Plastic Logic,[8] Bridgestone,[9] E Ink,[10] Fujitsu,[11] Sharp,[12] and others. Companies that have introduced flexible displays on the market include Fujitsu, with the Flepia eReader based on a stacked red, green, and blue cholesteric liquid-crystal (CLC) display using plastic substrates, introduced in Japan in 2009, and recently by Plastic Logic, which introduced eReaders based on plastic substrates and electrophoretic technology in Russia.

A foldable display has different mechanical states in the product, so the flexibility of the display is really used. It must be able to be bent many times. Also, the bending radius has to be small enough to fit in a compact device. A more quantitative definition is that a foldable display should be able to be bent at least 1000 times to a radius smaller than 7.5 mm (0.3 in.), although for typical consumer products a specification of at least 25,000 times bending is required.

The first report on foldable displays dates back to 2005.[1] A number of companies have

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demonstrated advanced foldable-display prototypes[2–5] that enable thin, light-weight products with displays as large as 6 in. and a form factor not larger than an average smartphone.

The Use Case and Competing Solutions for Foldable Displays

Foldable displays are only one solution to the problem of having a small device with a large perceived display area. In Fig. 1, a foldable display device is shown along with other competing solutions: pico-projectors and near-to-eye (NTE) displays.

Pico-projectors have already found their way into mobile phones, with the introduction of the Samsung Galaxy Beam in 2010, while LG and NTT introduced models with add-on pico-projectors. They are all based on Texas Instruments' DLP technology and are particularly useful for presenting data or photos to groups. For private and mobile use, it has its limitations due to the projection surface that is required. Also, battery life is limited to a few hours of projection.

NTE displays, also referred to as head-mounted displays (HMDs), are already on the market and are particularly useful for watching video or playing games individually. There are also see-through HMDs designed for augmented-reality applications. The recently introduced Sony HMZ-T1 is the first HMD with support for 3-D viewing and surround-sound aimed at the mass consumer market. Because it is immersive and requires AC power, it is not intended for mobile use.

Foldable display devices retain the advantages of current mobile phones, such as small form factor, low weight, and long battery life, while extending the display size. The key innovations needed for such a device are the display and the mechanics to support the display in all configurations. Prototypes of foldable displays have been shown by Polymer Vision since 2005[1] and later also by Seiko-Epson[5] and Sony.[3,4]

Current State of the Art of Foldable Displays

Some of the latest foldable displays are shown in Fig. 2. Polymer Vision has demonstrated foldable displays that are only 0.1 mm thick and can be bent more than 100,000 times to a radius as small as 5 mm (0.2 in.).[2] These displays are based on plastic substrates of 25 μm combined with organic transistors processed at low temperature and an electrophoretic-display medium. The latest display module has a 6-in. diagonal and SVGA resolution (170 ppi). Finger touch is included in the panel by use of a novel integrated capacitive-sensing solution.

Epson demonstrated a foldable display with a thickness of only 0.1mm in 2006.[5] The display was based on plastic substrates combined with polycrystalline transistors and an electrophoretic-display medium. There have not been any recent disclosures by Epson on this topic.

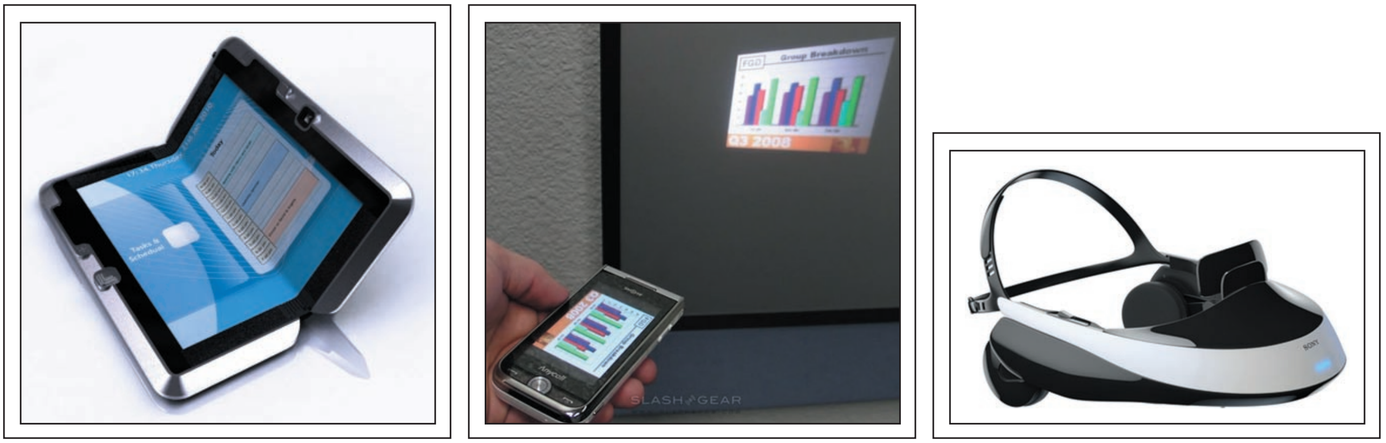
Sony demonstrated a foldable display both by using electrophoretic material[4] and OLED material[3] in 2010 and 2011. Plastic substrates are used combined with organic transistors processed at low temperature. Sony is still actively working on this technology.

Samsung demonstrated in 2009 and 2010 a very different type of foldable display construction,[13] where only the bending zone is non-rigid. Two glass-based OLED panels were stitched together by a very narrow foldable stitching zone in such a way that in the flat position the stitching was almost not visible. Of course, this approach does not have the low-weight and thickness advantage of the other approaches where truly foldable displays are used.

At the moment, foldable displays are still in research and development like most flexible-display technologies. The main reason is that the process flow for making these displays is not the same as the flow for glass displays. The temperature budget is lower due to novel plastic materials and, in some cases, novel patterning methods are used as well. This requires substantial changes to the standard manufacturing flow used for glass displays and also the development of new manufacturing equipment. For foldable displays, the form factor of new products needs to be changed: they are not a simple drop-in replacement for glass displays.

Technologies Used to Produce Foldable Displays

The main technologies used to produce foldable or flexible displays are shown in Fig. 3. The general issue to solve is that a flexible substrate is not suited for thin-film processing



(a) (b) (c)

Fig. 1: Three different ways to create a large perceived image from a small device include (a) a foldable display device, (b) a pico-projector, and (c) a head-mounted near-to-eye display.

Fig. 2: The current state of the art of foldable displays is represented by (a) a Polymer Vision foldable electrophoretic display, (b) a Seiko-Epson foldable electrophoretic display, (c) a Sony foldable electrophoretic display, (d) a Sony foldable OLED display, and (e) Samsung OLED glass panels with foldable stitching.

without attaching it to a flat and rigid support carrier somehow. Although plastic substrates are supplied on rolls, processing takes place sheet-to-sheet as the resolution and overlay requirements for displays are in the micron range, which is beyond the current capabilities of roll-to-roll processing.

With bond–debond processing, the plastic substrate is glued to a glass plate. The plate is then processed on standard tooling for processing displays on glass plates. The plastic substrate imposes temperature restrictions on the processing, as it starts to deform and melt at temperatures above 200°C, although recently high-temperature plastics have been developed that are less foldable but can withstand temperatures up to 300°C. At the end of the processing, the display is debonded from the glass plate. If the display is sufficiently foldable, it can be rolled off the glass plate at moderate temperature. The glass plate can then be cleaned and reused. This technology is used by Polymer Vision to produce foldable displays. Sony is using a similar technology to produce foldable displays and AUO, LG, and Plastic Logic have been using such technology to produce flexible displays.

Another technology is so-called transfer processing. Here, the display is produced on rigid glass plates and subsequently transferred to a foldable substrate. Key to this process is a (partly) sacrificial layer, typically a-Si or polyimide, that is used to separate the stack from the glass plate by a laser release process. This layer is one of the first layers that is put down on the glass. After the release step, the final plastic substrate is glued to the backside of the stack. Seiko-Epson has been using this process to make foldable electrophoretic displays. In this process flow, an additional temporary top substrate was used to protect the stack during the release process. E Ink also uses a similar process for flexible electrophoretic displays.

With yet another technology, so-called etch-back processing, displays are produced on a rigid glass or steel substrate. At the end of the processing the substrate is etched back so far that the display becomes flexible. LG has used this process route to make flexible electrophoretic and OLED displays. Foldable displays have not been made using this route because the etched back substrates are, in general, not flexible enough to allow bending.

Display Media Suitable for Foldable Displays

Display media suitable for foldable displays must be very thin, as the display in total should be at most 0.2 mm thick. Besides the switching material itself, display media might also require certain optical layers, such as polarizer films or retarders. These layers add significant thickness to the stack. For example, polarizer films are typically 100–300-µm thick, which is too thick for a foldable display. There have been efforts to make very thin polarizing films, but the quality is too low to be competitive.

Liquid-crystal displays are by far the most dominant type of rigid flat-panel displays on the market. Since LCDs require two polarizer films, flexible LCDs are quite thick and have never been prototyped at the extremely low thickness needed for bendability. The backlighting unit needed for a foldable transmissive LCD is an additional complication.

OLEDs have the advantage that they do not require a backlighting unit, but they do rely on an optical stack at the front side that typically includes a polarizer and retarding film to increase the daylight contrast. The extreme sensitivity of the OLED material stack to oxygen and water puts high barrier requirements on the substrates that are used, something that glass and steel substrates do provide but that plastic substrates cannot provide without multi-layered barrier coatings. The transistors in OLEDs have higher stability and uniformity requirements compared to that for LCDs, which is more difficult to achieve on a restricted temperature budget. LG,[7] Samsung,[6] and recently AUO have demonstrated flexible OLED displays. Sony has demonstrated a foldable OLED display[3] and, recently, Polymer Vision also made a foldable OLED panel together with the Holst Centre (to be discussed shortly).

Electrophoretic displays have been in eReaders since 2004. The electrophoretic layer is 20–40 μm, which is relatively thick, but does not require any optical films, a backlight, extreme oxygen barriers, or high transistor performance. Therefore, this display medium is very well suited for flexible and foldable displays. Polymer Vision,[2] Seiko-Epson,[5] and Sony,[4] have shown foldable electrophoretic displays, while a large number of companies have shown flexible versions.

Electrowetting displays have been prototyped since 2003. They rely on switching by manipulation of the contact angle between a dielectric layer and a fluid system by a voltage. Although electrowetting displays are not bistable, they have all the other advantages of electrophoretic displays, combined with video-speed switching. Liquavista is well known for its work on electrowetting displays.[14] (The company was acquired by Samsung in early 2011.) Its technology is best suited for rigid displays, as the fluid

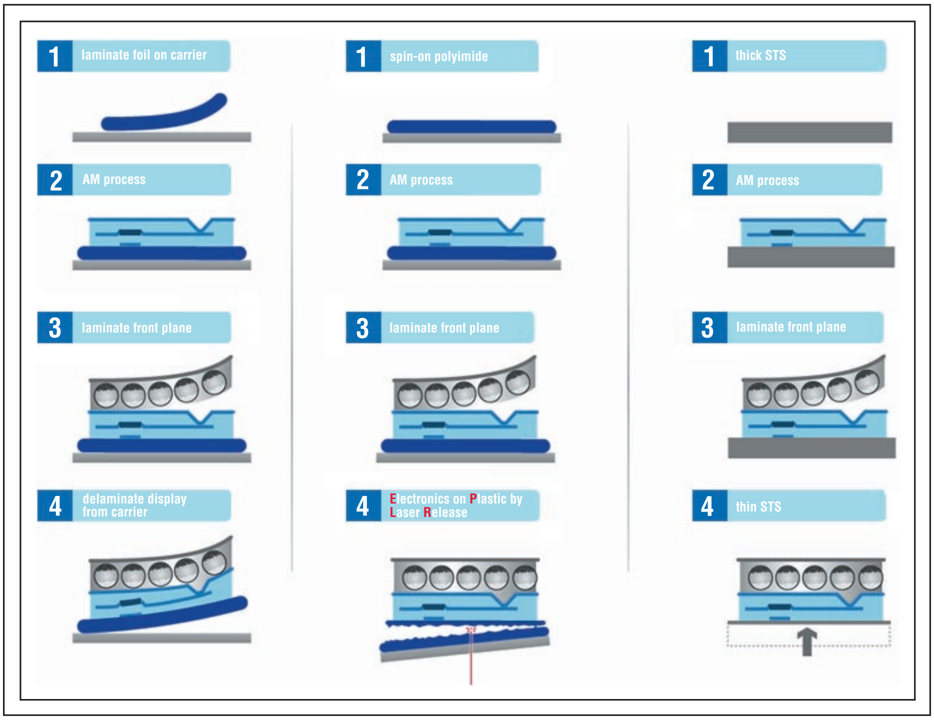


Fig. 3: The main process methods used to make flexible and foldable displays are (a) bond–debond process, (b) laser release process, and (c) etch-back process.

layers are more than 50 μm thick. In 2009, Gamma Dynamics, a spin-off from the Novel Device Laboratory of the University of Cincinnati, launched a new electrowetting concept that is better suited for flexible and foldable displays.[15] In this so-called electrofluidic display concept, the fluid layers are only 3–5 μm thick, thus enabling robust flexible and foldable electrowetting displays. Gamma Dynamics is working with Polymer Vision on foldable displays.

Product Concepts for Foldable Displays

Although no products using foldable displays are on the market yet, a number of interesting concepts have been revealed (Fig. 4). Polymer Vision has shown a family of concept devices over the years. The first was a foldable eReader concept and prototype in which the display was wrapped around the body of the device. The size of the eReader was as small as a mobile phone, while the display was 5–6 in. The company has also shown a foldable eReader phone concept, in which the foldable eReader display is stored inside the device. The bend radius is controlled by a hinge construction that creates a controlled loop inside the device. An extension of this is a phone-tablet concept in which a foldable full-color video display is stored inside the device. After the device is opened, the foldable display can be further extended by pulling the two device halves apart, thereby unwinding the display from a roll at the far end of the device.

Samsung recently published the Samsung Galaxy Skin phone concept using a foldable OLED display. It is not clear what the mechanics are that support the display except that graphene is mentioned as the material to be used for the flexible casing. Sony recently published a foldable laptop concept in which one continuous foldable OLED display is used.

When Will Foldable Display Devices Come to Market?

Over the past several years, the technology and concepts for foldable display devices have been maturing. Polymer Vision and Sony are leading in this capacity. The final steps toward commercialization will be early market acceptance of these novel form-factor devices,

Fig. 4: Product concepts using a foldable display include (top row left to right) a Polymer Vision foldable eReader, a foldable eReader phone, and a foldable tablet phone and (bottom row, left) a Samsung foldable phone and (bottom row, right) a Sony foldable laptop.

allowing the final investment into production capacity. The market is more ready than ever with the increasing pressure on the display size in mobile devices. Investment into production capacity can be kept relatively low by having a technology that is compatible with the already existing LCD manufacturing infrastructure. Polymer Vision's technology is fully compatible and only requires lamination and delamination equipment to be added for the bond–debond process.

The first type of devices using foldable displays will be pocket-sized electrophoretic eReaders with 5–8-in. displays. The displays have been demonstrated, and the foldable electrophoretic display technology is more mature than foldable OLED and electrowetting technologies.

Foldable OLED or electrowetting devices will be the next wave, as they offer full-color video performance. As there are still technical hurdles to overcome for both technologies, such as improved switching speed and optical performance for electrowetting and proven operational and shelf lifetime for both OLED and electrowetting technologies, it will probably take 3–5 years before these devices will be on the market. When they finally arrive, they will truly offer a tablet in your pocket.

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Tablets Impact the Notebook Market: Enter the Ultrabook

The tablet PC, in its short lifetime, has already influenced the mobile PC market in numerous ways, but none more concretely than in inspiring the emergence of the Ultrabook.

by Richard Shim

TABLET PCs have given consumers what they have been asking for from notebook and desktop PCs for years – convenience. At DisplaySearch, we describe the currently emerging era of computing as convenience computing, in which devices enable instant-on capability and all-day battery life in extremely portable form factors. Notebook and desktop PCs have made incremental advances in convenience computing over the years, but those products remain predominately performance-computing devices. Tablets are more oriented toward convenience and tablet makers (more specifically, tablet-maker Apple) have experienced tremendous success and shipment growth as a result (Fig. 1).

