FLEXIBLE AND LOW-POWER DEVICES

Information DISPLAY

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The Imminent Invasion of High-Efficiency Flexible Displays

THE MAKING OF A FLEXIBLE e-READER WITH PLASTIC ELECTRONICS

ADDING COLOR, VIDEO, AND FLEXIBILITY TO e-READERS

OPPORTUNITIES FOR FLEXIBLE PHOSPHORESCENT AMOLEDs

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COVER: This flexible display module from Plastic Logic was made with plastic electronics and Vizplex display media provided by E Ink Corp. It has a resolution of 1280 × 960 and 150 ppi. Cover image courtesy of Plastic Logic Limited, 2009.

CREDIT: Cover design by Acapella Studios, Inc.

Next Month in *Information Display*

Touch Technology

- LCD In-Cell Touch
- Tabletop Touch
- The State of the Touch-Screen Market
- Display Week 2010; First Look
- *Journal of the SID* April Contents

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editorial

Now More than Ever Before: Flexible and Low-Power Technology Meets a Need

by Stephen P. Atwood

This month, as we send our Low-Power and Flexible Devices issue to press, we continue to ponder how much energy efficiency has taken over our engineering vocabulary. In just a few short years, the otherwise usually quiet lobby for environmental protection has taken center stage, giving us entirely new business imperatives and a new vocabulary of "Green." "Living Green," "Going Green," "Green Friendly," and other similar terms are now a part of our daily dialog, at least on the marketing side. We have discussed this a few times in the past year, but it just keeps coming up everywhere we look. As you shop the aisles of the consumer-electronics stores, energy consumption, battery life, and other metrics are now prominent features listed on displays and have become serious comparison points for consumers. Even in the industrial display marketplace where I participate, energy efficiency and total power consumption have become serious major considerations and competitive elements. A few years ago, these factors were only minor considerations because of other design parameters such as maximum operating temperature or product lifetime. Now, energy efficiency is of paramount concern as industrial installations scramble to meet new government initiatives and bring their facilities into compliance with total-energy-efficiency mandates.

Going back to 2005 or even earlier, *Information Display* has published many articles on the subject of low-power display technologies, including electronic paper. In fact, the concept of e-paper goes back more than 10 years with a constant theme of bistability, low power consumption, and, of course, flexibility. So, although this is a fairly new topic in the mainstream electronics industry, it has actually been part of our vocabulary for a long time.

Author Steve Sechrist in his Display Marketplace feature, "Round-up of Ultra-Low-Power Technologies," explains how the new government mandates and the focus of the display industry are surprisingly in alignment, as many aspects of display technology are being enriched to bring more power efficiency to products such as TVs and mobile devices. Even OLED technology is maturing to the point where it can significantly improve on the current baseline power consumption of AMLCDs in mobile devices, as explained by authors Ruiqing Ma, Mike Hack, and Julie J. Brown in the article titled "Flexible AMOLEDs for Low-Power, Rugged Applications." We have always been enthusiastic about the potential for energy efficiency of OLEDs because of their emissive nature and the opportunity to increase battery life through judicious use of content, but now we see that even the underlying materials have achieved fundamentally improved efficiencies that will challenge AMLCDS in mobile devices regardless of image content. We already know from last year's September 2009 *ID* article, "Emerging Technologies for the Commercialization of AMOLED TVs," written by Hye Dong Kim, Hyun-Joong Chung, Brian H. Berkeley, and Sang Soo Kim, that UDC's PHOLED technology offers significant opportunities for energy-efficient HDTVs over their LCD counterparts.

Of course, ruggedization, lighter weight, and flexibility are also important attributes for displays, and as our returning Guest Editor Robert Zehner explains in his editorial, having a flexible-display substrate is sometimes not as much about bending the display as it is about not breaking the display in the normally harsh environment of the real

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Prime View International, HYDIS Technologies, and LG Display Announce Comprehensive Cooperation Agreement

by Jenny Donelan

The e-paper industry infrastructure continues to evolve, as is evidenced by the recent announcement of an agreement among Prime View International Co., Ltd., HYDIS Technologies Co., Ltd. (a subsidiary of PVI), and LG Display Co. Just before the new year, the companies reported that they planned to launch a "comprehensive cooperation" with regard to technology, capital, and sourcing in order to co-develop products for the global display market.

The agreement will, in essence, allow the above parties to make more e-paper products. While capacity is not currently constrained, signs point to a considerable increased demand for eBooks in the years to come, with unit sales more than doubling from 2009 to 2010, according to recent figures from market-analyst iSuppli (see "What's Next for E-Readers," also in this issue). Now, PVI/E Ink will have LG Display as a customer for E Ink's Vizplex imaging films. In turn, LG Display will have access to technology from E Ink, which is now owned by PVI, and also to HYDIS's fringe-field-switching (FFS) technology. HYDIS is a Korea-based display maker for which PVI is a majority owner; FFS enables a wide viewing angle for LCDs used in mobile phones, laptops, and gaming machines.

These arrangements represent a deepening of already-existing relationships among all the above e-paper players. PVI, which manufactures small- and medium-sized LCD modules, and describes itself, no doubt accurately, as "the world's largest supplier of e-paper display modules," acquired E Ink in 2009. E Ink makes the electronic ink that forms the basis of most of the e-readers on the market, including the Barnes & Noble Nook, Amazon Kindle, and Sony Reader. The PVI/E Ink deal was announced in May 2009, and completed on December 23, 2009.

LG Display, a major manufacturer of TFT-LCD panels, also has connections to the above parties. "LGD has been making some backplanes for [E Ink-based] e-readers, though PVI was doing most of them," says Vinita Jakhanwal, principal analyst with iSuppli. LGD invested $10 million in PVI's GDR (global depository receipts) issuance in December 2009, when, as part of PVI's acquisition of E Ink, PVI raised funds in the equity market by offering GDRs (which raised $165 million). As part of the new agreement, LG Display will invest in HYDIS technology through $30.5 million in corporate bonds. Both companies have also entered into a cross-license agreement, which includes the FFS. According to the recent announcement, the two parties will also mutually support production capacity on "certain e-paper and high-end TFT-LCD products." And LG Display will provide consulting to HYDIS on production efficiency and quality.