The notebook market is not in decline, but the shipment forecast is not anywhere near as promising as that of the tablet market. In 2011, DisplaySearch estimates over 72.8 million tablets will ship, as compared to 187.5 million notebooks. By 2015, tablet shipments will reach 271.1 million units, as compared to 332.5 million notebooks. In response to the rapid growth of the tablet market, a new category of notebook is emerging that is supposed to offer the key features of a tablet – notably instant-on and all-day battery life – in a thin (thinner than that for conventional notebooks) form factor. Further down the road, we expect notebooks to take on characteristics found first in tablets, such as an app store and applications whose usefulness is tied to the Internet. The notebook is called the Ultrabook, and expectations are high that this product category can fulfill the current needs of consumers and compete with tablets. (Display industry members should note that other than thinner glass and design, Ultrabooks are similar to notebooks

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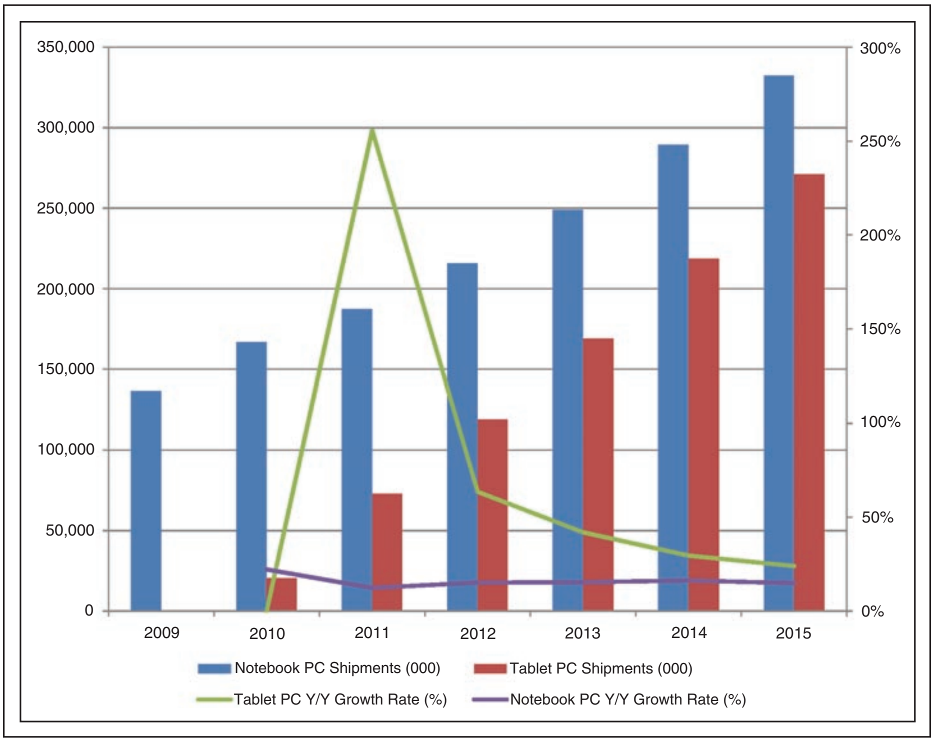

***Fig. 1:** Tablet sales increased spectacularly in 2011. While the rate of growth will not continue at 2011 levels, tablet shipments will continue to increase through at least 2015. Source: DisplaySearch.*

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and are not expected to enable many new display characteristics at this point.)

One of the key beneficiaries of the rise of tablets is the ARM processor architecture developed by ARM Holdings. All tablets running Android, iOS, webOS, and QNX use ARM processors. These relatively simple but low-power-consuming processors are a good fit in tablets as well as smartphones, and their rise in popularity is a sign that high performance is not the only characteristic used to measure experience on computing devices.

For 2011, DisplaySearch estimates over 71 million tablets using ARM processors will ship, and by 2015 that number is expected to increase to nearly 258.3 million units (Fig. 2). In 2011, no tablets running Android, iOS, webOS, or QNX are using ×86 processors and by 2015 DisplaySearch estimates less than 12.8 million tablets will be using 86 processors. Additionally, Microsoft is looking to make Windows 8 available on ARM and ×86 processors, and while Google is working on an Android OS version for the ×86 microarchitecture, it is in the early stages of development. This all makes ×86 chip-making-giant Intel nervous. There is clearly a hole in the market where ×86 is not yet tapping into the key needs of consumers (instant-on computing, all-day battery life, and extremely portable form factors). To address this market, Intel is promoting the Ultrabook.

While the rise in the popularity of tablets points to the rise in convenience computing, at the same time, convenience-oriented computing platforms are adding higher levels of performance capability. For example, current tablets already have dual core processors, and upcoming tablets are expected to offer multiple cores. The tablet platform is evolving to incorporate more performance capabilities and, similarly, the notebook platform is adopting more-convenience-oriented characteristics. The resulting computing platform that lies at the intersection of convenience and performance computing is the Ultrabook.

The Ultrabook Push

The role of ringleader among Ultrabook backers in large part belongs to Intel. Though Apple's MacBook Air can arguably be pointed out as the first notebook to fit the Ultrabook description, Intel has been working to define the category and to lower it from premium status to make it available to the mainstream market. Intel went as far as obtaining a trademark for the term Ultrabook so it can control who can use the term as well as benefit from the chip maker's Ultrabook marketing campaign. Being under the halo of Intel's marketing is very helpful, as Intel typically invests hundreds of millions of dollars in brands such as Centrino. However, fitting under the definition can be tough.

The Ultrabook experience is meant to enhance performance, response, security, form factor, and battery life compared to conventional notebooks, all at a price within reach of mainstream PC buyers. This is a tall order that will take time to be completely fulfilled. The Ultrabook definition is expected to evolve with several stages. The stages are dependent on price and the availability of key technologies. In many instances, the components needed are expensive, which will make it difficult to produce a product that is affordable to mainstream consumers.

For example, solid-state drives (SSDs) enhance the notebook experience on several levels, making them ideal for use in Ultrabooks, but there is a hefty price premium that puts them out of the realm of affordability for the mainstream market. As a result, the Ultrabook definition currently recommends SSDs but also allows for thin hard drives. Intel has announced that it will invest $300 million in various areas of the supply chain in which it can drive economies of scale to lower the price of premium components for use in Ultrabooks.

According to Intel's specifications, the current retail price point for Ultrabooks (notebooks using Intel's "Sandy Bridge" CPU, with more than 5 hours of battery life, a +Z height of less than 21 mm for units with screens larger than 14 in. and less than 18 mm for units with screens smaller than 14 in.) is less than $1000. In 2012, the price point should become lower – less than $700 for notebooks using Intel's "Ivy Bridge" CPU, having more than 8 hours of battery life, USB 3.0/Thunderbolt ports, and a Z height of less than 21 mm for units with screens larger than 14 in. and less than 18 mm for units with screens smaller than 14 in. By 2013, the price point becomes lower, less than $600, for notebooks using Intel's "Haswell" CPU, having more than 8 hours of battery life, USB 3.0/Thunderbolt ports, and a Z height of less than

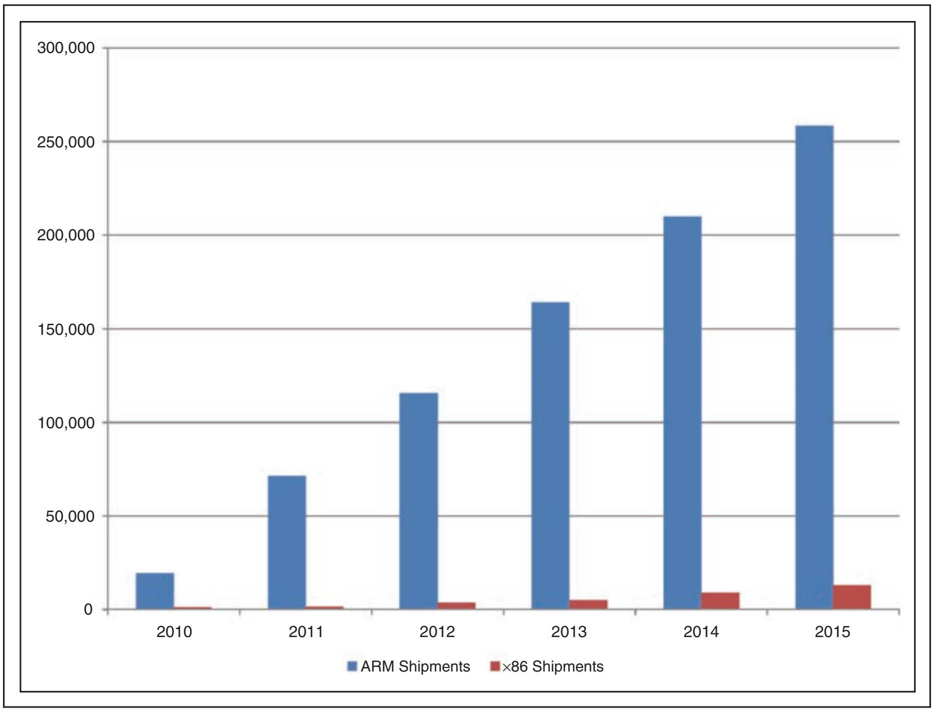

Fig. 2: Shipments of tablets with ARM processors will far exceed shipments of tablets with ×86-based processors at least through 2015. Source: DisplaySearch.

21 mm for notebooks with screens larger than 14 in. and less than 18 mm for notebooks with screens smaller than 14 in. (Table 1).

Next to price, the challenge for Ultrabook makers is getting to the right Z-height requirement. As has always been the case in the notebook world, thinness and portability have mass appeal. Ultraportables, sub-notebooks, and even mini-notes/netbooks were appealing to consumers mainly because they were slim and lightweight.

For Ultrabooks, two methods of enabling the required thinness focus on the notebook lid. There are limits to how thin the base of a notebook can get, given the heights of ports such as VGA and Ethernet that are typically included in notebooks. By reducing the Z height of the lid, manufacturers and brands can get significantly closer to Intel's requirements.

One method of getting to thinner notebook lids involves using 0.4 mm or thinner glass panels. Currently, the demand for thin panels is relatively modest, and handling such thin panels requires sensitive equipment that can properly manage thin glass without breaking it. This has limited thin-panel production, but such production is on the rise. Currently, the major panel makers are committing on the order of single-digit percentages of overall production for thin notebook panels. However, consumer trends are increasingly pointing to a preference for thinner design, so we expect to see thin-panel production to rise, although wide availability for notebooks is not expected until 2015.

The other method to enable thinner notebook lids is LG Display's Shuriken solution. This method essentially streamlines the assembly process, eliminating the need for secondary front and bottom covers, not only reducing the thickness but removing some cost from the build of materials. Instead of the panel maker simply sending the device maker a finished panel to be added to the notebook production process, the panel maker and the device maker are more aware of each other's production plans. The panel maker sends the device maker a panel specifically for a notebook model. This helps to cut back the need for secondary front and bottom panel covers for use in the notebook lid. This method has its risks; in particular, single sourcing since LG Display is the only panel maker offering it. As far as incorporating non-mainstream display technologies to create thinner, more-cost-effective Ultrabooks, current plans do not exist for it because new screen technologies would add to the build of materials.

Reducing cost will be a central theme in Ultrabooks for the next couple of years and the reason is simple: notebooks over $1000 appeal to less than 15% of the addressable market. Currently, Apple owns the rarified air of price points above $1000, accounting for more than 50% of notebook shipments. However, that upper price echelon does not translate to high shipment volumes, which is what Intel is aiming for with Ultrabooks. Intel has stated a goal of 40% of premium consumer notebooks shipped at the end of 2012 to be Ultrabooks (Table 2).

The DisplaySearch forecast for Ultrabook shipments highlights the benefits of a device that offers the convenience of a tablet and the performance capabilities of a notebook. In the short term, the potential for Ultrabooks is going to be helped in late 2012 by the expected launch of Windows 8 and Intel's Ivy Bridge processor, but will be slowed by not having a full year of availability of either and by premium pricing of components, leading to high price points for the category. In 2013, Ultrabooks will be helped along by a full year of availability of Windows 8 and the expected mid-year release of Haswell. In 2014, we expect the Ultrabook platform to essentially be at full strength with Windows 8, the Haswell processor, and more opportunity to drive down costs and price points.

The Ultrabook represents the intersection of two competing computing platforms currently in the market; convenience versus performance computing. Devices representing the two platforms, tablets for convenience and notebooks for performance, are taking on the differentiating characteristics of the other. It is logical for the evolution of these platforms to cross because it is clear, based on the size of the market for each, that consumers want the best of both worlds. In the short term, the cost and price of the Ultrabook will test the appeal of the device, but if consumers can be convinced that the Ultrabook represents the best of both worlds, it will enter the mainstream market. ■

Table 2: Ultrabook shipments are forecasted to increase aggressively through 2014. Source: DisplaySearch *QMPC Q4 '11 Shipment and Forecast Report.*

	2011	2012	2013	2014
Ultrabook I	3,413	16,842	34,911	57,101

Table 1: Ultrabooks, as defined by Intel, will become thinner and less expensive each year through 2013. Source: DisplaySearch *QMPC Q4 '11 Shipment and Forecast Report.*

	2011	2012	2013
CPU	Sandy Bridge	Ivy Bridge	Haswell
Z-Height	<21 mm for >14 in. notebooks <18 mm for <14 in. notebooks	<21 mm for >14 in. notebooks <18 mm for <14 in. notebooks	<21 mm for >14 in. notebooks <18 mm for <14 in. notebooks
Battery life	>5 hours	>8 hours	>12 hours
I/O		USB 3.0/Thunderbolt	USB 3.0/Thunderbolt
Retail price	<$1000	<$700	<$600

CES 2012 Display Highlights

Displays large and small played a dominant role in the products exhibited at the most recent Consumer Electronics Show in Las Vegas.

by Steve Sechrist

ONE walk around the show floor at this year's CES would have been enough to convince even the uninitiated that the center of consumer electronics (and any device) is without question the display. Billions of pixels from millions of displays flooded the show from every direction, and everywhere you looked a display was the primary device – the "what you are looking at" technology that is often the difference between product success and failure. Even model numbers are now based around display sizes.

At the show, the display du jour seemed to be the new AMOLED displays from the likes of Samsung, which dominates the small OLED display space, as well as from other suppliers such as LG. Also present were the tried-and-true LCD and plasma panels, along with new advances in alternative displays such as E Ink Holding's Triton color panels, Pixel Qi's unique transflective panel, and Qualcomm's iMOD-based mirasol display.

Real OLED TVs Finally Appear

One cannot talk about this year's CES without starting with active-matrix organic LED (AMOLED) displays. Top Korean TV makers LG and Samsung delivered in abundance at the show, and not only with stunning 55-in. TVs with knock-your-socks-off color, contrast, and resolution. These first-ever sets came in "ready-for-prime-time" packaging, complete with model numbers, pricing (sort of), and delivery dates measured in months, not years.

If the press reaction to the new TV technology, which had been promised many times over the last decade, was any indication of pent-up consumer demand, then OLED TVs are sure to be an instant hit in the marketplace. But it's delivering on technology, in a sustainable manufacturing process, and producing acceptable (efficient) yields, color uniformity, and the kinds of lifetimes that consumers have come to expect, that will determine the true success of these products.

If one company was the belle of the ball, it was Samsung. Its booth (Fig. 1) was mesmerizing, with an untold number of displays and tens of billions of pixels from those many types of displays flooding the booth and surrounding area.

The centerpiece of the booth was a dozen or more of its 55-in. AMOLED panels on display at the entrance for all to see. The sets' extremely vivid colors came packaged in an almost invisible black bezel that melted into the picture when a black image came on the display (Fig. 2). Its thin packaging and 55-in.-diagonal screen size created a compelling image of the future of television, but unfortunately prices and technical specifications were not released as of this publication date. After the show, the company did release a new model number for the AMOLED TV: KN55ES9000.

Samsung also carried away a host of awards from *Popular Science* (Best of CES), *Stuff Magazine* (Hot Stuff), and *G4 TV* (Best of the Best), plus the coveted Best of CES

Fig. 1: *Samsung's CES booth was a sea of humanity, with everyone trying to get a closer look at the award-winning products.*

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Fig. 2: Samsung's new OLED panels in 55-in. sizes are due to ship in 2012.

Innovations Award from the Consumer Electronics Association (sponsor of the show).

According to OLED-Display.net, Samsung has developed a way of extending the LTPS manufacturing process to the 55-in.-class OLED TV from a new manufacturing method created at its Gen 5.5 plant. That fab uses a 1300 × 1500 mm motherglass substrate. OLED-Display.net also reported that Samsung has discovered how to keep from cutting the glass substrate during production in order to create larger panels with sizes up to 65 in. on the diagonal using the LTPS process. This method was ramped up at the Tangjeong A3 Production line. Samsung will thus extend production from its current Gen 5.5 size to Gen 8 (2200 × 2500 mm) to produce the next-generation TV sets it says will be delivered later in 2012. Samsung dominates the current OLED panel market, with some estimates as high as plus 90% of market share, delivering 2–7-in. panels mostly in the mobile-display space. It has adopted both a conventional RGB and the unique PenTile pixel-structure technology. The company uses both in producing smaller AMOLED panels for the mobile market.

LG Display started off early on CES press day, revealing its 55-in. white OLED display complete with a price ($4K–$8K depending on whom you ask) and a forecasted ship date of mid-2012. Most remarkably, at 16.5 pounds, it is 4 mm thin (just a few credit cards thick) and clocks in at a whopping 0.1-μsec refresh rate (Fig. 3).

The product is built based on the Kodak approach to white OLEDs, and it took the "CNET Best of CES" award from the CNET editors in attendance there. (CNET Best of CES represents the cream of the crop as judged by the group sent by CNET to cover the show.)

LG Display (LGD) first licensed (then later bought) its OLED technology from Kodak. This technology uses white OLED emitters underneath a color filter at each subpixel to make the RGBW matrix of each full pixel, rather than RGB-colored OLED material like that used in Samsung's panel. By taking this approach, iSuppli says that LG gains the benefit of eliminating the fine metal mask in production of the panel that leads to "…improved efficiencies and increasing the ease of making finer pitch pixels on the panel," according to iSuppli analyst Vinita Jakhanwal, in an IHS iSuppli reference document on the displays. At the show, both Samsung and LG OLED displays looked spectacular, with colors and blacks unrivaled. A side-by-side comparison will be very interesting.

LG plans to move directly to a Gen 8.5 production line that leverages the existing TFT-LCD manufacturing process but substitutes oxide silicon for a-Si. True to OLED Association President Barry Young's prediction, the approach should offer a significant savings in capital investment in the process. In fact, according to Jakhanwal, using an existing LCD production fab "…will require almost 50% less investment than a new LTPS-LCD fab."

Moving directly to a Gen 8.5 fab process allows the creation of three 55-in. AMOLED panels from a single substrate, which will help boost manufacturing efficiencies with the potential to offer quick price reductions as adoption moves forward.