All the above moves make sense, according to Jakhanwal, who says that LGD's factory facilities will add considerably to PVI's ability to turn out products. In addition, she says, all these agreements set up PVI/LGD to be more competitive with major LCD manufacturer AUO, which acquired access to SiPix Imaging's electronic-ink technology (a competitor to E Ink's) last year. ■

guest editorial

A New Breed of Display Starts to Flex Its Muscles

by Robert Zehner

If you want a glimpse of the future of display technology, I recommend that you head to your local neighborhood multiplex and catch the latest sci-fi or fantasy movie. I'm not talking about the stunning 3-D effects in James Cameron's billion-dollar blockbuster, *Avatar*. Instead, I'm referring to the displays used by the characters in these types of movies. Whether it's the A.D. 2054 edition of *USA Today* in *Minority Report* or Harry Potter's animated *Daily Prophet*, filmmakers are captivated by flexible displays.

This month, we feature articles by two companies that are racing to commercialize real-life flexible displays that could eventually bring those movie props to life. These two different efforts span the breadth of approaches to building a non-glass display. Ray Ma from Universal Display Corp. (UDC) writes about emissive OLED displays, primarily built on thin, stainless-steel substrates that have been processed through a conventional amorphous-silicon display fab, while Seamus Burns discusses Plastic Logic's polymer-based organic transistor backplane, mated to an electrophoretic reflective imaging film. These two displays also represent the culmination of decades of research and development in fields ranging from semiconductor physics to packaging design – research that, along the way, yielded a Nobel Prize in chemistry for the discovery that organic molecules can be made to conduct electricity, a fact central to the success of Plastic Logic and UDC.

In between these two extremes are a myriad of other flex research and development efforts from a variety of sources, each with its own, unique approach. There are enough of these, in fact, to warrant a new SID Display Week program subcommitte for flexible and e-paper displays, which was inaugurated in 2009.

In the past, it may have seemed as if the reality of a flexible display would forever hover just out of reach. However, as I write this, I have just returned home from the 2010 Consumer Electronics Show, where Plastic Logic announced the launch of its Que electronic-reader product, constructed around the company's own flexible e-paper display. First shipments are not slated until April, but pre-orders are already being accepted. In the midst of the Plastic Logic launch, another e-publishing concern named Skiff quietly announced that it will be coming to market with its own reader device, based on an 11.5-in. metal-foil flexible display. Beyond these two announcements, there are reports that other display companies are readying their own flex technologies for mass production, including Prime View International's plastic-based EPLaR displays which were profiled in the December 2009 issue of *Information Display*.

Having held the Plastic Logic Que in my hands, it is worth noting that the device itself is emphatically not flexible, regardless of the display technology within. The Skiff device, too, is a rigid reader. So, why go with flex? Both companies tout the ruggedness that a non-glass display brings to their products, so that users do not have to sweat when their e-reader takes a tumble from the desk to the floor. Freed from the weight of a large sheet of glass, these devices also promise to be thinner and lighter than anything we've seen with an 11-in.-diagonal screen. You may not be able to roll up either of these readers and put them in your pocket, but flexibility pays off, even when encased in a rigid form factor.

We are all used to thinking of flexible displays as a technology of the future. If things go as planned for Plastic Logic, Skiff, and and the other contenders out there, 2010 will mark the year that this particular bit of technology becomes a reality. I guess that sci-fi writers will have to find something else to dream about. ■

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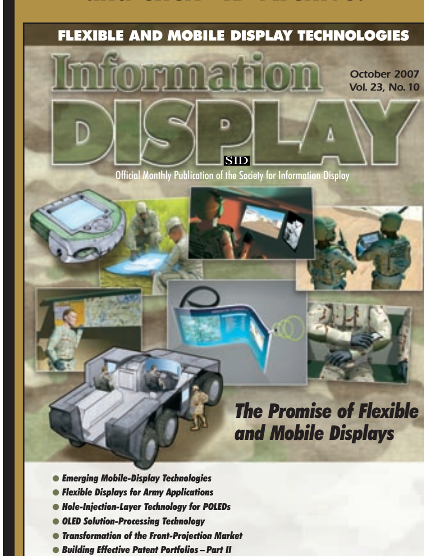

president's corner

Getting Excited about Seattle

by Paul Drzaic
President, Society for Information Display

In a few short months, it will be time once again for the annual SID Symposium, Seminar & Exhibition, this year to be held in the always-popular venue of Seattle, Washington, during the week of May 23–28. As the display industry (and the rest of the world, for that matter) shakes off the economic crash of 2009, Display Week will prove that some very impressive innovation has been going on over the past year in electronic displays. It is clear to me that this is going to be a very special gathering.

After a year in which travel and conference participation was restricted, there is a lot of pent-up energy on the part of display technologists looking forward to revealing their latest advances to the world. While we expect to see contributions across all areas, this year we are planning a special focus on several emerging display technologies. The aim is to provide attendees with an intensive view of a select number of topics that will be driving future growth for the industry. These special-focus areas include advanced technologies for television, green technologies, electronic paper, touch interfaces, and solid-state lighting. The importance of these topics is well-known to anyone participating in the electronic-display industry. SID is pleased to enable the ensuing collaboration and idea generation that will continue to drive progress in these fields.

Another topic of interest is the way in which organic light-emitting diode (OLED) displays are encroaching into areas traditionally dominated by liquid-crystal displays. Dr. S. S. Kim of Samsung Mobile Display will provide a keynote address at Display Week that describes a future with OLED displays becoming the display system of choice in several key application areas. OLED displays will also be well-represented in the technology and business programs for the week.

SID is taking advantage of its location in Seattle to tie into two areas where local companies are driving groundbreaking applications. Steve Bathiche, Director of Research at Microsoft, will describe in a keynote address some exciting advances in interactive displays, with applications in entertainment, commerce, and communications that rely on a combination of sensors and displays. If you know any teenagers, you can whet their appetite for developments in future gaming systems by mentioning this talk to them.

Boeing Vice President and Chief Engineer Mike Sinnett will address avionic-based displays in a third keynote talk. Displays appear in aviation in areas ranging from cockpit controls to entertainment systems. Aircraft present a unique set of challenges for implementing displays, with increasing integration into the avionic infrastructure.

Solid-state lighting will also be a major theme of the upcoming SID meeting. There will be extensive coverage in the technical and business conferences and some special extra coverage as well. At the SID Awards Luncheon, Terry Schmidt, Chief Scientist at Christie Digital Systems, will provide a behind-the-scenes look at the projection technology used in the last summer Olympic games, in Beijing. Who can forget the spectacular use of lighting and displays in the games architecture and in the opening ceremony? You can learn how it was all done in Seattle.

This year, submissions to the technical program were so numerous, and of high quality, that we're near the bursting point. Nearly 500 papers were accepted from the

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Flexible AMOLEDs for Low-Power, Rugged Applications

Flexible AMOLEDs equipped with phosphorescent OLEDs are well-positioned for low-power, rugged, full-color video applications. Replacing glass with flexible substrates and thin-film encapsulation makes displays thinner, lighter, and non-breakable – all attractive features for portable applications. With enhanced flexibility and low power consumption, a range of revolutionary opportunities are being created.

by Ruiqing Ma, Mike Hack, and Julie J. Brown

FLEXIBLE DISPLAYS refer to those that can be fabricated and perform well on non-glass substrates such as plastic films or metal foils. There are two main categories of flexible-display technologies: reflective bistable types, such as cholesteric liquid-crystal displays and electrophoretic displays, and full-color video-rate organic light-emitting-diode (OLED) displays. While bistable reflective displays are ideally suited for e-reader applications and have the potential to replace printed-paper media, OLED displays are a much better choice for high-information-content full-color video applications because of their high contrast ratio, inherent ultra-fast switching, and vivid visual full-color appearance. Additionally, because of their simple, organic thin-film design, OLEDs can be easily built on flexible substrates. Finally, the incorporation of phosphorescent OLED (PHOLED) technology enables OLED displays to have a lower power consumption than conventional active-matrix liquid-crystal displays (AMLCDs) in video-mode operation.

A roadmap for flexible-display development in both bistable reflective and OLED displays is shown in Fig. 1.

The authors envision a five-phase roadmap for the PHOLED display: (1) low power – the displays are actually built on rigid glass and offer low power and thin form factor; (2) rugged – glass is eliminated so the displays are thin and non-breakable and may have limited flexibility, (3) bendable – displays are bendable and conformable, (4) rollable – the displays in this phase are extremely flexible in one dimension so they can be rolled around a cylinder with a small diameter, and (5) free form – this is the ultimate phase of flexibility, in which displays can be made into any form, just like paper.

Commercial products based on flexible-display technologies are currently in the low-power phase. There are already several e-readers and small-to-medium-sized AMOLED displays and televisions on the market. The chosen display technologies all offer low power consumption. Bistable reflective displays save power for e-reader applications because no power is needed to maintain a static image and the display does not emit light. For full-color video applications, AMOLEDs with PHOLED materials consume much less power than AMLCDs.

Rugged Applications

The second phase in the evolution of flexible displays has significant importance because it represents a new era in terms of flexibility. With the glass substrate replaced by rugged substrate materials, displays will be thinner, lighter, non-breakable, and safer – all extremely attractive features for portable applications. (Note that in Phase 2, the display itself may still have a flat-use form factor.) Many e-reader users are already nervous about their glass devices sitting next to hard objects or being dropped on the floor. A rugged display will resolve this problem.

Rugged AMOLED displays are increasingly being considered for a range of military and commercial applications. The first example involves a portable communications system incorporated into a wearable wrist display unit, as shown in Fig. 2(a). This system enables the user to view a variety of information, including real-time video, with hands-free operation. To demonstrate this technology, Universal Display Corp. (UDC), with its partners LG Display (LGD) and L3 Communications Display Systems (L3), fabricated a low-power-consumption wearable display wrist unit,[1] which is thin, lightweight, and non-breakable, as shown in Fig. 2(b). In its present version, the flexible PHOLED wrist unit receives video signals from a separate interface electronics unit also worn by the user.

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Fig. 1: *Device evolution proceeds from left to right in this chart of flexible-display developments for bistable reflective displays (top) and full-color AMOLED video displays (bottom).*