LG's UD 3-D TVs Hit 3480 × 2160 Pixels

LG also showed off its UD-resolution TVs in 60-, 72-, and 84-in. sizes and a picture quality very close to 4K resolution (Fig. 4). The line includes 2-D to 3-D real-time conversion that uses a depth dial (control) to adjust the 3-D experience. All feature a 1-mm bezel and 28-mm thin design, and while the 3-D image was shown using conventional LG passive glasses, there was no word on the specific approach the company was using to generate the 3-D image.

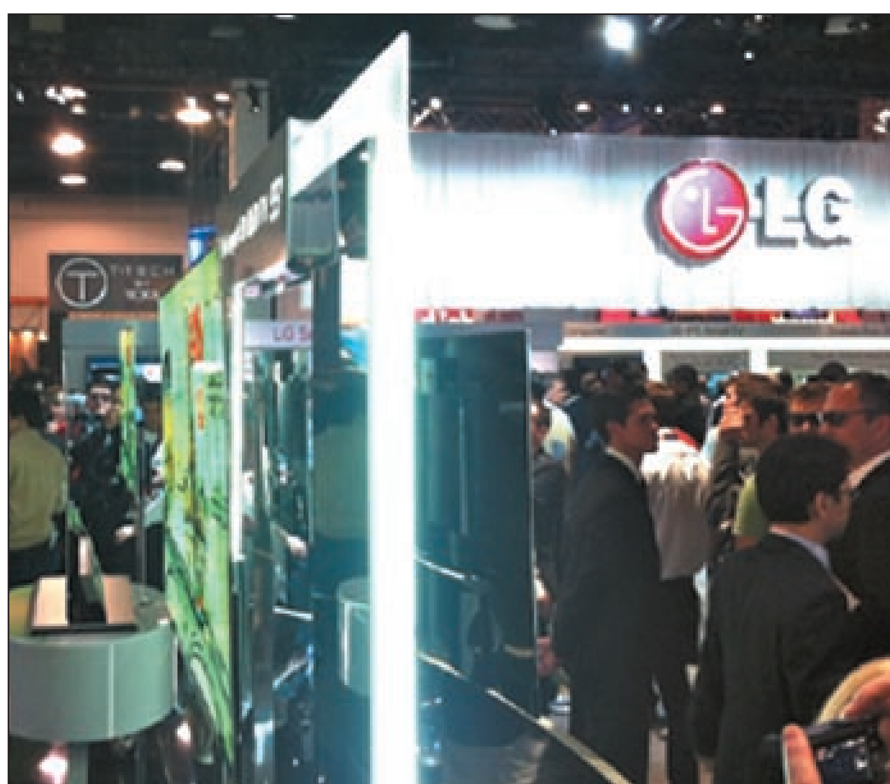

Fig. 3: Look closely to see just how thin the new LG OLED TV is (4.0 mm).

Fig. 4: LG's 84-in. ultra-definition TV uses the passive-glasses approach to 3-D.

The company is bullish on 3-D even if the market does not seem to be. At its press conference, LG claimed up to 30% market share for its passive 3-D approach, which offers lighter and (more importantly) much cheaper 3-D glasses. The technology even works with the RealD glasses moviegoers sometimes bring home from the theater.

Improv Electronics Introduces the Rip e-Writer

Improv Electronics, based in Kent, Ohio, the computer products subsidiary of Kent Displays, was at CES with its line of Boogie Board e-Writers. The company was created from Kent University and Kent Displays in 1993 and makes use of the university-developed electrophoretic bistable technology. Improv has leveraged the low-power write/erase/write again display into a nifty "e-Writer" the company hopes creates as big a market as the e-Book reader with display sizes that range from 8.5 to 10.5 in. on the diagonal.

The Rip e-Writer includes internal memory for 200 typical images; a high-resolution vector PDF format with nearly infinite scalability that is editable in Adobe Illustrator, Photoshop, and most other popular illustration and image-editing programs; a 9.5-in. writing surface (measured diagonally); and rechargeable batteries with one week between charges under "typical use," a term that is a bit nebulous as there really is no "typical" established use for this new product category – yet. The company claims that in sleep mode, the Rip e-Writer will last up to 100 days between charges.

At CES, the company used a professional caricature artist to entertain booth visitors and show off the precision drawing capabilities of the tablet (Fig. 5).

Key benefits of the e-Writer include light weight, ease of use, ultra-low power, and long battery life, plus daylight readability. The emphasis, according to the Rip e-Writer marketing folks, is on visual communication and instant data capture in a digital domain. This includes digital notetaking that replaces bulky and expensive (by comparison) notebooks or even tablets. The new category device can help one migrate even farther away from the wasteful use of paper. Think of it as a note-taking replacement you take along anywhere, now with the ability to port the saved content for later printing, study, and archiving.

Samsung Mobile's Tablet

Samsung Mobile is consistently morphing its tablet strategy, looking for that niche market to get a toe-hold against the iPad's dominance. In its latest effort, the company showed its newest Galaxy Note LTE, with an eye-catching 5.3-in. Super (with bonded panel plus digitizer stack) AMOLED display in HD resolution (1280 × 800) and a sizeable 285 ppi, making the device close to Retina class in pixel density. The unit features the latest PenTile pixel matrix using RGBG layout in a unique subpixel structure that Samsung says is optimized for the human visual system.

Clearly, the company is looking to offer a unique size of tablet that stands out from the dominant iPad market with features like being able to be held in one hand and a precision pressure-sensitive pen stylus/touch input that allows it to be used as an artist's sketch pad. Like Improv Electronics, the company had artists showing off their stuff in the booth at CES to demonstrate just how well these devices can perform as sketch pads (Fig. 6).

Other specs for the new pen tablet include a 1.5-GHz dual core processor, 16 GB of onboard memory, and front- and rear-facing cameras. Samsung said its Galaxy Note will be available in the U.S. in Q1 '12 for US$299.99 with a 2-year wireless agreement from AT&T.

Samsung Galaxy Tab 7.7-in. AMOLED Display

The other breakthrough device from Samsung Mobile is its 7.7-in. Galaxy Tab with a Super AMOLED Plus display. It features the same high-resolution 1280 × 800 pixel display as the Galaxy Note, but is laid out using a more conventional RGB pixel structure (not PenTile) as well as an optically bonded panel/touch stack . Other features include Android 3.2 Honeycomb, a front-facing 2-Mpixel camera for video chat, and 16 GB of on-board storage

Fig. 5: A caricature artist shows off the capabilities of the Rip e-Writer at CES.

Color mirasol Panel in New Chinese Tablet

At the Qualcomm booth at CES was a new device from China's largest e-Book reader and tablet maker, Hanvon. Qualcomm's mirasol display team proudly showed off its latest OEM, the Hanvon C18. mirasol uses interferometric modulation (iMOD), a micro-electromechanical technology, to generate color from ambient reflected light. The technology is also low power and offers daylight readability. For more about iMOD technology, see previous articles in *Information Display*, including "Enhancing Mobility through Display Innovation" in the October 2009 issue.

The C18 Hanvon tablet was first shown at the Qualcomm keynote address given by CEO Paul Jacobs on the opening day of the show. Unique features include a color touch display that works even in sunlight that is based on a mirasol 5.7-in. XGA that delivers 223 ppi and Qualcomm's 1.0-GHz Snapdragon (S2 class) processor running the Android 2.3 vintage O/S.

Hanvon also includes its version of handwriting recognition. This feature is beginning to surface more on displays that offer pen/touch input. The company is the number one electronic-book-reader (EBR) maker in China, and number three globally.

The first mirasol display tablet, the Kyobo eReader (not Canada's Kobo product) shipped in South Korea just before Christmas 2011. That Android OS device uses a 5.7-in. XGA (1024 × 768) display at 223 ppi and includes a touch screen. With 30 minutes of reading a day, the Kyobo offers up to a week of reading on a single charge of the battery. The device sells for around US$300 in Korea.

Two-for-One 3-D

In the Samsung booth, the company showed off a new use for 3-D in what the company calls Dual-View and Dual-Sound technology (Fig. 7). Simply put, it allows two viewers to watch the same screen using 3-D active-shutter glasses by displaying completely different video images, filtered by the 3-D glasses, with the audio to match. This works by using 3-D glasses to place a 2-D image on the left eye channel, then showing that single 2-D image to both eyes simultaneously. A second program can be shown using the right eye channel, again displaying the unique 2-D image to both eyes with audio synced up to the second program. So, while the 3-D set is still shuttering between two channels, rather than show a left- and right-eye perspective of a single image that is synced to left- and right-eye glasses, the clever engineers at Samsung shutter two completely different programs in 2-D to two pairs of eyes wearing 3-D glasses. Sound is sent to the audio headset added to the 3-D glasses. The right channel of the set might be playing a Western while the left is showing *American Idol*. I tried it out and the system worked flawlessly. So much for the social aspects of watching TV together.

New OEM partners for Pixel Qi

No CES would be complete without a visit to Pixel Qi. On hand in the Pixel Qi meeting room far in the back of the hall was a new 7-in. display sporting a 1024 × 600 pixel image that was daylight readable with a transflective design that uses high ambient light to its advantage. Outdoors, it rivals the EBR-class panels, but inside, with its backlight switch engaged, the display shows full-color images. Chinese OEM Sunbook Notebook PC integrated the technology, which was produced on a modified Chunghwa Picture Tubes (CPT) LCD line. Pixel Qi CEO Mary Lou Jepsen has been spending lots of time in Taiwan these days, a place with lots of unused fab capacity and a penchant for fabless display designs (Fig. 8).

***Fig. 6:** The Samsung Galaxy Note tablet uses a Super AMOLED HD display with a 285-ppi density and a precision (pressure) pen input, useful for drawing images.*

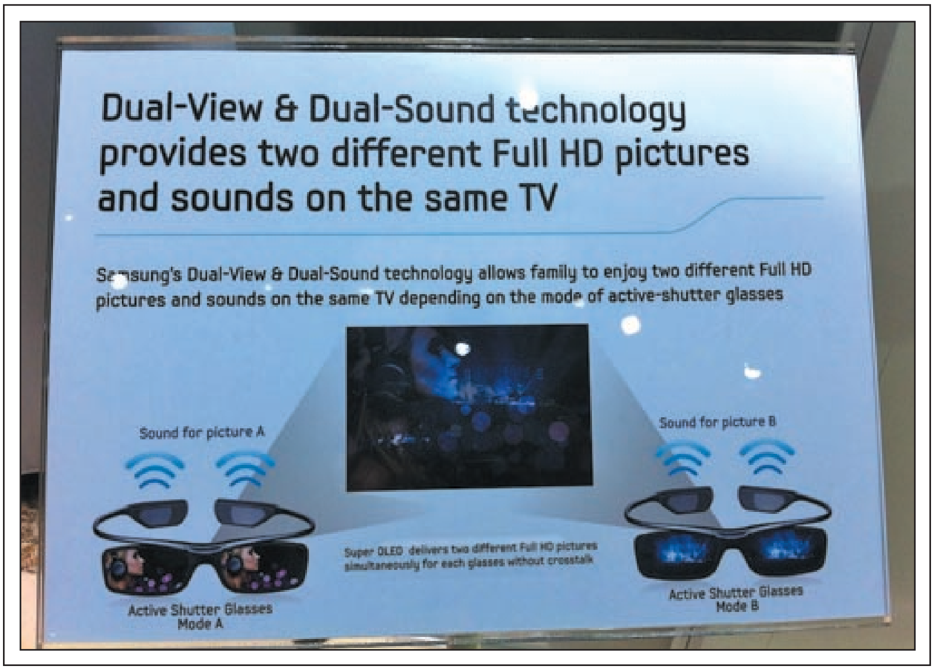

***Fig. 7:** Samsung's new dual-view and dual-sound technology uses 3-D to allow two views to experience different content on the same set at the same time.*

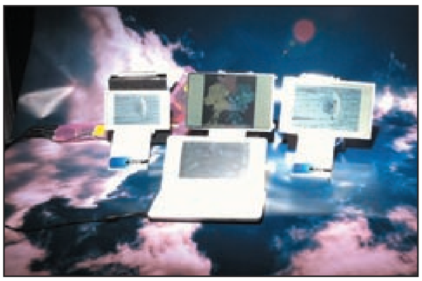

Fig. 8: The Pixel Qi displays are sunlight readable.

E Ink Triton Color Display e-Book

At a special event at CES, E Ink Holdings VP of Marketing Sriram Peruvemba was showing off the company's latest Triton color electrophoretic display (EPH) in the newest OEM Ectaco's jetBook Color eReader. The product was announced in December with a 9.7-in. 800 × 600-pixel display and renders 4096 colors. Peruvemba said the display maintains the E Ink display tradition of high ambient readability (including outdoor viewing) combined with very low power consumption. The new EBR is designed with the student in mind and comes complete with Wi-Fi and 3G connectivity, as well as touch and stylus support for marking up text and notetaking. Peruvemba also told us the jetBook is already deployed in schools in Russia, and the company expects to gain great traction in the education sector. (For more about e-textbooks, see "Dual-Pigment Electrophoretic Displays for Reading Textbooks" in this issue.) E Ink was at CES to announce the worldwide launch of the jetBook. The product received a CES Innovation award in Las Vegas.

Nokia Windows Phones and Intel Ultrabooks

On the cell phone front, Tiger (Windows) based cell phones finally made their debut, in a Nokia iteration with the new Lumia 900 Windows phone (and Qualcomm Snapdragon processor) that launched with a 4.3-in. WVGA (800 × 480) pixel AMOLED display. According to a June 2011 report from Korea news service iNews24, LGD supplies the AMOLED displays to Nokia.

Windows and Nokia, a past market leader in the cell-phone category, have a bit of an uphill climb to win market share back from the smartphone dominance of both Android and iOS devices that collectively command 90% market share in the smartphone space overall.

Intel also made a splash at CES with its Ultrabook launch (see this issue's Display Marketplace article, "Tablets Impact the Notebook Market: Enter the Ultrabook"). The company also cast an eye toward smartphones. Intel disclosed that the newest Lenovo K800 smartphone is running a version of its Medfield SoC processor (currently on Android) with a long-term plan to get the Win-Tel duo (windows software running on Intel chips) back into the game. The K800 made it to the stage with Intel President Paul Otellini during his keynote address at CES, in which he said the product will launch first in China with carrier Unicom and promised U.S. delivery before the end of the year.

CES Wrap-up

Even though it was just the second week in January, some analysts at CES were beginning to call 2012 the year of the AMOLED display. At the early morning LG launch on CES Press Day, excitement over the just-announced 55-in.-class AMOLED sets was so high that there was a rush to the stage by the press that overwhelmed company security. They could only stand by as the hoard of reporters, camera crews, and videographers "occupied" the LG stage.

But while it was clear that AMOLED displays were the "belle of the ball" at CES, the show included a diversity of new panel technology, now being used to develop new market areas. Suffice it to say that consumer-electronic companies will continue to differentiate products using the display, and display panel makers will continue to innovate to bring the next big (or small) thing that makes life just a little more productive, interesting, and even fun. Ultimately, isn't that what it's all about? ■

The Evolution of Displays

Electronic information displays touch nearly all aspects of modern life. Display Week's 2012 Keynote addresses will provide a vision of how the evolution of display technology will change the shape of displays of the future.

Keynote Speakers

Dr. Byung Chul Ahn, *Senior Vice-President and Head of the OLED Development Center, LG Display Co., Ltd.*

"Recent Breakthroughs for Larger-Sized OLED Displays and Their Application to OLED TV"

This year will mark the first year of the launch of larger-sized OLED TVs. This talk will highlight recent advances made in OLED technology and reveal the manufacturing breakthrough that led to the production of larger-sized OLED panels. Dr. Ahn will also describe the core technologies behind this breakthrough. Dr. Ahn led the development of the mass production of the first 5-in. OLED TV in 2009. In addition, he recently has been involved in the commercialization of LG's 55-in. Full-High-Definition (FHD) OLED TV.

Dr. Sung Tae Shin, *Senior Vice-President, LCD R&D Center, LCD Business, Samsung Electronics, Co., Ltd.*

"Display Transformation for Continuous Growth of the Display Industry"

Three waves of display evolution have been responsible for the continuous growth of the LCD market – notebook PCs in 2001, monitors in 2005, and LCD TVs in 2008. However, during the past few years, the display industry has become saturated due to stagnation in market growth, low panel price as a result of oversupply, and stagnant investment after Gen 8 production even though new applications, such as 3D, smart TVs, and tablets, have entered the marketplace. This talk will describe the next wave of display evolution – Display Transformation – that will stimulate healthy growth in the display industry. Here, Display Transformation means the multi-purpose use of displays, such as in smart windows, smart e-Boards, and digital art displays, that will deliver various online content and services for the "Smart Society." The talk will also describe what types of future technologies will be needed for this display transformation and the prospects of the display industry of the future. Finally, Samsung's vision and strategy of the next display world will be introduced.

Dr. Ramash Raskar, *Associate Professor of Media Arts and Sciences, and Co-Director, Center for Future Storytelling, MIT Media Lab*

Computational Displays: New Optimization for Interactive Lighting-Sensitive 3D Displays

Dr. Raskar will focus on the development of novel displays by the Camera Culture Group at the MIT Media Lab that (1) respond to ambient illumination (lighting-sensitive displays), (2) support intuitive multi-touch and gestural interaction (interactive displays), and eliminate the need for 3D glasses (automultiscopic 3D displays). At their core, these architectures exploit both the design of optical elements (*e.g.,* lenslet arrays and layered light-attenuating masks) and the development of the associated light-field encoding/decoding algorithms. Some of the novel displays to be described include the High-Rank 3D (HR3D) display, which contains a stacked pair of LCD panels rather than heuristically defined parallax barriers, the Bidirectional (BiDi) screen, an example of a new type of I/O device that possesses the ability to both capture images and display them, and a 6D optical system, which responds to changes in viewpoint as well as changes in back-lit transmitted illumination.