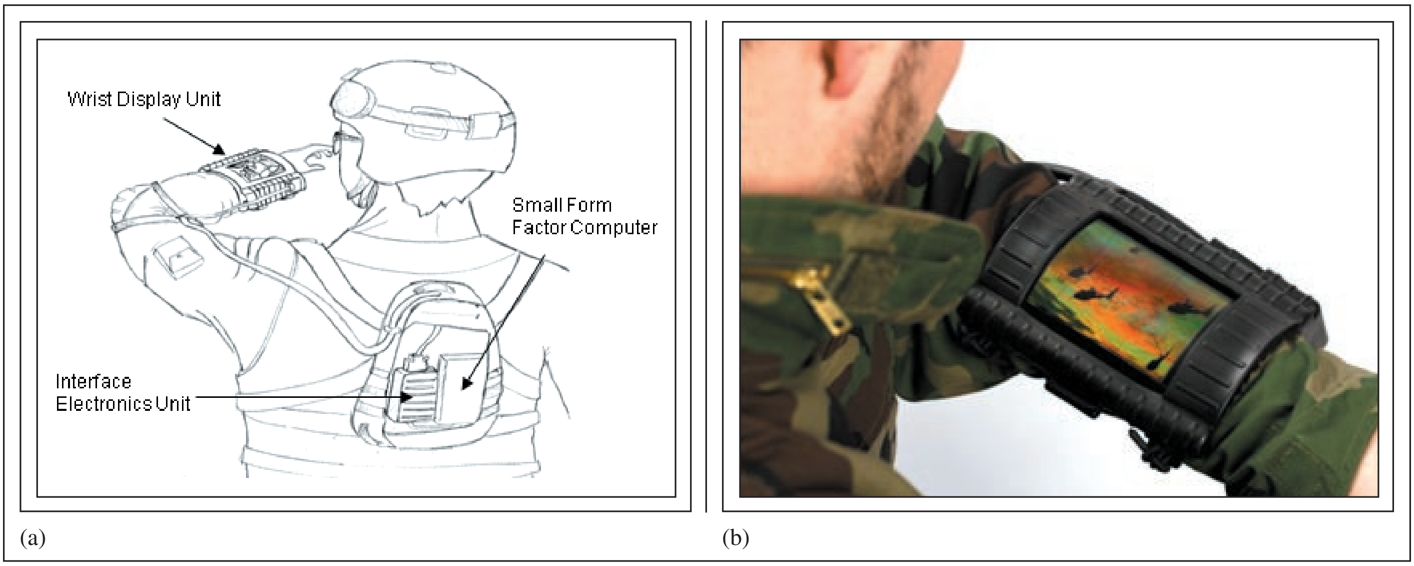

Fig. 2: *(a) At left, an artistic rendering shows a complete portable communications system with a wearable display and (b) at right, a user models a wearable prototype.*

Another potential product is a non-glass ejection-safe digital display designed to replace printed-paper maps and checklists on pilots' knees in tactical cockpits. This will give the pilot access to a large amount of information in digital form without the need to carry a large number of paper documents. When the displays are flexible, they can be rolled up to save space. Moreover, removing the glass from a display system can allow a pilot to safely eject from an aircraft with the display still available for use outside of the aircraft. One can also envision applications of such a non-breakable display in the consumer marketplace.

Yet another example is a full-color flexible hands-free personal-digital-assistant (PDA) display to increase the operational capability of its user for both daytime and covert night-time functionality. The PHOLED display could be made to have both visible and near-infrared (NIR) emitting pixels. The visible pixels would be operated during the day and the NIR pixels at night with the visible pixels turned off and viewed through the use of night-vision equipment. The rugged high-information-content display would not give away the user's position during nighttime situations. This dual-mode operation will be a unique attribute of the display. A prototype display with both visible and IR capability[2] is shown in Fig. 3.

A hands-free PDA would have numerous consumer uses as well, some of which may not even be contemplated until such a display is readily available.

Low-Power PHOLED

Through the use of phosphorescent OLED (PHOLED) technology for the pixel design, AMOLED displays can offer lower power consumption than AMLCDs. In conventional fluorescent OLEDs, the internal quantum efficiency is limited to approximately 25% because only the singlet excitons recombine to emit light. In a PHOLED system, however, heavy-metal atom centers enable efficient spin-orbit coupling.[3] The spin-orbit coupling allows both singlet and triplet excitons to be harvested as phosphorescent radiation in the guest-host systems, leading to internal quantum efficiencies (IQEs) of up to 100%.[4]

The IQE is the percentage of injected electrons that form photons and is directly related to the power consumption of the OLED device. Another key attribute of OLEDs is lifetime, which limited their early adoption in commercial products but has improved significantly in recent years. One typical measurement of OLED lifetime is LT50, defined as the time it takes an OLED, under constant current, to reach 50% of its initial luminance level (typically at 1000 nits).

The very high IQE makes PHOLED technology ideal for both flat-panel-display and solid-state-lighting applications, and close to 100% internal emission efficiency has now been reported for all primary colors. Additionally, phosphorescent device lifetimes have rapidly increased to the point where they are competitive with the best in the industry. Two recent examples of red-PHOLED performance includes bottom-emission devices with 1931 CIE coordinates of (0.67,0.33) and (0.65,0.35) and a luminous efficiency and (LT50) lifetime at 1000 nits of 22 and 24 cd/A and 200,000 and 300,000 hours, respectively. Very recent progress in bottom-emission green PHOLEDs has achieved a luminous efficiency of 63 cd/A and an LT50 lifetime at 1000 nits of 500,000 hours. Advancements are continuously being made in blue-PHOLED device performance towards commercial entry levels. Most recent progress has been reported with an all-phosphorescent system for warm-white lighting applications with a long-lived phosphorescent light-blue emitter-host material set. At 1000 cd/m^2, the 2×2-mm^2 phosphorescent white-OLED (WOLED) pixel has a power efficacy of 79 lm/W, CRI of 80, CCT = 2910K, CIE = (0.456, 0.430), and lifetime LT70 = 30,000 hours.[5]

Low power consumption is a key display requirement for mobile applications. The use of PHOLED technology will enable displays

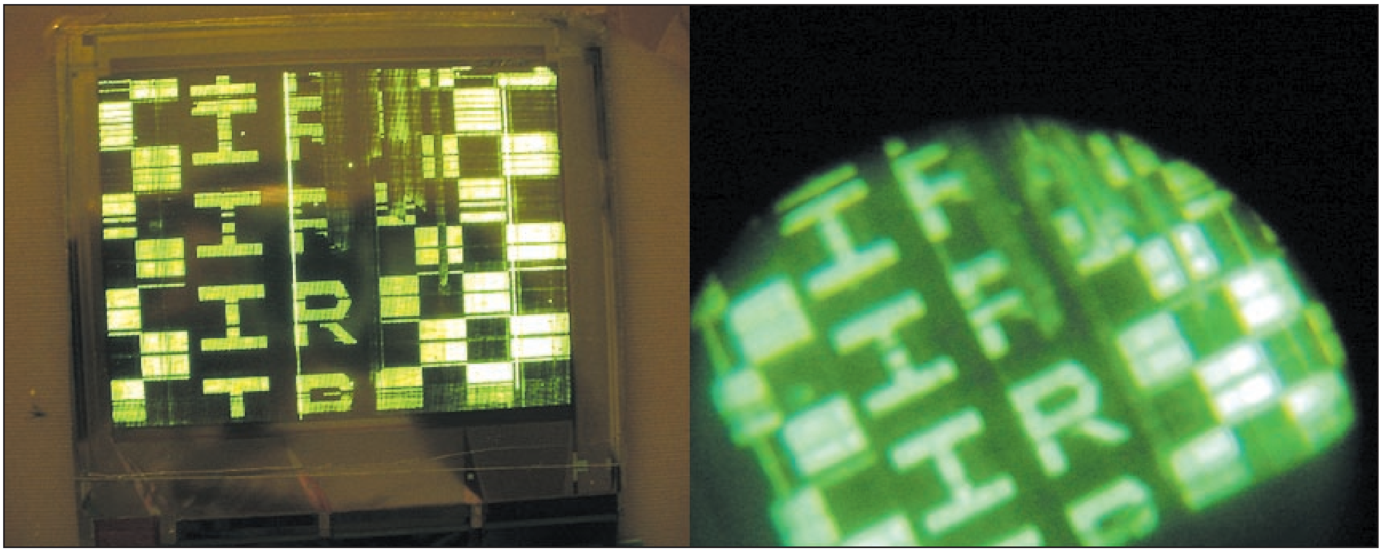

Fig. 3: A prototype PDA is shown in visible mode (left) and IR mode (right). The IR mode is imaged through an IR monocular which replaces IR emission with green emission.

to have a lower power consumption than that of backlit AMLCDs, significantly extending battery life for mobile devices and providing significant power savings compared to that of fluorescent OLED technology. Figure 4 shows simulations of the power consumption of a 3.5-in. display showing video content operating at 360 cd/m^2 for various technology options.

Also shown for comparison is the power consumption of an equivalent AMLCD operating at 450 cd/m^2, having perceived visual performance similar to that of an AMOLED operating at 360 cd/m^2 because of the higher contrast ratios of OLED displays. While the AMLCD backlight consumes 550 mW, the plot shows power savings that can be achieved by incorporating PHOLED technology. First, using just a red PHOLED subpixel, power consumption can be reduced to 428 mW; the addition of green-PHOLED subpixels leads to a further power reduction to 269 mW, and the use of an all-PHOLED system will reduce the power consumption to less than 175 mW.

The high conversion efficiency of PHOLEDs has additional benefits to AMOLED technology, and particularly to flexible AMOLED displays. The lower-drive-current requirement of PHOLEDs will make it easier to use lower mobility backplanes such as a-Si (and perhaps eventually organic TFTs). These technologies will be very important as they enable backplanes to be fabricated at lower temperatures than that of conventional low-temperature polysilicon (LTPS), facilitating the launch of AMOLEDs on plastic substrates. In addition, the lower-drive-current requirement of PHOLEDs also reduces the display operating temperature, which will extend the display operational lifetime. The higher efficiencies lead to at least a three-times reduction in display temperature rise compared to that of a fluorescent OLED display.[6] This is an important consideration for mobile devices. Lower pixel currents will also allow for higher bus-line resistances, enabling thinner metallization, which will also simplify the manufacture of displays on flexible substrates.

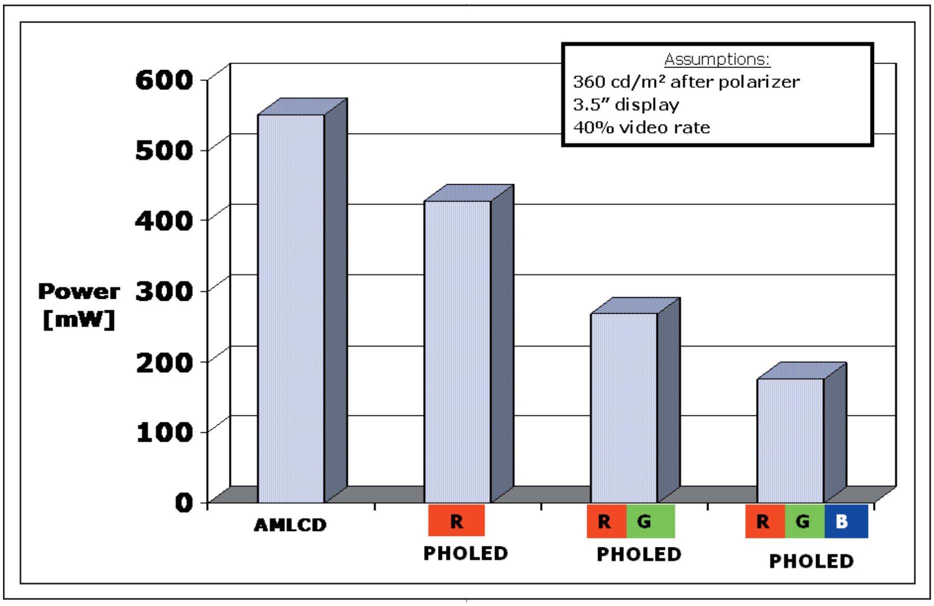

Fig. 4: A simulated power-consumption roadmap for a 3.5-in. AMOLED display uses different combinations of fluorescent and phosphorescent OLED technologies. Assumptions are 360 cd/m^2 and a 40% video rate. Also shown is the equivalent power consumption for backlit AMLCD at 450 cd/m^2.

Rugged AMOLED Fabrication

Two critical technologies that enable flexible AMOLEDs are flexible active-matrix backplanes and thin-film encapsulation.