2012 SID Technical Program to Include Special Technology Tracks

The Society for Information Display's annual Symposium at Display Week offers a wide selection of presentations on display technology that simply cannot be found anywhere else. This year's program consists of 73 technical sessions with a total of 256 oral presentations and an additional 138 papers to be presented at the Thursday afternoon Poster Session. Please join us in Boston (Tuesday, June 5 – Friday, June 8) to share the latest research and development discoveries of the display industry and to join in the celebration of the 50th Anniversary of the Society for Information Display (1962–2012). This year's special areas of focus are 3D, Green Technologies, Solid-State Lighting, Flexible Electronics and Printed Displays, and Touch and Interactivity. Here is just a sampling of those topics and other innovations you can expect to find at this year's symposium.

3D

Possibly the biggest commercial story in displays in recent years is the arrival of 3D-ready TVs. Now that they have arrived, the story is far from over. Researchers continue to pursue the different approaches of active-shutter *vs.* passive glasses technology, and glasses-free viewing is a major challenge that many experts believe must be met in order to make 3D displays truly successful. This year's presentations also cover topics such as autostereoscopic 3D displays, 3D comfort and perception, volumetric and holographic displays, and stereoscopic and display applications. The Symposium includes the following sessions:

- Oxide TFTs
- Oxide-TFT Manufacturing
- e-Paper I & II
- Oxide AMOLED Displays
- Flexible TFTs
- Printed Displays and Electronics I, II, & III
- Flexible Processes

Green Technologies

Display technology continually advances to provide more resolution, larger size, and better performance – all at a lower cost. At the same time, environmental, social, and legislative forces are combining to ensure that manufacturers use the greenest-possible processes to create the most energy-efficient displays. What are the anticipated production and end-of-life issues for the display industry and how can they be addressed? The Symposium includes the following sessions:

- Driving Methods for Low-Power Displays
- Low-Power Displays and Materials
- Green Optics for Display Systems
- Display Manufacturing: Novel Devices & Green Technology

Solid-State Lighting

Solid-State lighting has begun to fulfill its promise with regard to saving energy and providing design flexibility. However, LEDs have made more commercial inroads in this area than OLEDs, which are currently available only in high-end architectural applications. OLED papers therefore form the bulk of this year's solid-state-lighting sessions, as the industry pushes to develop higher-efficiency, higher-performing OLED panels. Other solid-state-lighting papers will focus on trends in LED illumination. The Symposium includes the following sessions:

- Solid-State-Lighting Applications
- Solid-State Lighting I–IV
- Lighting Devices
- Fabrication Processes and Solid-State Lighting

Flexible Electronics and Printed Displays

Recent advances in the area of flexible electronics and printed displays have created the potential for lightweight, low-cost, and flexible devices based on technologies such as oxide TFT, organic light-emitting diode (OLED), and organic photovoltaics (OPV). This is the first year that SID has dedicated sessions to flexible electronics and printed displays; among the exciting work that will be described at the Symposium are the printing of organic TFTs and a new way to use high-temperature processes on low-temperature substrates. The Symposium includes the following sessions:

- Oxide TFTs
- Oxide-TFT Manufacturing
- e-Paper I & II
- Oxide AMOLED Displays
- Flexible TFTs
- Printed Displays and Electronics I, II, & III
- Flexible Processes

Touch and Interactivity

Since the launch of touch-enabled mobile devices several years ago, touch has become an increasingly crucial component for numerous display products. Yet, the industry has not found the ideal touch-technology solution. Touch is in an evolutionary phase now, and this year's papers reflect the diversity of approaches: projective-capacitive, optical, and many more. Which touch technologies hold the most promise and what is the next application or technology on the horizon? The Symposium includes the following sessions:

- Optical Touch Panels
- Enabling Technologies for Touch
- Projected-Capacitive Touch Panels

The topics described above are only a portion of the wealth of information you will discover at this year's Symposium. Visit www.displayweek.org to view the Preliminary Program. No one involved in the display industry can afford to miss this event. Please join us this June to engage, learn, and discover what you need to know about the innovations occurring right now in the display industry.

Market Focus Conferences

After a very successful debut in 2010, the Market Focus Conferences, now in their third year, will once again be held in conjunction with Display Week. They will cover the following two topics:

- The LED Lighting Evolution (Wednesday, June 6, 2012)
- The Future of Touch & Interactivity (Thursday, June 7, 2012)

Each Market Focus Conference will concentrate on the critical market development issues facing each of these technologies. Developed in collaboration with IMS Research, the conference will feature presentations and panel sessions with executives throughout the display supply chain. Conference fees include a continental breakfast, lunch, refreshments, access to the Exhibit Hall and Symposium Keynote Session on Tuesday morning, and electronic copies of the presentation material. Market Focus Conference registration does not require a current SID membership.

The LED Lighting Evolution – From Sapphire to Lumens: The LED Lighting Evolution conference will take place on Wednesday, June 6. The goal of this event is to allow global-industry leaders throughout the supply chain to explore the cutting-edge innovations that will shape the future of lighting and backlighting. This conference will feature keynotes and presentations from industry leaders, panel sessions, and ample time for networking.

The Future of Touch & Interactivity: The Future of Touch & Interactivity conference is the premiere event for display-industry professionals to learn about the latest in human–machine-interface technologies. The event will take place on Thursday, June 7, and cover how touch and interactive solutions are shaping the display industry. The Future of Touch & Interactivity will feature keynotes and presentations from industry leaders, panel sessions, and ample time for networking.

For further updates visit **www.imsconferences.com/sidfti/html**

SID Business Enterprise (Business Conference and Investors Conference)

Business Conference: The Business Conference will take place on Monday, June 4. The event will feature some of the leading minds from both Wall Street and the display industry and address the opportunities and challenges we are facing in this highly volatile economic environment. The Business Conference will feature keynotes and presentations from industry leaders, lively panel sessions, and ample time for networking.

For further updates visit **www.imsconferences.com/sidbc.html**.

Investors Conference: Co-sponsored by Cowen & Co., LLC, a securities and investment banking firm, this Conference, to be held on Tuesday, June 5, will feature company presentations from leading public and private display companies, intended to appeal primarily to securities analysts, portfolio managers, investors, M&A specialists, and display company executives.

For further updates visit **www.cowen.com**

2012 SID Seminar Series

Sunday Short Courses

The Society for Information Display presents four 4-hour short courses on diverse topics related to information display on Sunday, June 3. The tutorials are characterized by technical depth and small class size. The classes will cover the fundamentals of electronic information displays and will be held on the morning and afternoon of the Sunday preceding the Symposium. Full-color tutorial notes will be distributed to all participants and are included in the fee. Ample time will be provided for questions from the audience. The speakers are leaders in their respective fields and bring an international perspective to information display.

- **S-1:** Fundamentals of Solid-State Lighting and Manufacturing Technologies
- **S-2:** Fundamentals of Flexible-Display Technology
- **S-3:** Fundamentals of Touch Technologies and Applications
- **S-4:** Fundamentals of Active-Matrix Devices and Applications

Monday Technology/Applications Seminars

The SID Technology Seminars present lectures on diverse topics related to electronic information displays. These seminars are tutorial in nature, and an attempt is made to provide information at three levels. First and foremost, the technical foundations of the topic are treated in detail. Next, recent technical advances are discussed, and, finally, the current state of the art and the projection of future trends are analyzed. The Applications Seminars focus on the application and evaluation of information displays.

These seminars benefit both newcomers and experienced professionals. Engineers new to assignments in information display find them especially helpful in getting up to speed quickly. Experienced professionals attend to keep up with recent developments in fields closely related to their specialties. Managers attending the seminars obtain a broad perspective of the display field and a sense of its recent dynamics. Attendees will receive an excellent set of full-color notes, consisting of the instructor's presentation slides replete with references and illustrations. Ample time is provided for questions from the audience in each session. The speakers are leaders in their fields who bring an international perspective to information display.

Track 1: Liquid-Crystal Technology
- **M-1:** Photo-Alignment of LCDs and Polymer Films by Side-Chain Photopolymers
- **M-6:** Microsecond-Response-Time Blue-Phase LCDs

Track 2: Flexible Displays
- **M-2:** Flexible-Display Technologies
- **M-7:** Flexible Display Types and Applications

Track 3: Touch and Interactivity
- **M-3:** Capacitive Touch
- **M-8:** The Leading Edge of Touch

Track 4: 3D Technology
- **M-4:** Signal Processing for Stereoscopic 3D Displays
- **M-9:** Non-Glasses 3D Technology

Track 5: Nanotechnology and Mobile Displays
- **M-5:** Nanotechnology for Displays: A Potential Breakthrough for OLED Displays and LCDs
- **M-10:** Mobile Multimedia Displays

Track 6: OLED Technology
- **M-11:** OLED Lighting
- **M-16:** AMOLED-Based Displays for Future TV Markets

Track 7: e-Paper
- **M-12:** A Critical Review of the Present and Future Prospects for e-Paper
- **M-17:** Displays for eReaders: Selection Criteria and Technologies

Track 8: Pico-Projectors
- **M-13:** Introduction to Pico-Projectors
- **M-18:** Pico-Projector Applications

Track 9: Large-Area Displays
- **M-14:** The Future of Out-of-Home Displays
- **M-19:** Flexible Film Display Media for Signage

Track 10: Emerging Display Applications
- **M-15:** The Next Big Thing
- **M-20:** New Application Trends

For further details visit **www.sid2011.org**.

Special Event

Boston's Museum of Science — Sponsored by Corning Incorporated

CORNING

Come join us on this special event to Boston's Museum of Science and celebrate the 50th Anniversary of SID courtesy of Corning Incorporated on Wednesday evening, June 6. Attendees will dine amid high-tech devices, mingle among Mesozoic creatures, and experience a journey to the stars. The Museum offers film presentations in digital 3D using their state-of-the-art 3D digital projection system that incorporates polarized light instead of the traditional red/blue lens filters. Truly one of the region's most unique settings, the Museum offers novel surroundings and out-of-the-ordinary experiences that promise to intrigue and entertain.

Buses will leave the Boston Convention and Exhibition Center between 6:30 and 6:45 pm on Wednesday evening to take attendees to the museum for the 7:00 start time. Buses will return after the event ends at 10:00 and drop off guests at each of the SID-blocked hotels (Westin and Seaport).

Tickets are $50 per person and can be purchased at the SID Registration Desk during Display Week.

Display Week 2012 Overview

Boston Convention & Exhibition Center, Boston, MA USA
June 3–8, 2012

TIMETABLE	Sunday Course	Monday Seminars	Monday Bus Conf	Tuesday Symp	Tuesday Exh	Tuesday Inv	Wednesday Symp	Wednesday Exh	Wednesday Focus	Thursday Symp	Thursday Exh	Thursday Focus	Friday Symp
7:45 AM - 8:30 AM			Business Conference	SID Bus Mtg									
8:30 AM - 9:00 AM		Seminars M1 -M5		Welcome & Keynote Addresses									
9:00 AM - 9:30 AM	Short Courses S1 & S2						Oral Sessions 21-26	Exhibits / Exhibitors Forum Sessions / I-Zone	Market Focus Conference: The Lighting Evolution	Oral Sessions 39-44	Exhibits/ Exhibitors Forum Sessions	Market Focus Conference: Future of Touch and Interactivity	Oral Sessions 63-68
9:30 AM - 10:00 AM													
10:00 AM - 10:30 AM													
10:30 AM - 11:00 AM		Seminars M6 -M10		Oral Sessions 3-8	Exhibits / Exhibitors Forum Sessions / I-Zone	Investors Conference	Oral Sessions 27-32			Oral Sessions 45-50			Oral Sessions 69-73
11:00 AM - 11:30 AM													
11:30 AM - 12:00 PM													
12:00 PM - 12:30 PM			Bus. Conf. Lunch				Luncheon: DYA & Best-in-Show Awards						Auth. Int.
12:30 PM - 1:00 PM													
1:00 PM - 1:30 PM										Oral Sessions 51-56			
1:30 PM - 2:00 PM		Seminars M11- M15	Business Conference										
2:00 PM - 2:30 PM				Oral Sessions 9-14			Designated Exhibit Time						
2:30 PM - 3:00 PM													
3:00 PM - 3:30 PM	Short Courses S3 & S4									Oral Sessions 57-62			
3:30 PM - 4:00 PM		Seminars M16 - M20		Oral Sessions 15-20			Oral Sessions 33-38						
4:00 PM - 4:30 PM													
4:30 PM - 5:00 PM										Auth. Int.			
5:00 PM - 5:30 PM			Bus. Conf. Recept	Auth. Int.		Inv. Conf. Recept	Auth. Int.			Poster Session			
5:30 PM - 6:00 PM													
6:00 PM - 6:30 PM							Special Event						
6:30 PM - 7:00 PM													
7:00 PM - 7:30 PM													
7:30 PM - 8:00 PM													
8:00 PM - 8:30 PM		Awards Banquet											
8:30 PM - 9:00 PM													
9:00 PM - 9:30 PM													
9:30 PM - 10:00 PM													

Display Week 2012 Symposium at a Glance

2012 SID Display Week Symposium at a Glance – Boston Convention and Exhibition Center									
	Times	Ballroom East	Ballroom West	Room 205AB	Room 205C	Room 210A	Room 210B	Times	
Tuesday, June 5	8:00 – 10:20	SID Business Meeting and Keynote Session (Concourse Hall)						8:00 – 10:20	Tuesday, June 5
	10:50 – 12:10	3 Oxide TFTs	4 Blue-Phase Liquid Crystal 1	5 Stereoscopic Display Applications (Joint with Applications)	6 Innovations in FPD Analysis	7 Plasma-Display Technology	8 e-Paper I	10:50 – 12:10	
	2:00 – 3:20	9 Oxide AMOLED Displays	10 Blue-Phase Liquid Crystal 2	11 Polarization-Based 3D Displays (Joint with Systems and Liquid Crystal)	12 Advances in 3D Display Characterization (Joint with 3D)	13 CaMgO Protective Layer for Low-Power Plasma Displays	14 e-Paper II	2:00 – 3:20	
	3:40 – 5:00	15 AMOLED Displays	16 Blue-Phase Liquid Crystal 3	17 Autostereoscopic 3D Displays I (Joint with Systems)	18 Advanced and 3D Display Applications (Joint with 3D)	19 Solid-State Lighting Applications (Joint with Applications)	20 Flexible TFTs	3:40 – 5:00	
	5:00 – 6:00	Author Interviews (Exhibit Hall)						5:00 – 6:00	
Wednesday, June 6	9:00 – 10:20	21 OLED Displays I	22 Liquid-Crystal Alignment I	23 Autostereoscopic 3D Displays II (Joint with Applications)	24 Novel and Emerging Display Applications	25 Optical Touch Panels (Joint with Active-Matrix Devices)	26 Flexible Display Manufacturing (Joint with Manufacturing)	9:00 – 10:20	Wednesday, June 6
	10:40 – 12:00	27 OLED Displays II	28 Liquid-Crystal Alignment II	29 LC Lens for 3D (Joint with Liquid Crystal)	30 Video Processing for 2D/3D (Joint with 3D)	31 Enabling Technologies for Touch	32 Printed Displays and Electronics I (Joint with Flexible)	10:40 – 12:00	
	2:00 – 3:30	Designated Exhibit Time (Exhibit Hall)						2:00 – 3:30	
	3:30 – 4:50	33 OLED Devices I	34 Ferroelectric and Antiferroelectric LC Effects	35 3D Lightfield Imaging and Displays (Joint with Systems)	36 Image-Quality Enhancement	37 Projected-Capacitive Touch Panels	38 Printed Displays and Electronics II (Joint with Flexible)	3:30 – 4:50	
	5:00 – 6:00	Author Interviews (Exhibit Hall)						5:00 – 6:00	
Thursday, June 7	9:00 – 10:20	39 OLED Devices II	40 Cholesteric LCDs	41 Solid-State Lighting I	42 Intra-Panel Interface	43 Driving Methods for Low-Power Displays	44 Display Manufacturing: Flexible Processes (Joint with Flexible)	9:00 – 10:20	Thursday, June 7
	10:40 – 12:00	45 Solid-State Lighting II (Joint with Lighting)	46 Novel Non-Emissive Displays	47 3D and Multiview Projection (Joint with Projection)	48 Display Driving Techniques	49 Low-Power Displays and Materials	50 Display Manufacturing: Lamination & Testing	10:40 – 12:00	
	1:30 – 2:50	51 Solid-State Lighting III (Joint with Lighting)	52 Electrophoretic Displays	53 Lens Design for 3D Displays (Joint with Systems)	54 Color	55 Green Optics for Display Systems (Joint with Green)	56 Display Manufacturing: Oxide TFTs (Joint with Active-Matrix Devices)	1:30 – 2:50	
	3:10 – 4:30	57 Solid-State Lighting IV (Joint with Lighting)	58 High-Resolution TVs	59 Volumetric, Lightfield, and Holographic Displays (Joint with Systems)	60 Image Quality and Viewing Experience	61 Cool Lasers for Projection	62 Display Manufacturing: Novel Devices and Green Technology (Joint with Green)	3:10 – 4:30	
	4:30 – 5:30	Author Interviews (Exhibit Hall)						4:30 – 5:30	
	5:00 – 8:00	Poster Session (Exhibit Hall)						5:00 – 8:00	
Friday, June 8	9:00 – 10:20	63 FED and Emissive Devices	64 High-Performance Mobile Displays	65 3D Comfort (Joint with Applied Vision)	66 Novel Backlights (Joint with Lighting)	67 Optical Components for Projection	68 Display Manufacturing: Fabrication Processes and Solid State Lighting (Joint with Lighting)	9:00 – 10:20	Friday, June 8
	10:40 – 12:00	69 Lighting Devices	70 Novel Display Devices	71 3D Perception (Joint with Applied Vision)		72 Projection Display Systems (Joint with Systems)	73 Display Manufacturing: Substrates	10:40 – 12:00	
	12:00 – 1:00	Author Interviews (Exhibit Hall)						12:00 – 1:00	

TECHNOLOGY TRACKS KEY					
3-D	Active-Matrix Devices	Applications	Applied Vision	Electronics	Emissive
Flexible	Green	Lighting	Liquid Crystal	Manufacturing	Measurement
OLEDs	Printed Displays and Electronics		Projection	Systems	Touch

Dual-Pigment Electrophoretic Displays for Reading Textbooks

In recent years, electronic paper has been hugely successful in augmenting traditional paper in the area of "leisure reading." Now its developers are aiming at academic textbooks.

by Sriram K. Peruvemba

THE BENEFITS of today's eReaders are well-known. They are easy on the eye, providing a reading experience similar to that of paper. They can be read in bright sunlight, making it possible to read an "e-Bestseller" on the beach. They can store thousands of books, enabling a reader to carry a year's worth of reading or more in a purse or briefcase. At the same time, they offer instant gratification in the form of downloadable reading matter that is available 24/7.

Many of these qualities make eReaders especially suitable as e-Textbooks (Fig. 1). Electronic-textbook content, as a percentage of total textbooks sold in North America, is growing rapidly. While the overall textbook market is fairly flat, e-Textbook content is exhibiting double-digit growth rates according to various industry surveys. Xplana's research[1] estimates that digital textbook content will comprise almost 50% of the entire Higher and Career Education market by 2017. The content is currently consumed via dedicated eReaders and multipurpose devices such as laptops and tablets.

Sriram K. Peruvemba is Chief Marketing Officer for E Ink Holdings. With 25 years of experience in the electronics industry, he leads worldwide marketing for e-paper and LCD products at E Ink. He can be reached at speruvemba@eink.com.

The Most Successful Information Display to Date

Information display to most of us in the industry means an electronic display. To many of us it means specifically a liquid-crystal display (LCD), since that technology comprises over 90% of the roughly $100 billion electronic-display industry. And we would be wrong. The most widely used information display is printed paper – yes, the kind you get by chopping down trees.

Human beings love printed paper, and the publishing industry alone is four times as large as the entire electronic-display industry. Printed paper is a 500-year-old technology that is used everywhere. It's proven, rugged, and inexpensive relative to its competition; it just works. This information display is very readable, but its contents cannot be changed.

The $100 billion electronic-display industry comprises technologies including LCD, CRT (yes there are still some CRTs around), plasma, vacuum fluorescent, electroluminescent, LED, organic EL/OLED, electrophoretic, electrochromic, and emerging technologies such as MEMS, electrowetting, electrofluidic, laser, nanocrystal/quantum dot, and others still in the lab, together with projection displays and electro-mechanical displays. All offer one major advantage over printed paper – their content is changeable.

With the ability to change content, as well as other advantages to be discussed later, electronic displays have been gradually displacing printed paper in applications ranging from large signage to small phone books. However, printed paper, a tough competitor, continues to hold its own in performance and cost. This is why we still have printed-paper signs indoors and out – and in the author's town the printed phonebook is still delivered. Printed paper continues to hold more than a 90% share of the publishing world.

Rock, Paper, e-Paper

One of the strongest bastions of printed paper is in the area of reading media – books, magazines, and newspapers. Until recently, electronic displays could not come close to providing the reading pleasure offered by printed paper. However, this category is where electronic paper was first able to compete, in the form of widely popular eReaders. The first technology for eReaders that went from "emerging" status to mainstream was electrophoretic technology. Other display technologies labeled as e-paper that are also aiming to displace printed paper in reading applications include MEMS, electrowetting, and variations of conventional LCD technologies, including cholesteric, transflective, polymer-dispersed liquid crystals, and others.

What Is Reading?

It may sound odd that printed paper reigns supreme when it comes to "reading." How

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Fig. 1: eReaders are being used in an increasing number of schools and universities to display textbook content. Image courtesy E Ink.

can this be true when most of us spend the entire day in front of our laptops, watch TV for hours, converse on mobile phones until the battery drains, and sit through innumerable slide presentations shown via electronic projectors on a screen? Surely, the hours spent in front of electronic displays add up to far more than those spent reading from printed paper. And this may be true when it comes to consuming information, but "reading" is something else.

Reading is the process of recognizing text or words and converting an image of a word into audio, either aloud or silently. Once this image is converted, reading leads to comprehension, fluency, deeper understanding, acquisition of knowledge, improvement of vocabulary, and enjoyment. There is more than one form of reading, and there is much ongoing research about the different forms, as well as research about our reading habits with both electronic media and conventional printed paper.[a] For the sake of simplicity, reading can be divided into two broad categories: short-form and long-form reading.

Short-form reading involves reading a letter, a note, a brochure, headlines, billboards, or menus. With short-form reading, we are skimming, trying to gather a lot of information quickly, and this type of reading has become even more important in the last decade. With printed paper's inability to provide vast and up-to-date content instantaneously, electronic displays have made great inroads and are increasingly preferred for short-form reading. We read e-mails on our laptop LCD, track sports scores on our plasma TV, read a text message on an OLED screen of our mobile phone, and browse the Internet on our fringe-field-switching (FFS) LCD tablet.

Long-form reading refers to an entire novel, a physics textbook, a company's annual report, a religious text, or a lengthy book prescribed by your CEO that you are obligated to read. With long-form reading, one reads more than a few minutes at a time. One may read many pages or spend many minutes per page going through a chart or table. One attempts to gain a deeper understanding of the subject, is immersed in the subject, or is "lost" in the book. More than 90% of all long-form reading is still performed on printed paper. Only 4 years ago, nearly 100% of long-form reading was via printed paper, but e-paper, in particular dual-pigment electrophoretic-based e-paper, has now taken significant share. Use of electrophoretic displays in eReaders for long-form reading has been tripling in volume since 2006. In that year, there were roughly 100,000 dual-pigment electrophoretic displays shipped to eReader applications. That number is projected to exceed 25 million units in 2011.

Electrophoretic Basics

Electrophoretic displays are based on the principle of electrophoresis, which explains the motion of charged particles in a fluid under the influence of an electric field. The principal component of a dual-pigment electrophoretic display is a microcapsule with a diameter about the size of a human hair, and each display contains millions of microcapsules. Each microcapsule contains a mixture of very tiny, positively charged black particles and negatively charged white particles suspended in a fluid. When a positive or negative electric field is applied, corresponding particles move to the top of the microcapsule where they become visible to the user. This makes the surface appear white or black at that spot.

To form a dual-pigment electrophoretic display, the microcapsules are suspended in a liquid "carrier medium," which allows them to be coated onto a sheet of plastic film that is laminated to a layer of circuitry. The circuitry forms a pattern of pixels that can then be controlled by a display driver. The final laminate can be applied onto virtually any surface, including glass, plastic, fabric, or even paper. Figure 2 shows a large-scale example of dual-pigment display film.

Where eReaders Excel

Dual-pigment electrophoretic displays look like printed paper – and are as pleasant to read as printed paper – because they utilize the same pigments used in the printed-paper industry. With resolutions up to 300 dpi, they render a smooth image with gray tones that mimic the book or newspaper reading experience. They are reflective and therefore sunlight readable and do not cause eyestrain[b] and/or battery-weight strain, as is commonly associated with displays used in computer monitors and laptops. Because they lack a backlight and require no power to maintain an image on-screen (using a small amount of power only when changing the image), they are low-power devices that can perform for

Fig. 2: E Ink's dual-pigment electrophoretic display is made in a roll-to-roll processing plant in Massachusetts. In this picture, the latest generation of E Ink's display film, Pearl, is unrolled alongside the Charles River near Boston. Source: E Ink.

approximately 2 months on a single battery charge (Fig. 3).

Better Textbooks

As mentioned earlier, many of the eReader's qualities make these devices especially suitable as textbooks. These qualities include:

Interactivity: An eReader can help the interaction between teacher and student move beyond the classroom. A teacher can easily tell what areas of the subject matter pose greater challenges to the students based on interaction between the students' e-Textbook device and the teacher's e-Textbook. The teacher can then focus on those specific areas. Tests can be graded almost instantly. While researching, students can search the e-Textbook to locate remembered passages that support an argument for a paper (a process that can be laborious with a conventional textbook).

Cost Savings for Students: The cost-saving potential for electronic content is tremendous. In the near term, students can borrow books via their eReader devices,[2] as libraries have already begun lending electronic textbooks. In the long run, the publishing industry will benefit due to the cost savings from not having to print on paper. Today, all books are created in electronic form and then printed on dead trees (the true cost of printed paper is very high; see the YFY Group disclosure below). In the future, the printing step can be eliminated.

Fig. 3: The Nook dual-pigment eReader by Barnes & Noble can be read for 2 months on a single battery charge. Photo courtesy Barnes & Noble.

Viewing Angle and Glare: Just like printed paper and unlike many other display technologies, dual-pigment electrophoretic displays have a very wide, almost 180° viewing angle. That makes it easy for students using an e-Textbook application to share information from the same device. Most of the e-paper displays used in eReaders today have an anti-glare, anti-fingerprint/anti-smudge coating that reduces glare and makes the display look clean compared to a glossy tablet device with a lot of fingerprints.

Controllable Font Size: Changing font size to match individual needs, and especially increasing the font size while reading on e-paper, has been shown to be very beneficial for people with less-than-perfect eyesight. Increased font sizes reduce "crowding" of words, leading to better reading rates for the typical reader. This is even more beneficial for the dyslexic reader, as concluded by William DeLamater in an EReadia article dated April 29, 2010.[3]

Less Distraction: Single-purpose eReader devices can be configured so they do not support non-school video or web browsing, therefore reducing distractions for younger students. The content is typically teacher-selected, allows for interaction with the teacher's e-Textbook device, and enables note-taking and annotation. The risk of accidentally downloading viruses onto the device is minimized.

Library in Every Backpack: Today's school backpacks filled with printed books can weigh about a quarter of a student's body weight, causing back pain. According to the American Chiropractic Association, young children are experiencing back pain sooner than previous generations and overweight backpacks are a contributing factor.[4] e-paper-based devices replacing textbooks allow students to carry all of their textbooks, most of their reference materials, all of their notes, and all of the instructions from the teacher, in their backpacks. A typical device can carry a few thousand books, about the size of a small library for about the weight of one book (Fig 4). (In a lighter vein, *The New York Times*, quoting Dr. J. Kubiatowicz, says that thousands of eBooks actually have some weight, about one atogram or 10–18 grams, but unmeasurable by the most sensitive scale.[5]

The Future of e-Textbooks

In the relatively near future, electronic-textbook devices will continue to evolve, more content will be available via these devices, the cost of content will reduce drastically, and there will also be greater access to content. Recently introduced flexible electrophoretic displays allow designers to envision products that can take the everyday rough-and-tumble experienced by pulp-based books and newspapers. These displays are extremely thin and will not easily dent; there is also no polarizer to scratch or glass to shatter. Designers do not have to "cushion" the display like they would with a glass-based display. Such a display can sustain bumps and vibration and withstand drop tests easily. It might finally be "student proof."

Fig. 4: This Jetbook eReader from Ectaco displays a page from a biology textbook. Like all eReaders, this device can hold the contents of the stack of books behind it and much more. Image courtesy Ectaco.

Future e-paper displays will show animated content, stimulate faster interaction with the teacher, enable quicker feedback on tests, eliminate library late fees, and stop the problem of out-of-stock books – all of which gives students more time to learn. An e-Textbook device is interactive, intuitive, able to convert text to voice, and provides a ubiquitous learning medium. The greatest barriers to the adoption of e-Textbook applications appear to be non-hardware related and include cost of content, access to content, and availability of content.

Printed paper is the toughest of all display competitors because everyone loves it. But consider that if one person decides to change his or her behavior by reading all of their books, magazines, and newspapers on an eReader, that one person alone can save at least 20 trees in the next 2 years. And in the field of education, electronic displays, especially flexible ones, can make for a better textbook. We are talking about putting an entire library in a child's backpack. Our children are already researching primarily on the Internet and are less and less dependent on the traditional library. Imagine the Boston Public Library open to students in Baghdad, Bangalore, Beijing, and Budapest with no books lost, no additional printing or transportation costs, no late fees, and no out-of-stock books. This is not an evolution but a revolution in education and it has already started, though without much fanfare.

What does this mean to the electronic-display industry? It is a multi-billion dollar market opportunity that could compare with smart phones and TVs in volume. Its target audience (students) demands display ruggedness along the same lines as the military. And it is an opportunity for a huge ecosystem surrounding the display to develop and deliver a smart electronic device – a better textbook.

Acknowledgments

[a]Benjamin Paletsky, Product Marketing Manager, E Ink Holdings, for sharing his insight on this subject.
[b]Steve Battista, Jen Barlow, and Ana Lopes for their inputs.

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Disclosure

E Ink's parent company, the YFY Group, has a large paper and pulp business. ■

Touch Technology for eReaders

Four touch technologies are currently used in eReaders: analog resistive, electromagnetic pen digitizer, scanned infrared, and projected capacitive. None of these meet 100% of the user and system requirements for optimum touch in eReaders.

by Geoff Walker

WITH MORE THAN 500 million people using smartphones and tablets equipped with projected-capacitive touch technology, a *de facto* standard has arisen for what users expect on any touch-capable mobile device – including eReaders. The key requirements of this standard include the following:

- Extremely light touch
- Fast response
- High accuracy for selection
- Multi-touch for zoom (with images stored at higher resolution)
- Flush bezel for a high-tech look.

The touch usage model of eReaders adds another requirement: annotation capability. At the minimum, this means high-resolution digital ink for good readability; ideally, it includes handwriting recognition for automatically converting ink annotations into text.

The primary characteristic that differentiates a dedicated eReader from a tablet is the use of an electrophoretic display, often referred to as an "electronic-paper display" (EPD). EPDs are reflective displays, so the light that produces the image seen by the user must travel twice through whatever layers are on top of the display. This puts a premium on touch screens with very high transmissivity. Low reflectivity of the touch screen is also very important, since reflected light reduces the image contrast.

Additional system-level requirements for touch screens in eReaders include the following:

- Very low power consumption (like that for EPDs)
- Light weight, ideally achieved with no added glass layer
- Durable surface for annotations.

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Four Current Touch Technologies

There are four touch technologies currently used in eReaders (see Fig. 1), as follows in order of decreasing popularity:

- ***Analog resistive*** (*e.g.*, in the Sony PRS-600 and many others)
- ***Scanned infrared*** (*e.g.*, in the Kindle Touch, the Nook Simple Touch, the Sony PRS-950, and a number of others)
- ***Electromagnetic pen digitizer*** (*e.g.*, in the Onyx Boox M90, the Hanlin V90, the Hanvon WISEreader E920, which adds finger touch, and several others)
- ***Projected capacitive*** (*e.g.*, in the Pixelar MReaders, the Hanlin V60T/V61T/A6/A9, the Kogan Reader, and a few others)

Analog Resistive: While resistive is commonly used in touch eReaders because of its low cost, it is actually the worst choice. Transmissivity is typically in the 80–90% range, which means that up to 40% of the light can be lost during its two trips through the touch screen. Because there are four reflective surfaces in a resistive touch screen, reducing surface reflectivity is very expensive. Resistive requires a relatively heavy touch, but works well with a passive stylus – except that the lack of palm rejection makes annotation difficult. Resistive as used in eReaders today provides single-touch only. Resistive is available in an "almost-flush bezel" form in which the touch-screen's plastic cover sheet is extended to cover the entire top surface of the product.

Scanned Infrared: Infrared (sometimes called "optical") touch technology has not historically been used in mobile products. However, one company (Neonode in Sweden) has made significant progress in miniaturizing infrared touch components over the past half-dozen years, with the result that it is currently the only supplier of infrared touch in eReaders. (Neonode's patent portfolio provides a significant barrier to entry for other suppliers.) Infrared's major advantage in an eReader is the lack of need for a substrate. This is ideal for use with a reflective EPD, since no light is lost. On the other hand, sensing touch with infrared requires breaking a matrix of light beams that are present above the surface of the display, so a flush bezel is not possible. Conventional infrared is relatively low resolution, so annotation with a stylus typically is not very satisfying, and multi-touch is generally limited to two not-very-robust touches. Infrared is susceptible to unintended touches from contaminants (or if the user forgets to turn off the device before putting it in a briefcase) and from ambient IR radiation.