Flexible Backplanes: The two material groups being considered as substrates for rugged AMOLED displays are metal foils and plastic films. Thin plastic films have excellent flexibility; however, their moisture-barrier property is poor and their thermal properties limit the maximum process temperature of the backplanes. Conventional Si-based TFT-backplane processes for AMOLED displays require temperatures in excess of 250°C, which cannot be supported by current available plastic-substrate systems. Flexible metal foils offer a number of desirable advantages, including reasonable flexibility, enhanced thermal and mechanical durability, and excellent permeation barrier property, but the surface tends to be rough and the materials are opaque.

Currently, most glass-based AMOLEDs are fabricated using poly-Si backplanes, and several commercial products are already in the marketplace. Poly-Si has high mobility and the advantage of enabling the integration of driver circuits around a display periphery. This is advantageous for small arrays because it significantly reduces the cost of the driver electronics. However, with the use of poly-Si TFT backplanes, the variation in TFT threshold voltages can cause significant variations in image intensity across a display. Improved display uniformity can be obtained by employing correction schemes, either external or internal to each pixel. While poly-Si is proving itself to be a viable AMOLED backplane technology, the high efficiency of the phosphorescent material system enables the use of a-Si backplanes. (For more information on poly-Si and OLEDs, see “Emerging Technologies for the Commercialization of AMOLED TVs” in the September 2009 issue of *Information Display*.) The advantages of a-Si backplanes for AMOLED production are excellent uniformity, lower cost, and the ability to leverage off the large a-Si TFT manufacturing base that already serves the AMLCD industry. In addition, a-Si TFTs perform better under strained conditions due to the amorphous nature that makes them better suited for flexible applications. The main issue with a-Si is the shift of threshold voltage over time. Some of the on-going efforts to address this challenge include (1) improvement in the transistor design and fabrication process – one example is to use an inverted OLED structure, (2) pulsed driving or negative bias – these have been proven to be effective in reducing the threshold-voltage shift,[7] and (3) compensation circuit – this requires a complex circuit at the pixel level (more than four transistors).[8]

Some other backplane technologies being investigated, which may also prove viable for flexible displays, include oxide TFTs, micro-crystalline-silicon TFTs, and organic TFTs. Researchers around the world have been actively working in this field, and progress has been made over the years. These include an AMOLED driven by LTPS on metal foil developed by Samsung,[9] an AMOLED driven by OTFT on plastic developed by Sony,[10] an oxide-driven AMOLED on metal foil developed by LGE, and an a-Si driven all-phosphorescent AMOLED on metal foil developed by UDC–LGD–L3.

Thin-Film Encapsulation: The other critical component for flexible OLEDs is the development of a flexible permeation barrier. OLEDs degrade as a result of exposure to atmospheric oxygen and water, causing oxidation and de-lamination of the metal cathode, as well as detrimental electro-chemical reactions within the organic layers. Because most OLED work to date has been focused on the development and manufacture of glass-based displays, the degradation problem has been addressed by sealing the display in an inert atmosphere using a glass or metal lid attached by a bead of UV-cured epoxy resin. For flexible displays, the rigid glass covers cannot be used, so a flexible encapsulation solution is needed. For OLEDs built on plastic, both sides of the OLEDs need barrier protection. Because metal is an ideal oxygen/water permeation barrier, OLEDs fabricated on metal foil only require encapsulation after display fabrication.

UDC has demonstrated encapsulated flexible PHOLED displays on metal substrates using a thin-film-encapsulation system developed by Vitex Corp. Vitex is pursuing a multi-layered barrier consisting of alternating layers of polymer and inorganic oxide layers that can be deposited as a monolithic encapsulation over an OLED cathode. By incorporating these multiple layers, the polymer films "decouple" any defects between the oxide layers, thereby preventing propagation of defects through the multi-layered structure and allowing the organic films to protect the barrier layers from mechanical damage.

More recently, a novel permeation barrier has been reported that uses a single-chamber plasma-enhanced chemical-vapor-deposition (PECVD) process capable of depositing a low-stress transparent single-layer barrier film for flexible OLED encapsulation.[11] The barrier is a single-phase hybrid material deposited by PECVD from hexamethyl disiloxane and oxygen that combines the hermeticity of SiO_2 with sufficient toughness similar to that of a silicone polymer, such that it appears not to form microcrack permeation paths. In accelerated storage tests at 65°C and 85% relative humidity, the half-life of OLEDs coated with this barrier has exceeded 1 year. Figure 5 shows the results of pixel photos and active area versus ageing.

Preliminary results of this work show great promise from both performance and manufacturing-process simplicity.

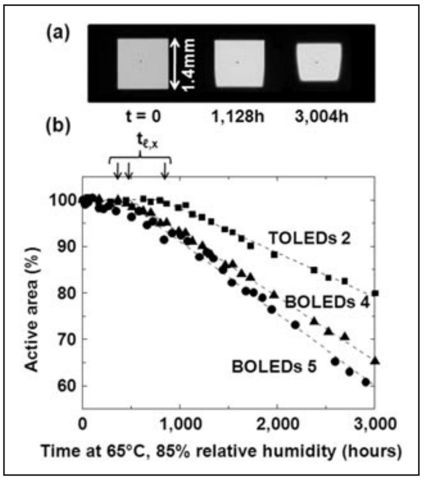

Fig. 5: *Shown are the results of 65°C/85% RH ageing of 2-mm² test pixels encapsulated using single-layered thin-film encapsulation. TOLED and BOLED stand for top- and bottom emission OLEDs, respectively. TOLED2, BOLED4, and BOLED 5 represent different samples.*

UDC Flexible AMOLED Prototypes

UDC, working with LGD and L3, demonstrated a 4-in. QVGA 100-ppi top-emission AMOLED display on a-Si TFT backplanes built on metal foils at Display Week 2007, as shown in Fig. 6(a). One year later, the company was able to obtain much better display performance, and the 4-in. QVGA full-color video prototype consumed less than 1 W at 100 cd/m² full white, as shown in Fig. 6(b). At SID '08, UDC also demonstrated an ultra-thin AMOLED having a total thickness of ~30 µm.[12] Flexibility results on this razor-thin display showed that it operated when conformed to a tight diameter of only 5 mm, as shown in Fig. 6(c). This work demonstrated the possibility of achieving a rollable AMOLED display at some point in the future.

At CES '09, the team demonstrated the world's first wrist-worn communications device built upon a flexible low-power-consumption full-color AMOLED. The device offers the wearer the ability to see high-information-content video-rate information in a thin-and-rugged-form-factor 4-in. QVGA display, conformed around a human wrist, as shown in Figs. 2(b) and 6(d).

At SID '09, the company published its result of 4-in. QVGA flexible AMOLED displays on temporary bonded polyethylene naphthalate substrates with 180°C a-Si:H TFTs, as shown in Fig. 6(e).[13] This work was in collaboration with the Flexible Display Center at Arizona State University, and it demonstrated the viability of plastic substrates for flexible AMOLEDs. At FPD 2009, UDC demonstrated a 4.3-in. HVGA full-color display in collaboration with LG Display, as shown in Fig. 6(f). The display was built on 76-µm-thick metal foil with a total thickness of 0.3 mm and can be bent in both inward and outward directions. It offers 256 gray-scale levels per color (8 bit) and can portray a variety of images, including full-motion video. The specifications of the finished flexible display are shown in Table 1.

Table 1: Specifications of the 4.3-in. HVGA flexible AMOLED display.

Display type	Emissive (Top-emission OLED)
Active area	87.7 (H) × 65.6 (V) mm: 4.3-in. diagonal
Resolution	HVGA 480 × RGB × 320
Pixel density	134 ppi
Colors	16.7 M
Color method	Phosphorescent OLED (PHOLED)
Luminance	150 cd/m² @Full White
Contrast ratio	1,000:1
Bending radius	2 in.
Panel thickness	0.3 mm

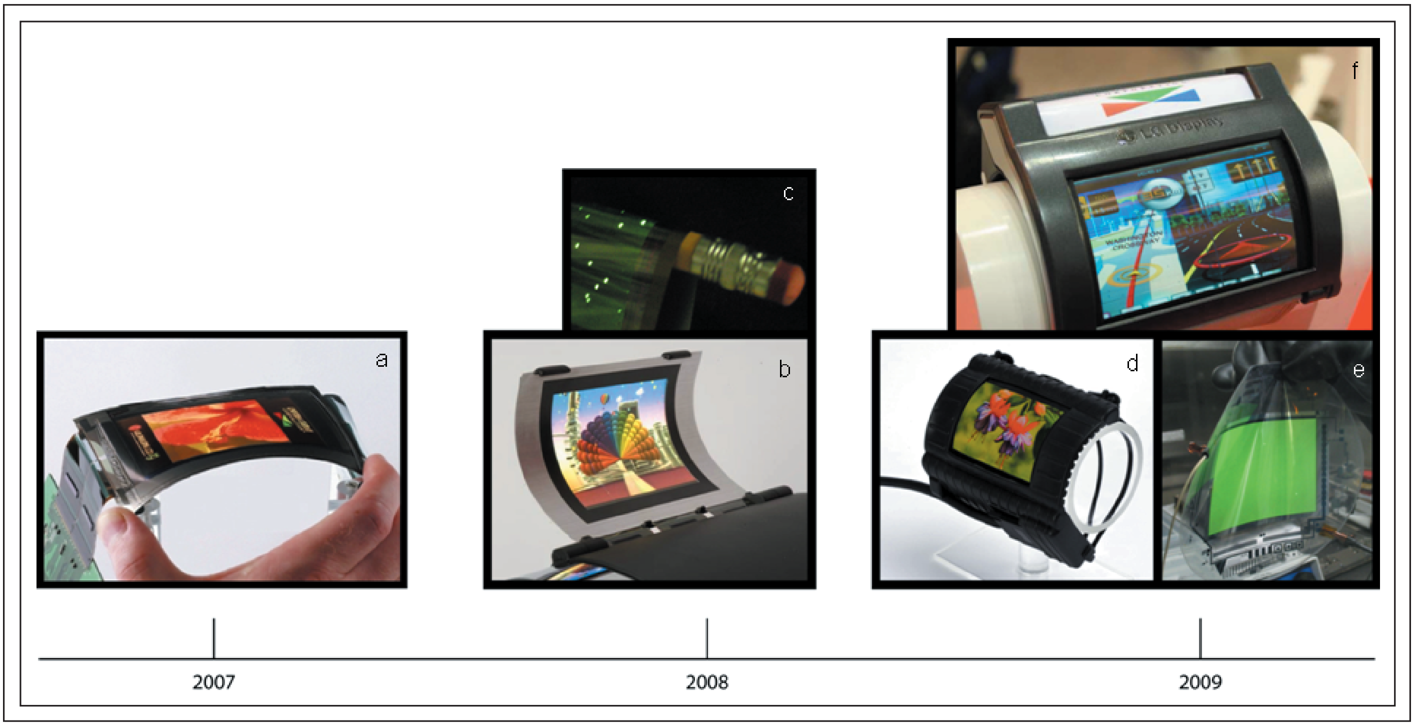

Fig. 6: (a)-(f) Some recent prototypes demonstrated by UDC and its partners.

Summary and Outlook

Today, AMOLEDs on glass substrates are gaining traction in the marketplace. And significant progress is being made to achieve low-power AMOLED displays by using PHOLED technology. Building upon this platform, we believe that AMOLEDs in non-breakable substrates should soon be one of the next growth areas. Although there is no current commercial product, the case for flexible displays to be used for rugged applications is very convincing, as demonstrated by the examples and prototypes described in this article. Without glass, the display will be thinner, lighter, and non-breakable, all very attractive features for portable devices for both military and consumer applications. To make this happen, the two key challenges are the demonstration of a reliable, high-performance backplane technology on a flexible substrate and the development of a high-yield manufacturable thin-film encapsulation process.