Electromagnetic Pen Digitizer: Pen digitizers have been used in mobile products for

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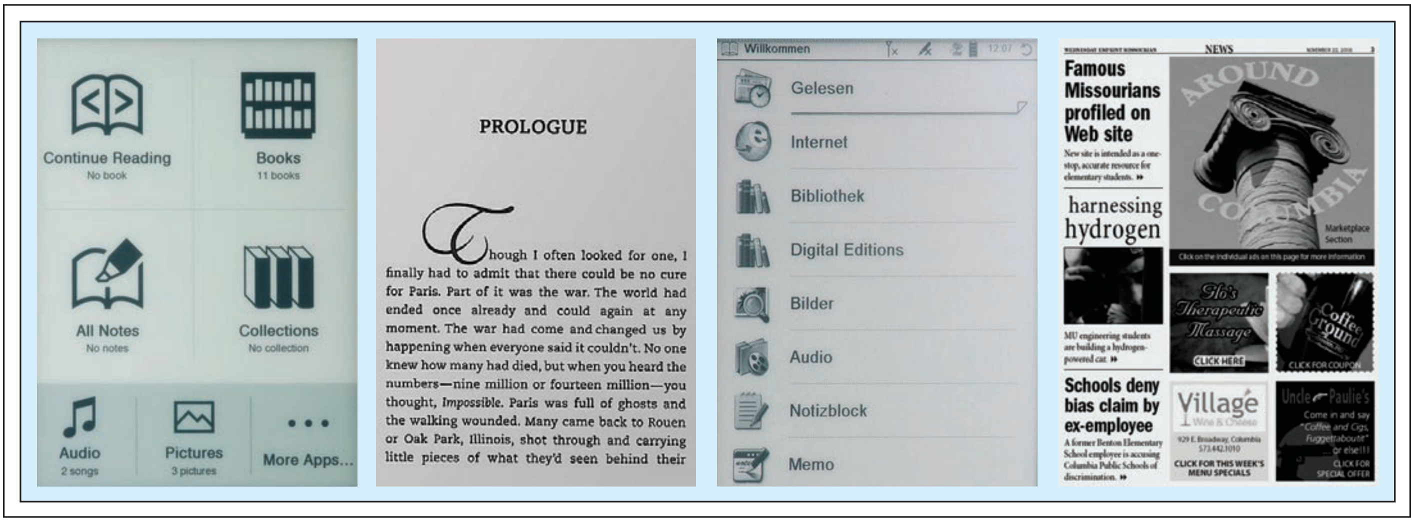

Fig. 1: Four 6-in. eReaders are shown, one with each touch technology (left to right): Sony's PRS-600 (resistive), Amazon's Kindle Touch (infrared), Hanvon's N618 (electromagnetic pen digitizer), and Jinke's Hanlin A6 (projected capacitive). Most eReader manufacturers offer only one or two touch technologies; Jinke in China is the only one that offers all four. Source: Manufacturers.

over 20 years, so it is not surprising that they are used in some eReaders. Like infrared, this technology's major advantage is its lack of a need for a substrate (the digitizer's sensor goes behind the EPD, so no light is lost). Since there is no touch-screen substrate, the possibility of a flush bezel depends on the design and construction of the EPD. Pen digitizers are typically very high resolution (often as high as 1000 dpi) with inherent palm rejection, which makes them very well-suited for annotation. However, with the exception of Hanvon's "Dual-Touch" technology (which supports both pen and single-touch finger), pen digitizers are pen-only.

Projected Capacitive: "Pro-cap," as it is often called, is the touch technology used in most smartphones and tablets today. However, it is relatively expensive (a 9-in. pro-cap touch screen is typically 3× the cost of resistive), so it is less frequently used in eReaders. Pro-cap's advantages are its very light touch, multi-touch, and flush-bezel capability – all of which are characteristics of the *de facto* standard, so usage is likely to increase despite the cost. Currently, it is finger-only, so annotation is not possible (although some pro-cap touch-screen suppliers will start supporting both active and passive styli during 2012). When stylus support arrives, pro-cap is capable of providing good palm rejection, so the user's annotation experience can be almost as good as with a pen digitizer. Light loss is not a major issue with pro-cap, since transmissivity is in the 95–98% range. However, limiting the reflectivity of the touch screen's top surface adds even more cost. Two of the three sample eReader suppliers listed under pro-cap on the previous page use the SiPix/AUO EPD; this form of pro-cap uses two patterned-electrode films laminated on top of the EPD during manufacturing and is covered with a hard coat (*i.e.*, no glass). While the cost of this form is relatively low, future stylus support seems unlikely.

Power Consumption

Power consumption in an eReader is dominated by page-turns; *i.e.,* by changing the image on the EPD. The power consumption of all four of the touch technologies described in this article is orders of magnitude less than that of the EPD. While some power-consumption differences do exist between the technologies, experience has shown that the quality of the power-management algorithms used to control the touch screen is actually much more significant than the differences between technologies.

Emerging and Future Solutions

As noted earlier, none of the four touch technologies described here meet 100% of the user and system requirements listed in the beginning of this article. Of the four, the one that is the closest to meeting all the requirements is Hanvon's Dual Touch pen digitizer. Hanvon achieves finger touch by adding some low-cost components to the digitizer sensor behind the EPD; if Hanvon can meet its goal of supporting touch with multiple fingers, the only remaining negative will be the electronic (but batteryless) stylus.

Another technology that has a good chance of meeting all the requirements is waveguide infrared. Created by RPO in Australia and branded "Digital Waveguide Touch" (DWT), it is essentially a lower-cost and higher-performance version of scanned infrared. Unfortunately, RPO shut down due to lack of funding during 2011 and its extensive patent portfolio is currently for sale. It is possible that the technology (which was very close to mass production) may be purchased and made available by another touch supplier.

There is one additional touch technology that has at least some chance of meeting all the requirements once it becomes more mature. The technology is TE Connectivity's (Elo TouchSystems') Acoustic Pulse Recognition (APR). APR is capable of pen and finger touch with nothing added in front of the display. E Ink has done some prototyping of APR integrated into its EPD, but it is too early to determine the potential. ■

Toward the Ultimate 3-D Display

Holographic stereography and a new photorefractive material may help create a 3-D display that reproduces all human visual cues.

by Pierre-Alexandre Blanche

LET US START WITH a statement about displays: "It is all about the viewer." Understanding human physiology and how we perceive depth should lead display technology toward a flawless and thus successful 3-D system. What is true for the consumer market is even more relevant for special applications such as medical imaging, remote training, or intelligence analysis. In these fields, the 3-D image can incorporate elements or data from different instruments or sensors, making the fused information complex to analyze. But a complex image does not, and should not, be difficult to interpret. In areas where information interpretation is critical, the display ought to be perfectly adapted to the decision maker.

Several cues are used by the brain to determine absolute and relative distances[1]: occlusion, relative size of objects, atmospheric scattering, texture, and shading are already exploited in the case of 2-D displays. Indeed, we did not wait for the introduction of stereoscopic theater or television to understand relative positions of elements in a scene. When an explosion happens in the background in a 2-D movie, we understand why the hero remains unharmed. A film director can exploit these cues (and the absence of others) to make objects appear closer or farther away than they are in reality. The use of a telephoto lens is such an example because it normalizes the size and distance difference between near and far objects. However, these artistic touches can be misleading in cases where the display is used for critical analysis. You do not want a surgeon to think the artery is farther away than it is in reality; you do not want the intelligence analyst to think the structure or building is smaller than it is on the field. Discrimination in these cases can be improved when more cues are provided, thus the focus on integrating stereopsis, vergence, and accommodation into the display environment.

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Stereopsis, Vergence, and Accommodation

Stereopsis and vergence are phenomena resulting from binocular vision. Different images are perceived by the left and right eye due to their lateral separation, and these images are interpreted by the brain to deduce distance. Stereopsis is a consequence of the binocular disparity (mostly the parallax shift), while vergence is the rotation of the eyes in opposite directions around their vertical axis to fixate on the same point of an image [see Figs. 1(a) and 1(b)].

Stereoscopic displays use those cues to reproduce 3-D by employing a technique that was introduced in 1838 by Sir Charles Wheatstone. In a variety of implementations – such as color filters (anaglyph), polarizers, or shutters – stereoscopic displays present a different image to the left and the right eye and prevent crosstalk by using some sort of eyewear.[2]

Stereoscopy has many advantages: it is robust, quite easy to implement, and effective to a certain extent. It only requires a pair of images to be recorded and does not dramatically change the image-capture techniques (side-by-side cameras). In the case of polarization and active-shutter technologies, the display refresh rate only needs to be doubled to 60 or 120 Hz – reasonable frequencies for the current technology in both cinema and television. This convenience is the main reason for stereoscopy's recent commercial success, in theaters at least. Nonetheless, there are a few issues with this approach, one of which is that almost every stereoscopic technique today requires some sort of eyewear. The public has been fairly accepting of this eyewear tradeoff when it comes to experiencing immersive 3-D, as theater attendance has shown over the last couple of years. Likewise, millions of people wear prescription glasses without complaint – because the benefits far outweigh the discomfort.

Another limitation with stereoscopy is that it does not reproduce motion parallax: When the viewer moves in front of the display, the viewpoint does not change. You cannot look around an object as in real life. For a stationary audience such as one in a theater, this is not an issue at all. Motion parallax can also be addressed by a head-tracking system that determines the position of the viewer and calculates the viewpoint in real time.[3] However, head tracking can be implemented for one and only one viewer at any given moment. For a multi-viewer audience, there would be one master directing the display, resulting in awkward sensations for the other viewers.

While the mandatory eyewear and the lack of motion parallax are mild concerns with stereoscopic approaches, the most serious problem is the accommodation-vergence conflict. Indeed, even if the vergence cue is correctly reproduced by a stereoscopic

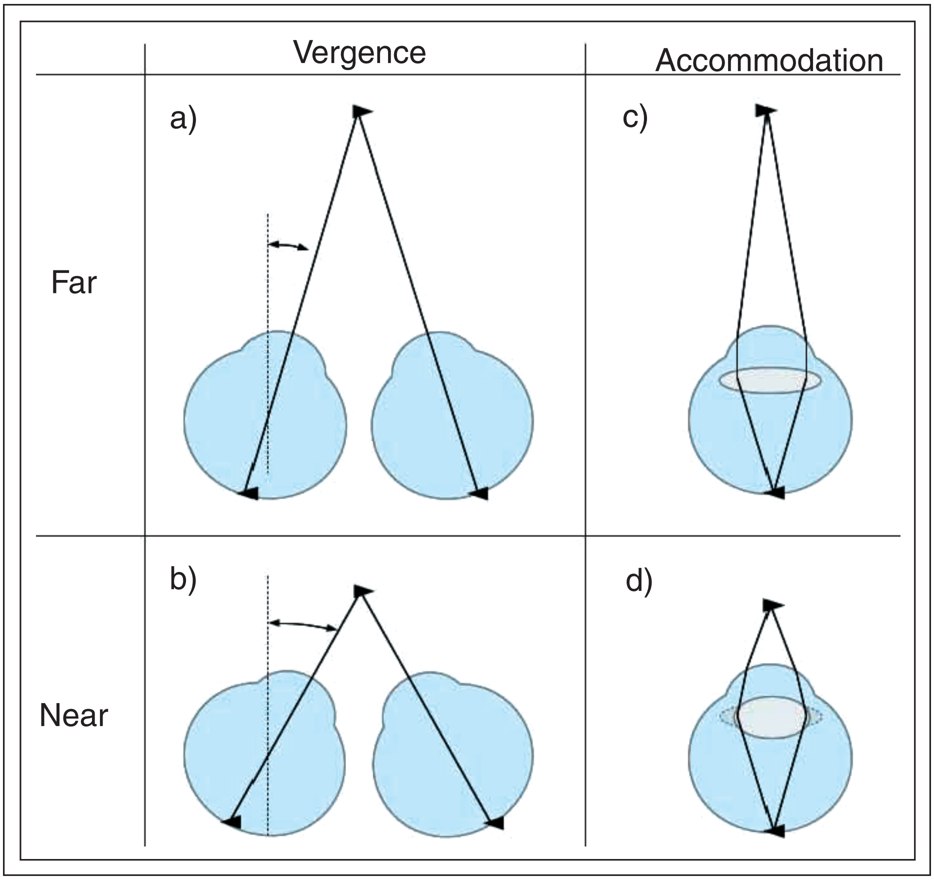


Fig. 1: Accommodation and vergence cues differ for a far or near object.

system, the accommodation is not. This infor-mation conflict inside the brain leads to asthenopia, *i.e.*, visual fatigue, including headache, nausea, and motion sickness.[4,5]

Vergence is the rotation of both eyes along their vertical axis to fix on a common point in a scene. It is shown in Figs. 1(a) and 1(b) how the eyes rotate so images are formed near the fova spot, which is responsible for sharp central vision. The brain interprets the tension on the eye muscles (media and lateral rectus) to aid in determining the object's distance. If that object is in the forefront of the scene, the eyes rotate inward, causing the lines of sight to cross near the viewer. If the object is farther away, the eyes rotate outward to make the lines of sights more parallel. One can see why this cue is correctly reproduced by stereoscopy, since the basis of this technique is laterally shearing the left and right image elements according to depth.

But the eye is also a single-lens optical system in which the image plane is fixed: the image must form on the retina. For such a system, a sharp image is obtained for only one position of the object. When the object position changes, the image position changes accordingly unless the focal length of the lens is adjusted, exactly describing what happens in the eye. The eye lens is not rigid and can be deformed by the ciliary muscles to change its optical power. This is the basis of the accommodation cue: the adjustment of the eye lens to focus on objects at various distances [see Figs. 1(c) and 1(d)]. Accommodation is not related to stereoscopic vision, since you still need to accommodate when viewing with a single eye. It should be clear by now why no stereoscopic technique correctly reproduces the accommodation required by a true 3-D scene: when looking at the display, your eyes accommodate to the position of the emitter plane (the screen), and this position, or distance from observer to image, remains constant.

As shown in Fig. 2, with stereoscopy the brain receives conflicting information. The vergence changes and is correctly reproduced, but the accommodation is fixed and thus incorrect. This conflict can lead to eye fatigue and related physiological effects such as headache, dizziness, and nausea. However, there is a certain degree of mismatch that the brain can tolerate, especially when the screen is far away, as in a theater. At large distances, accommodation is not used, and the eye lens stays at rest. This is why the vast majority of people can appreciate a 3-hour movie in a stereoscopic theater. But for displays that are located much closer to the viewer, such as a television or a workstation, the conflict becomes more pronounced and the effects can be intolerable.[5] This is especially the case in professional environments where workers spend most of their time looking at the display, or for young children, whose visual systems are still in development.[6] This is the fundamental reason why better techniques are needed to reproduce 3-D. That brings us to holography.

Holography

Holography is the reproduction of both the amplitude and the phase of a scene by a diffractive pattern. We are familiar with systems that display amplitude, or intensity. From a photograph to an LCD TV, every display reproduces the light intensity. The phase, or wavefront of a light field, is less common and describes how the light wave is particularly curved at each given point of a scene. For a 2-D image, the wavefront is flat because each emission point is at the same distance from the viewer (the Huygens–Fresnel principle) but for a real scene, objects at the forefront have a more convex wave pattern than elements in the background. This is precisely why the eye needs to accommodate. It is now obvious why holography is the ultimate technique to display 3-D: it reconstructs the correct light field, and in doing so all of the optical cues are reproduced.

There is a catch. The reason why we still do not have holographic television or theater, even though holography was discovered in 1947, is due to the last two terms of the above-mentioned holographic definition: the "diffractive pattern." To diffract light, the pattern (you can read pixel) needs to be of the scale of the wavelength. For visible light, this is around 500 nm. Now, if you want a reasonable screen size – let's say 0.5 × 0.5 m with a reasonable field of view (50°) – you need to

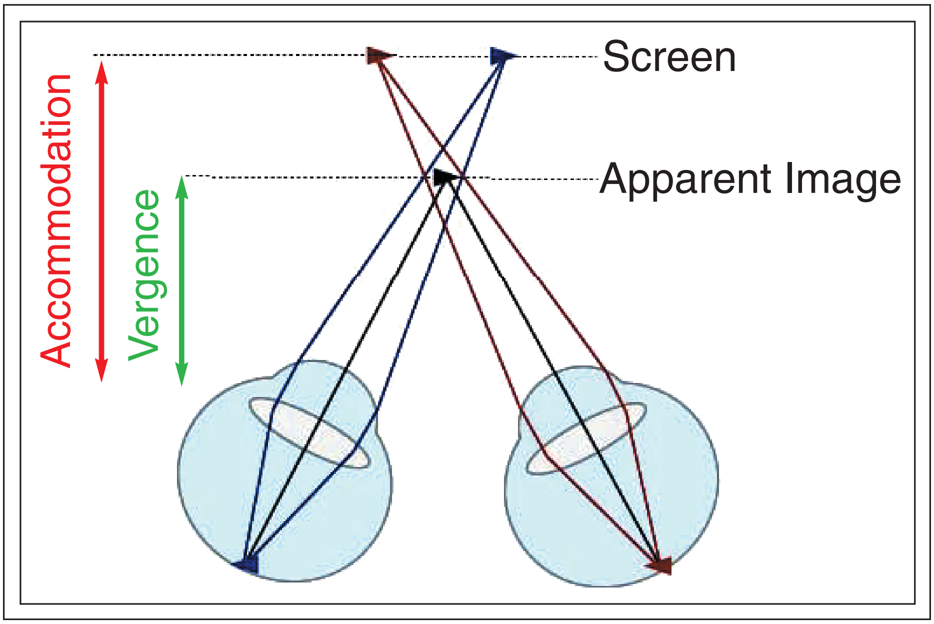
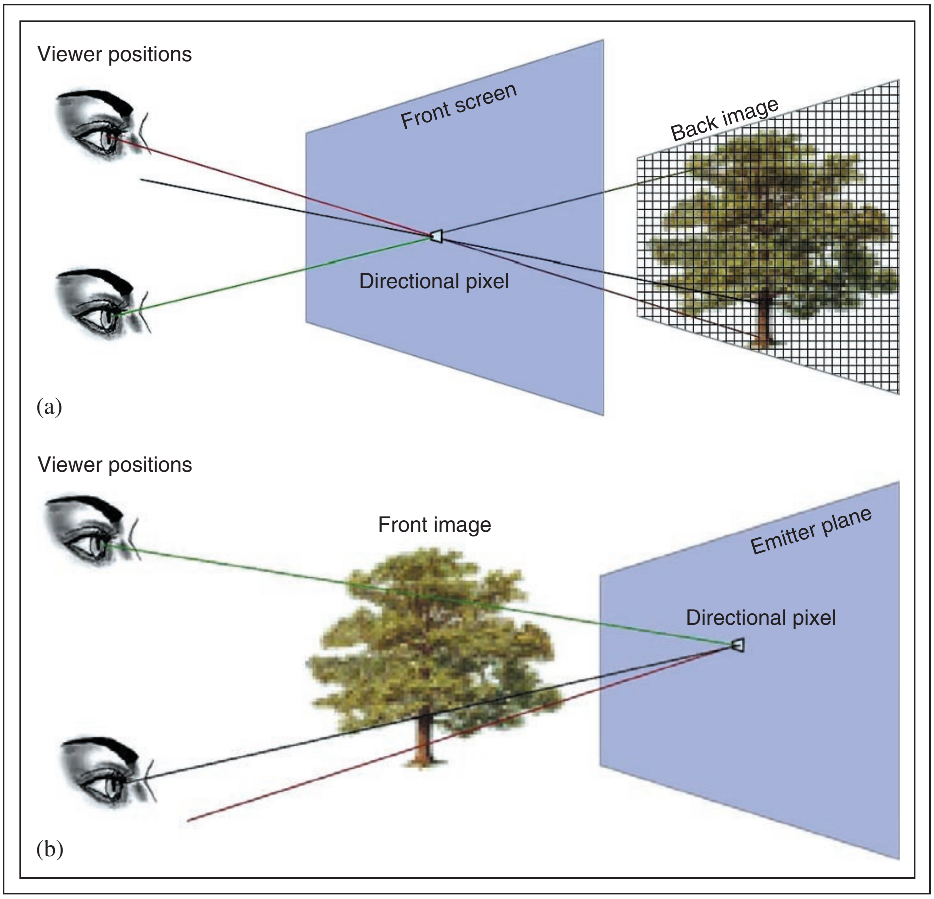


Fig. 2: The accommodation-vergence conflict occurs in stereoscopic displays because the eyes accommodate to the screen but rotate to fix the apparent image.



control 1×10^{12} pixels. At video rate (60 Hz), three colors and 8 bits per color, this multiplies to 5×10^{16} bits/sec, a bandwidth that is not easily accessible. To put these numbers into perspective, you would have to tile a 1080*p*/1080*i* HDTV with about 2×10^{6} pixels, 500,000 times, then shrink it to the size of a 15-in. monitor. Despite the sheer size of the problem, or maybe because of it, researchers around the world are working on solutions, and excellent works have been published by various groups.[7]

If holography is the ultimate solution to reproduce the light field, it might also be over-kill for human vision. Indeed, holography achieves nanometer resolution that cannot be resolved by the eye. Since the resolution of stereoscopy is not enough with 3×10^{6} pixels, and holography is way too much with 1×10^{12} pixels, could we achieve a trade off and find a technique in between these two extremes that will reproduce all the visual cues, but with limited bandwidth and a reasonable number of pixels? The answer to that question is stereography.

Stereography

Based on the work done by Gabriel Lippmann on integral photography in the early 1900s, a stereographic display projects different rays of light in different directions from each of its pixels. This is why this technique is also called multiple-viewpoint rendering. To explain it, think of the display as a frame through which the viewer looks to see a scene in the background. This principle is sketched in Fig. 3(a). If you trace all the rays of light coming from one point of the scene and passing through the frame, you will find they all have different angles. Those are the rays the display has to reproduce, for each and every point of the scene. Though this analogy with a frame and a background scene is useful for explanation, stereography can also reproduce objects in front of the screen (the frame in the example), where the ray-tracing method is identical [Fig. 3(b)].

How many rays a stereographic display should generate to reproduce all of the visual cues depends on the depth of field, as well as

Fig. 3: According to the principles of stereography, the pixels emit directional rays: (a) object in the back of the emitter plane, (b) object in front of the emitter plane.

geometrical factors such as the viewer pupil size, its distance from the screen, and the field of view of the display.[8] But considering a high-definition display that has 2×10^6 pixels (HDTV), and a depth of field about the screen diagonal, this would translate to about 2×10^9 rays.

The technique of angular reorientation of the light rays from the display is used in autostereoscopic (glasses-free) 3-D television.[9] In such a device, a lenslet array is laid over a 2-D screen. As shown in Fig. 4, each lenslet covers several pixels and redirects their beams in different directions, creating different view zones. When the viewer is correctly positioned, his left and right eyes intercept two different zones and a stereoscopic effect is created (note that this is stereoscopic and not stereographic). However, the accommodation cue is not reproduced with those televisions. This is because at least *two view zones* need to enter *each eye* to approximate the wave curvature. Compared to glasses-free 3-D television, many more view zones need to be projected in a stereographic system.

To obtain more view zones, one can imagine packing more pixels under each lenslet, but this means drastically reducing the pixel size (down to 0.001 mm), which is not technically possible yet. On the other hand, if you increase the size of the lenslet itself to cover more pixels, the lateral resolution of the display suffers.[10]

Different approaches have been proposed to realize stereographic 3-D displays by reproducing accommodation: optical demagnification of the pixels by a telescope,[11] and the use of acousto-optic modulators to reorient lasers beams and sweep the view zone.[12] But up until now, it seems that there is no display yet capable of providing a large autostereoscopic 3-D image without some sort of artifact. This can be understood by the sheer numbers presented above. It is not easy to move from a system driving 2×10^6 pixels to one that will manage 2×10^9, a factor of 1000 larger.

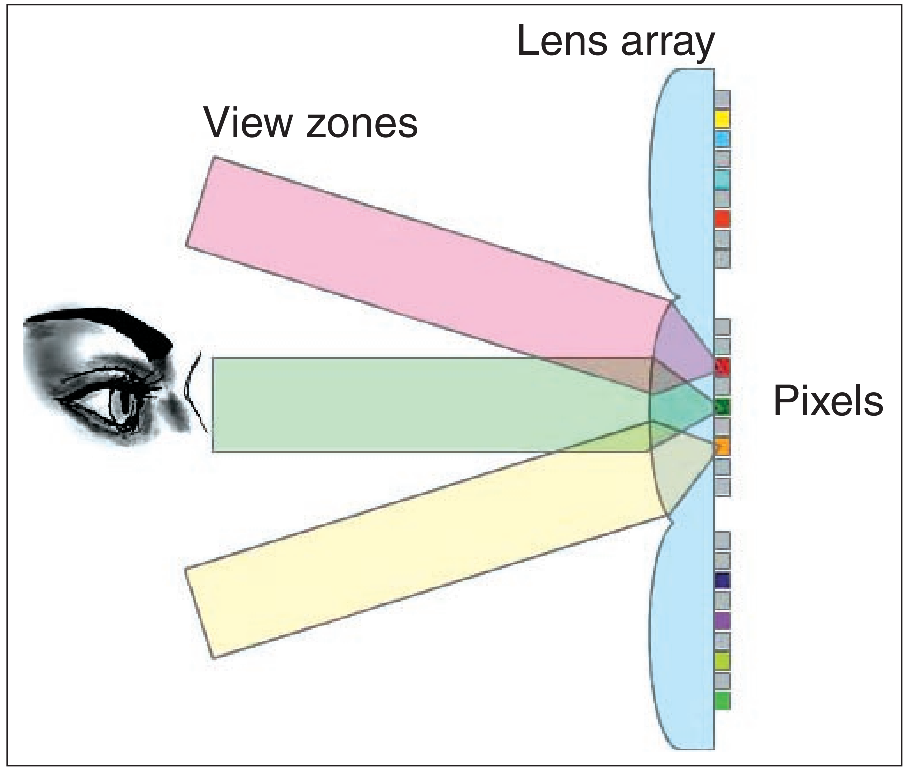


Fig. 4: The principle of autostereoscopic 3-D television is shown above: A lens array overlays a regular 2-D screen. Each lens redirects the light emitted from individual pixels, creating different view zones. When the viewer's eyes intercept two different view zones, the stereoscopic effect is achieved.

Hogels and Stereographic Still Imagery

While we wait for a dynamic stereographic display to emerge from research labs, stereographic still pictures can currently be made, thanks to holography. These images are composed of pixels, but each of those pixels is a hologram. They are named "hogels," for the contraction of both words. These hogels are recorded when two laser beams interfere in a holographic recording material. The first beam is called a reference beam and does not contain any information. The second beam is modulated by an LCD and focused by a lens into one spot. That means all the pixels from the LCD screen are compressed together by the lens into one single hogel. The holographic recording technique actually achieves what is shown in Fig. 3(a): The back image is shrunken into one pixel.

When this kind of hologram is replayed, the hogels reproduce a structured cone of light, so that each angle emits a different ray. That is the actual principle of stereography just discussed. What is important to notice here is the compelling beauty of these images, which are realistically reproducing vibrant colors and depth of field. The images are attractive from an artistic point of view, but they are also useful in technical areas such as medical imaging, architecture, and industrial design.[13] Recently, a study was conducted with regard to the performance of U.S. Army military personnel when using regular 2-D topographic maps (on which soldiers had been trained and were used to) and stereographic 3-D holographic maps.[14] The results revealed improvements in planning and execution on every single task when the soldiers were using the holographic maps. It is exciting to imagine what effect such a technology, if a display is made possible, could have in the civilian world.

Material Resources

One of the reasons holographic stereography has not yet been implemented into a 3-D dynamic display is because of the recording material. Indeed, holographic recording materials such as photopolymers, silver-halide emulsions, or dichromated gelatin are permanent. They are exposed to the laser beams once, then chemically processed to reveal the hologram, but cannot be refreshed. With these materials, holographic cinema can and has been demonstrated,[15] but a display with dynamic imaging is not possible.

A new type of material, called photorefractive polymers, was discovered in the early nineties. These polymers can be recorded, erased, and refreshed without any fatigue. They do not need any post-processing for the hologram to be revealed; it appears by itself after the exposure due to electronic charges re-localization.[16] The properties of this class of material have been extensively studied and improved in recent years to achieve very high figures of merit such as diffraction efficiency, sensitivity, speed, and reliability. Since the materials are in a polymeric form, they can be cast into a large screen and could be an ideal material to develop a dynamic stereographic 3-D display. That is the pathway the author's group at the University of Arizona, College of Optical Sciences, has followed to demonstrate a 3-D display with a screen size up to 17 in. (see Fig. 5), and a refresh rate of few seconds.[17]

Using the principle of holographic stereography, and with the photorefractive material at the heart of the system, a telepresence experiment has also been demonstrated that records images of a person in one location and prints the hologram in another, using the Internet to send the data. Figure 6 shows photographs of one of such holographic stereogram taken at different angles to demonstrate the parallax. The image can be erased and refreshed at will without any material fatigue. The photorefractive polymer might be to 3-D display what phosphor has been to 2-D CRT screens.

In its present state, this display is still an experimental setup that needs further development to achieve video rate and a compact system. However, this is a new direction toward a 3-D display that respects human vision by providing all the cues: accommodation, vergence, and parallax.

Fig. 5: The author holds a 17-in.-diagonal photorefractive polymer sheet.

Fig. 6: A photograph of the holographic stereogram at different angles shows the parallax.

So, while the challenges of stereographic 3-D displays are numerous in quantity and large in magnitude, we can expect that rapid progress will continue to be made on different fronts. Humans are meant to see in 3-D, and our quest for the ultimate display will continue until a system reproduces each and every visual cue, flawlessly.

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Part I: What Companies Need to Know about the Leahy–Smith America Invents Act (AIA) Patent Reform Legislation

The America Invents Act, the most significant change to the U.S. patent system since 1952, was signed into law on September 16, 2011. This series of articles will focus on selected provisions of the AIA that are likely to be the most relevant to companies in the display industry. Part I of this series of articles will focus mainly on key litigation-related provisions that are effective now.

by Clark A. Jablon

THERE are basically three different sets of provisions for the America Invents Act (AIA). The first set became effective immediately upon enactment, and thus are effective now. A second set becomes effective 1 year after enactment (September 16, 2012), and a third set becomes effective 18 months after enactment (March 16, 2013).

This article will focus mainly on key litigation-related provisions in the first set, which are effective now. One key provision in the third set, effective March 16, 2013, has been the most heavily discussed provision of the legislation in mainstream media; namely, the changeover in the U.S. patent system from a "first to invent" to a "first to file" system (see sidebar "First to File").

Provisions of the AIA that are effective immediately include a prior-use defense, tougher standards for asserting a "false marking" claim, and new joinder rules that severely limit the ability of a plaintiff to sue multiple defendants in a single patent lawsuit.

One provision of the AIA that becomes effective in September 2012 relates to new rules regarding advice of counsel presumptions in litigation. This provision is also discussed below because its impact may be relevant now, due to the typical delay time between preemptive opinion work and the filing of a patent lawsuit.

Prior User Defense

Prior to enactment of the AIA, a company that was commercially using an unpatented invention in secret, such as by treating the invention as a trade secret or simply practicing the invention in a manner that did not reveal how it worked, could be liable for patent infringement if another party subsequently invented the same invention without deriving the invention from the company and obtained a patent. Thus, the patent rights of the second inventor in time trumped the "prior use" rights

> ***The America Invents Act, the most significant change to the U.S. patent system since 1952, was signed into law on September 16, 2011.***

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of the first inventor. (If the company's use of the invention was not secret and revealed how it worked, then the second inventor's patent would be invalid and unenforceable.) Prior to enactment of the AIA, there was a limited exception to this rule for business method patents, wherein a company charged with patent infringement of a business method patent was entitled to assert a defense to the infringement by showing that it commercially used the invention in secret more than 1 year prior to the filing date of the business method patent. Very few technology companies were able to rely upon this provision since the vast majority of patent infringement lawsuits do not involve business method patents.

The AIA now expands the "prior user defense" to all technology areas. This provision is welcome relief for companies that wish to rely upon trade-secret protection for their inventions, as opposed to seeking patent protection for their inventions. There are limitations to this defense that must be considered before a company makes a deliberate decision not to seek patent protection on an invention, and to instead rely upon the prior-user defense if the company is sued for patent infringement.

> *The 'prior user defense' is welcome relief for companies that wish to rely upon trade-secret protection for their inventions, as opposed to seeking patent protection for their inventions.*

For example, to rely upon this defense, the accused infringer must provide "clear and convincing evidence" of the prior commercial use. Difficulties may arise in collecting and presenting the necessary proof to a court or jury. Also, if the accused infringer is found to have asserted the defense without a reasonable basis, and is found to be an infringer, the case shall be declared "exceptional," which means that the accused infringer will likely have to pay the legal fees incurred by the patent holder.

The prior-user defense has certain limitations that may prevent its use. For example, the prior commercial use must have occurred "continuously" during the infringement period. The defense also cannot be assigned or licensed to third parties, unless there is a sale of the business that uses the patented invention. There are also limitations that may prevent a company from expanding its use of the patented invention. Also, the defense is not available if the infringed patent was developed under a federally funded agreement or by universities without the use of private funds. Furthermore, the defense only applies to patents issued on or after the effective date of the AIA, namely, September 16, 2011.

"False Marking" Claims and the New "Virtual Marking" Provision

Prior to enactment of the AIA, any entity was allowed to file a lawsuit accusing a company of violating the patent marking statute, and if successful, collect 50% of the damages, with the remaining 50% collected by the U.S. government. The entity bringing the lawsuit did not have to prove that it was personally harmed in any manner by the false marking. There are many ways that a company could inadvertently violate the patent marking statute, such as by failing to remove a patent number from a marked product when it expired, or by inadvertently continuing to mark products with patents that no longer cover the product. In recent years, hundreds of such lawsuits have been filed by dozens of opportunistic law firms. Companies would often settle such lawsuits for nuisance value amounts.

The AIA changed the law so that a false-marking lawsuit may only be filed by the U.S. government or by a competitor who can prove that it suffered a "competitive injury." Furthermore, it is no longer a violation to mark a product with an expired patent number that formerly covered the product.

This provision of the AIA was not only made effective upon enactment, but was made effective to all pending false-marking lawsuits. The U.S. Courts are currently in the process of dismissing virtually all of the pending false-marking lawsuits since the vast majority of such suits were not filed by the

First to File

Presently, and until March 15, 2013, two different sets of inventive entities (inventors) who file a patent application for the same invention can become subject to an interference proceeding wherein the patent will be awarded to the inventor who can prove through documents and other evidence that they invented the invention first in time, regardless of which inventor filed the application first.

On March 16, 2013, the patent will be awarded to the inventor who filed the application first in time, regardless of when the inventor actually invented the invention. The only exception to this new "bright-line" rule is if the second-to-file inventor presents evidence that the first-to-file inventor derived the invention from the second-to file-inventor, such as by stealing it. In this case, the U. S. Patent & Trademark Office (USPTO) will conduct a "derivation proceeding" to ensure that the first inventor to file the application is actually an "original inventor" and that the application was not derived from the second inventor. (Only "original inventors" are entitled to obtain a valid, enforceable patent.)

The last article in this series will discuss the changeover from a "first to invent" to a "first to file" system in more detail since there are many complex subtleties surrounding this provision. Despite the significant amount of press devoted to this provision, it is not likely to negatively affect a company's ability to patent its inventions for at least the following two reasons:

1. True simultaneous invention scenarios are extremely rare.
2. Under the existing law, the first-to-file inventor is usually determined to be the first to invent in interference proceedings.

U.S. government or by a competitor of the asserted falsely marked product. While this law change is a welcome relief to companies, product marking should still be carefully monitored for accuracy because competitors can still file such lawsuits. Also, the failure to properly mark a product covered by a patent will prevent the patent owner from collecting damages for any infringements that occurred prior to the filing of a patent infringement lawsuit.

Also, new rules were provided to allow for "virtual marking" so that a product can be marked with a web site address that provides a listing of covered patent(s), thereby making it much easier for a company to manage the product marking process (*e.g.*, Patents: www.rim.net/patents).

New Joinder Rules

Prior to enactment of the AIA, a patent owner could file a single lawsuit against multiple defendants who are alleged to infringe the same patent, even if the infringing activity of the multiple defendants was completely different. For example, if a patent covering a smartphone power-saving feature is believed to be infringed by a Blackberry® and an iPhone®, the patent owner could file one lawsuit against both Research in Motion, Ltd., and Apple, Inc., even if completely different chipsets are used to implement the power-savings feature.

The AIA changed the law to prevent a patent owner from suing multiple defendants in a single lawsuit if the only justification for the joinder is that all defendants are alleged to have infringed the same patent. Furthermore, a court can no longer consolidate multiple patent lawsuits related to the same patent unless the defendants agree to allow for the consolidation. In the example above, the patent owner would have to file two separate lawsuits, one against Research in Motion, Ltd., and another against Apple, Inc. Depending upon jurisdiction and venue issues, the lawsuits may even have to be filed in different courts.

This provision increases the litigation costs of non-practicing entities (NPEs) who assert that their patents are being infringed by a large number of companies. The companies that lobbied for passage of this provision are hoping that it will reduce the number of such litigations by raising the costs. It remains to be seen whether this goal will be achieved.

> ***"The U.S. Courts are currently in the process of dismissing virtually all of the pending false-marking lawsuits since the vast majority of such suits were not filed by the U.S. Government or by a competitor of the asserted falsely marked product."***

This provision may also have the effect of raising litigation costs on the accused infringers because it will be more difficult for the accused infringers to enter into joint defense agreements to share litigation costs now that lawsuits must be separately filed.

New Rules Regarding Treatment of "Advice of Counsel" in Patent Litigation

For any patent litigation filed on or after September 16, 2012, the following provision of the AIA applies:

> *The failure of an infringer to obtain the advice of counsel with respect to any allegedly infringed patent, or the failure of the infringer to present such advice to the court or jury, may not be used to prove that the accused infringer willfully infringed the patent or that the infringer intended to induce infringement of the patent.*

Stated simply, the patent owner will no longer be able to attempt to sway a court or jury's views of the case by pointing out that the accused defendant did not obtain an opinion of non-infringement or that the defendant obtained an opinion but has decided not to present it as a defense to the charges of infringement. This provision may make it harder for a patent owner to prove that the infringement was "willfulness," which may result in enhanced damages and/or awarding of legal fees to the patent owner.

In view of this provision, can companies now forego the time and expense of obtaining opinions regarding whether their products or services infringe any patents since the failure to do so can no longer be used against them in a patent litigation?

The short answer is "no," since such opinions have many benefits that may far outweigh the costs. For example, a company may use the results of the opinion process to avoid infringing an identified troublesome patent by not proceeding with a proposed product or service, or to figure out how to invent around the identified troublesome patent, thereby potentially avoiding a lawsuit in the first place. A company may also be able to use the opinion to thwart an attempt by the patent owner to prove that the infringement was willful, thereby avoiding the possibility of having to pay enhanced damages and/or legal fees of the patent owner if the company ultimately loses the lawsuit.

Upcoming Articles

Part II of this series of articles will focus on key provisions of the AIA that are effective now and that relate to United States Patent and Trademark Office (USPTO) and patent examination provisions, including a new prioritized examination process, fee surcharges, and a new "micro entity" designation for patent applications that allow for significantly reduced government fees. Part II will also focus on new USPTO validity review proceedings, including a new post-grant review process (opposition proceeding). Part III will focus more thoroughly on the changeover in the U.S. patent system from a "first to invent" to a "first to file" system.

The U.S. Patent & Trademark Office (USPTO) has an information web page regarding the AIA at: http://www.uspto.gov/aia_implementation/index.jsp that provides links to specific details of the AIA. ■

Journal of the
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The following papers appear in the February 2012 (Vol. 20/2) issue of *JSID*.
For a preview of the papers go to sid.org/jsid.html.

Contributed Papers

The following papers appear in the March 2012 (Vol. 20/3) issue of *JSID*.
For a preview of the papers go to sid.org/jsid.html.

Special Section on Papers Based on Presentations from the 2011 SID Symposium (Part II)

Symposium First Looks

Printed Displays and Electronics

This year SID introduces a promising new special focus session track specifically for printed displays and electronics. Among the exciting work that will be described at the 2012 Symposium are the printing of organic TFTs and a new way to use high-temperature processes with low-temperature substrates.

by Jenny Donelan

Recent advances in the area of printed displays and electronics have created the potential for lightweight, low-cost, and flexible devices based on technologies such as TFT, organic light-emitting diode (OLED), and organic photovoltaic (OPV). RFID tags are probably the most talked-about printed-electronics application, with entire conferences focusing on RFIDs and related applications. Printed displays, according to SID 2012 Program Chair Norbert Fruehauf, have not received as much attention, which is partly why they have been added to this year's Special Focus lineup for the symposium. "We wanted to address a part of the spectrum that is not typically covered," says Fruehauf, a professor at the University of Stuttgart in Germany. "This is potentially a sizeable new market for displays," he says. And if some of the future applications, such as ultra-low-cost displays for packaging, are simple, determining how to manufacture them cost effectively is not.

Two symposium sessions will be devoted to Printed Displays and Electronics this year. While the featured papers cover a broad range of topics, a recurring theme is that of printing organic TFTs, according to ITRI's Janglin Chen, Chair of the Printed Displays and Electronics Special Focus group. Organic TFTs (OTFTs) are a particularly strong candidate for flexible displays because they can be produced on plastic substrates through printing technologies. Two papers on this topic are "Printing Technologies for Organic TFT Array for Electronic Paper" by Ryohei Matsubara of Toppan Printing Company and "Printable Organic Thin-Film-Transistor Backplanes for Mass Produced Displays" by Mark James from Merck Chemicals, Ltd.

Another presentation of note includes the invited paper, "Broad Implications Arising from Novel Sintering Process and Conductive Inks for Printed Electronics" from Stan Farnsworth of NovaCentrix, which offers photonic sintering as a solution to the problem with high-temperature curing processes that need to be employed with low-temperature substrates. "Photonic curing has been shown to be effective in heating inks and functional films to very high temperatures, in excess of 500°C, on low-temperature substrates such as polymers and paper," writes the author. This paper also reviews the basic principles of the technology as well as the implications with regard to applications, materials, cost, and performance.

Another paper of note is titled "Color filters on a flexible glass substrate fabricated in roll-to-roll processes" by Takayoshi Nirengi from Dai Nippon Printing. The key aspect of this innovation involves process innovations that keep the thin flexible glass substrate material from cracking or breaking while being conveyed through the rollers. The results may seem evolutionary rather than revolutionary, but this is yet another very important step in the process to reach commercialization of flexible-display manufacturing.

According to Fruehauf, companies in both Europe and the U.S. are working on printed-display applications ranging from electrochromic materials on a substrate to printable OLEDs to product labels that are actually displays. While printed displays are not yet on the market, "It is obvious that they're coming," says Fruehauf. The Printed Displays and Electronics sessions at Display Week will offer a unique look ahead at that future market.

SID Debuts Innovation Zone for Cutting-Edge Display Technologies

At Display Week 2012, the Society for Information Display is providing a new forum for live demonstrations of emerging information-display technologies and related areas. This new exhibit platform is called the "Innovation Zone" (I-Zone) and will take place in the main Exhibit Hall, under the sponsorship of E Ink Holdings, on June 5 and 6 at the Boston Convention and Exhibition Center in Boston, Massachusetts.

"Display Week has always been the best place for companies to exhibit their display products," says Jerzy Kanicki, Chairman of SID's I-Zone Committee. "The missing piece has been a platform concentrated in one area for small companies, labs, institutes, and other research entities with limited funding to exhibit the very newest display technology." The I-Zone will allow researchers to demonstrate their prototypes or other hardware demo units for two days free of charge at the premier display exhibition in North America. This new platform will also enable attendees to view best-in-class emerging information-display technologies in a dedicated area on the show floor. Access to free exhibition space encourages participation by small companies, startups, universities, government labs, and independent research labs. The I-Zone will make Display Week an even more exciting and relevant show, says Kanicki, noting "Some of this year's exhibits will showcase cutting-edge demos and prototypes that will power the products of tomorrow."

Proposals to demonstrate new displays, input technologies, and innovations in related fields such as solid-state lighting, flexible organic electronics, and bio-inspired electronics are currently being solicited by the I-Zone selection committee. Technologies should be in the pre-product stage, and demos that are being shown for the first time in a public forum are particularly encouraged.

The I-Zone selection committee will evaluate submissions and select the strongest proposals to receive free space within the I-Zone. Submissions are due by Monday, April 2, 2012, and anyone interested should visit http://www.sid.org/AboutSID/Awards.aspx for more details. To submit a proposal please visit http://www.cloznet.com/pcm/sidi3d/sidi3d.cfm

As an added incentive, at Display Week 2012, the I-Zone committee will select and announce a winner of the "Best Prototype at Display Week." The winning technology will also be featured in *ID* magazine. ■

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Display Week 2012

June 3–8, 2012
Boston Convention & Exhibition Center
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History in the Making

SID DISPLAY WEEK Boston 2012

Boston is a city with a rich history of innovation and progress. It serves as the perfect host for the 2012 SID International Symposium, Seminar & Exhibition. Display Week will be held June 3–8 at the Boston Convention & Exhibition Center. The exhibition will be open from June 5 to 7.

Display Week is the once-a-year, can't-miss event for the electronic-information-display industry. The exhibition is the premier showcase for global information-display companies and researchers to unveil cutting-edge developments in display technology. More display innovations are introduced year after year at Display Week than at any other display event in the world. Display Week is where the world got its first look at technologies that have shaped the display industry into what it is today; that is, liquid-crystal-display (LCD) technology, plasma-display-panel (PDP) technology, organic light-emitting-diode (OLED) technology, and high-definition TV, just to name a few. Display Week is also where emerging industry trends such as 3-D, touch and interactivity, flexible and e-paper displays, solid-state lighting, digital signage, and plastic electronics are brought to the forefront of the display industry. First looks such as these are why over 6500 attendees will flock to Boston for Display Week 2012.

continued from page 2

Meanwhile, although portable displays are still rigid, this has not stopped consumers from buying a lot of them in the past year. DisplaySearch estimates that over 64 million tablets were sold in 2011, and the market could exceed 250 million units by 2015. The problem is that consumers give up certain features when they buy a tablet – like this great old-fashioned keyboard I am typing on – and some manufacturers are missing out on the party because tablets and notebook PCs come from radically different family trees. The traditional PC makers, encouraged by Intel, are pushing a new segment of portable computer dubbed the "Ultrabook," which we understand were highlighted at the Consumer Electronics Show (CES) in January. I know all this because of our Display Marketplace feature this month written by Richard Shim from DisplaySearch, titled "Tablets Impact the Notebook Market: Enter the Ultrabook." Richard does a great job breaking down the key elements of the designs, the processor roadmaps, the economics for consumers, and the impact on displays. I'll let you read the article and draw your own conclusions, but I believe this is another new segment that has a bright future.

Speaking of CES, as always, *ID* was well represented in Las Vegas in January by Steve Sechrist, and we are pleased to have his CES show report on all the display news in this issue. As most of you have probably already heard, among the billions (or was it trillions) of pixels on display were the much-heralded and long overdue organic light-emitting-diode (OLED) TV panels from Samsung and LG. This is the event we have been anticipating for a couple of years now, and it appears that the industry may have finally given birth to mass-producible large-area OLED TV panels! I heard their performance was great and even the cynical electronics industry press was impressed. Cigars for everyone and now let's see how fast these kids can grow and mature.

As I said earlier, one of the things we were looking for were new applications for the current field of personal devices, and the subject of textbooks came up. While eReaders have become popular for general reading applications, they have been slower to find use in schools and other academic settings as part of formal education. Clearly, the advantage of putting a textbook on an eReader can be appreciated, if for no other reason than just reducing the weight on a student's back. However, the usage model for a textbook is different from that of a novel. Textbooks require more frequent searching and less linear reading. Digital readers themselves do not always offer the best method for exploring textbooks and they have other drawbacks when widely deployed in classrooms. In his Enabling Technology feature titled "Dual-Pigment Electrophoretic Displays for Reading Textbooks," author and E-Ink Holdings VP Sriram Peruvemba explains the advantages of e-Textbooks. Encouraged by Sri's article, I actually downloaded a new textbook to my Kindle recently and I'm evaluating for myself how well the experience works. I saved about $40 on a $200 book – not an overwhelming incentive, but I would argue that I just helped the environment and defrayed the purchase price of my Kindle by 25%. We'll see if this option gets more financially compelling in the future.

One common feature in every smartphone and tablet today is a touch screen. While many eReaders also have touch screens, some do not, and the application demands on an eReader touch screen are greater than those on other devices because of the need for annotation and hence digital ink. In our second Frontline Technology feature this month, "Touch Technology for eReaders," author Geoff Walker explains why putting a touch screen in an eReader can be difficult, and what the limitations and advantages of each technology candidate are. Geoff drills down to very specific details of the touch screens on each of the currently available reading devices, summing up their strengths and weaknesses. I always enjoy Geoff's insightful analysis. As he and I have said many times, there is no single touch solution that meets 100% of the user's demands for this or most other applications.

One thing users have been demanding recently are realistic 3-D displays without the need for glasses – virtual displays that go beyond current autostereoscopic modes and truly re-create the natural world. At a recent imaging-technology conference I attended, I was privileged to hear Dr. Pierre-Alexandre Blanche from the University of Arizona talk about his vision for a real-time holographic display. I was impressed with his concise analysis of the human-vision issues associated with current stereoscopic displays, and also by his very innovative approach to holographic stereography that uses a new photorefractive material that may help create a 3-D display that reproduces all human visual cues. At my invitation, Dr. Blanche agreed to contribute his article titled "Toward the Ultimate 3-D Display" and I hope you enjoy it as much as I did.

Another subject that we like to keep our eye on is intellectural property issues and this how they affect those of you who invent new products and technologies. This month we begin the first of a three-part series analyzing the sweeping changes to the U.S. patent process brought about by the passage of the "America Invents Act" (AIA) patent reform legislation. You may remember author Clark Jablon, Partner and Registered Patent Attorney at Panitch Schwarze Belisario & Nadel LLP (PSB&N) in Philadelphia, PA, for a series on intellectual property strategies he authored for *ID* a couple years ago. Clark has graciously agreed to return and help us all understand this new twist on the U.S. patent process. This month's installment, titled "What Companies Need to Know About the Leahy-Smith America Invents Act (AIA) Patent Reform Legislation: Part I" focuses on key litigation provisions that are taking effect right now. Staying informed on strategies and practices in the field of intellectual-property protection is a crucial part of running any successful technology business. I cannot thank Clark Jablon enough for offering his time and energy to educate the readers of ID on this critical topic.

With that, it's a "full lid," as they say in the White House press corps. I hope you enjoy this February/March issue of *Information Display,* and, as always, I look forward to your feedback. To send us comments or suggestions, you can reach us by e-mail at press@sid.org and on the web at www.informationdisplay.org. When you visit our Web site, be sure to help out our advertising partners by clicking their links and learning more about their valuable products and services.
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industry news

continued from page 3

and transflective modes, is designed to enable the creation of displays with bright, colorful images and reduced power consumption.

Since the acquisition, there has not been much news about Liquavista, so *Information Display* caught up with Liquavista CEO Johan Feenstra to see what has been happening. For one, Liquavista is now Samsung LCD Netherlands R&D Center (SNRC). The financial backing of Samsung has been great for the company, notes Feenstra, saying, "Samsung looks at this business more strategically than venture capitalists would. So we're focusing much more on R&D now. Since the acquisition, that has accelerated significantly." The focus of current R&D is primarily on LC alternatives with a view to eReader and tablet applications. So while there isn't a lot of product news at the moment, there will be some at some point. "We're making good progress and are quite happy to be part of Samsung," says Feenstra.

Large OLED TVs Show Up (As Promised) at CES

Among the most-anticipated exhibits at the 2012 Consumer Electronics Show in Las Vegas in January were the 55-in. OLED TVs from LG and Samsung. The TVs lived up to their reputation, judging from the many positive accounts to be found online. The next two questions on everybody's mind are: "How much?" and "When can I buy one?" The answers are still to come, but you can learn more from Steve Sechrist, who has reported on those OLED TVs and much more from CES in this issue of *Information Display*.

– Jenny Donelan

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Please send all press releases and new product announcements to:

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guest editorial

continued from page 4

I would like to thank *ID* magazine for the opportunity to serve as guest editor and to interact with these incredible authors and companies. I have been involved in SID for over a decade now, dating back to my early days developing inorganic EL displays. Personally, I plan to stay active in tablets/eReaders for years to come because from a research perspective many of the technology challenges are not yet solved even in a laboratory setting. We hope many of you enjoy this issue, especially by accessing the on-line version on your portable device.

Jason Heikenfeld is Associate Professor and Director for the Novel Devices Laboratory at the School of Electronic and Computing Systems at the University of Cincinnati. He can be reached at heikenjc@ucmail.uc.edu. ■

SID 2012 HOTEL MAP

① Westin Boston Waterfront ② Seaport Boston

Pedestrian walkway from Seaport Boston to the Convention Center, over 90.

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