Looking forward, the authors expect in the near future that flexible AMOLEDs will be first adopted in specialized applications in which rugged displays are needed. At the same time, the flexible AMOLED will keep improving in its optical performance, lifetime, and flexibility, and move into the rollable and ultimately free-form phases. With enhanced flexibility coupled with low power consumption, a range of revolutionary displays can be created: wrist-based PDAs, camcorders with a flexible screen (Fig. 7), cell phones with roll-

Fig. 7: A camcorder concept with a flexible AMOLED screen (designed by Emory Krall from Universal Display Corp.).

out screens, and TVs that can be carried around as scrolls.

Acknowledgments

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Flexible Displays Made with Plastic Electronics

Plastic Logic has designed and constructed a full-scale manufacturing facility for flexible display modules fabricated using organic semiconductors ("plastic electronics"). These display modules are lightweight, flexible, and robust and are used in the QUEproReader, an e-reader device for mobile business professionals that was introduced in January 2010.

by Seamus Burns

FOR MANY YEARS, there has been healthy market interest in flexible displays because they will enable display products that are thin, lightweight, robust, and ultimately rollable or foldable. These products and related technologies are finally starting to enter the mainstream after a long period of development. Display media technologies such as those of E Ink Corp. and SiPix Imaging have come of age in the last 6 years and are a key enabler for flexible displays. Generally referred to as e-paper, these technologies indeed share many of the properties of paper in that they are reflective and flexible and their images remain in a non-power-consuming state between image updates (a property known as image stability). They are commercially available in high volume with consistent electro-optical performance and in a form that is easy to integrate by directly laminating the display media foil onto the display backplane. Although these display technologies have been mainly used on rigid glass displays, they have also opened the door to high-resolution flexible displays and to products that use them.

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Another complex component, in addition to the e-paper display media, that is needed in order to make a high-resolution flexible display is a flexible active matrix. An active matrix is necessary for the majority of fast-update high-resolution displays: it is an array of electrodes and tiny electronic switches that is normally formed by multiple vacuum deposition and photolithography steps. These processes for deposition and patterning work well on glass – indeed, almost all displays in mobile phones, laptops, LCD TVs, and many other electronic devices are addressed by an active matrix built on a glass substrate. However, these deposition processes transfer poorly to flexible plastic substrates, and this has been a barrier to the implementation of flexible displays.

Flexible Prototypes

Flexible active-matrix display *demonstrators* have been fabricated by university laboratories and by corporate R&D departments many times since 1999 when Professor Ernst Lueder and his team at the University of Stuttgart made a flexible active-matrix liquid-crystal display (AMLCD) on a poly(ethersulfone) substrate. However, industrialization of these techniques has been less straightforward, despite the wealth of research and development in all aspects of flexible active-matrix manufacture and the intense market interest. There have been very few examples of products with flexible displays. However, a number of technologies are maturing that will enable flexible-display products to be available in the near future.

Recently, the Dutch company Polymer Vision announced the Readius, a beautiful and pioneering e-reader comprising a roll-out flexible e-paper display. This device is unique in that it is pocket size when its 5-in. display is rolled up. It was also to be the first consumer-electronics product to use organic thin-film transistors (TFTs). However, the Readius has yet to be made available to consumers.

Other approaches that are near commercialization are typically based on the adaptation of silicon display-making processes. Prime View International, a pioneering e-paper display-module manufacturer, has a flexible-display process based on laser release known as EPLaR. A very thin polymer film is deposited on a rigid substrate and conventional silicon processes are then used to form the active-matrix display. The polymer layer is then released from the rigid substrate by laser processing. Another company developing a flexible-display technology is LG Display, which has a process for flexible-display manufacture that uses thin, flexible, stainless-steel foil. This material can withstand the temperatures needed for silicon

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deposition and is sufficiently stable to allow mask alignment. For several years, LG Display has showcased flexible electrophoretic display modules in a range of shapes and sizes, including 12-in.-diagonal displays with a resolution of 1600 × 1200 and 174 ppi. Also worthy of mention is AUO, which demonstrated flexible e-paper displays in October 2009 with a 6-in. flexible display module using SiPix electrophoretic display media. However, the company has said little about the underlying technology used.

Organic semiconductors

Spun out from the University of Cambridge in 2000, Plastic Logic was created to commercialize advances in organic semiconductors that allowed TFTs to be printed on flexible plastic, a route to flexible electronics. Organic semiconductors enable flexible electronics by two means. First, unlike silicon, organic semiconductors can be deposited from solution at room temperature. Flexible plastic can therefore be used as a substrate material, as opposed to silicon deposition in which the temperatures required would cause the plastic substrate to melt or distort. Second, organic semiconductor devices can be formed without using mask alignment. Conventional silicon electronics require the subsequent alignment of a series of masks. This cannot be done in a straightforward way on a plastic substrate. Shifts in temperature and solvent absorption cause the substrate to distort between mask steps. With organic materials, mask alignment can be avoided by using print-based processes, which overcome distortion in plastic substrates. This is achieved by locally aligning the print heads to compensate for distortion while performing a print step. A further advantage of organic materials when used for flexible electronics is their inherent flexibility.

The Plastic Logic process is capable of depositing high-resolution electrical components on flexible plastic. The processing steps are at or near room temperature, so they are fully compatible with inexpensive plastic substrate materials. The standard substrate material used is poly(ethylene terephthalate) or PET, a very common plastic otherwise used in food and drink containers and synthetic fibers. The process can deposit features of down to a minimum size of 2 μm. The layer-to-layer alignment accuracy is typically ±5 μm. This is illustrated in Fig. 1.

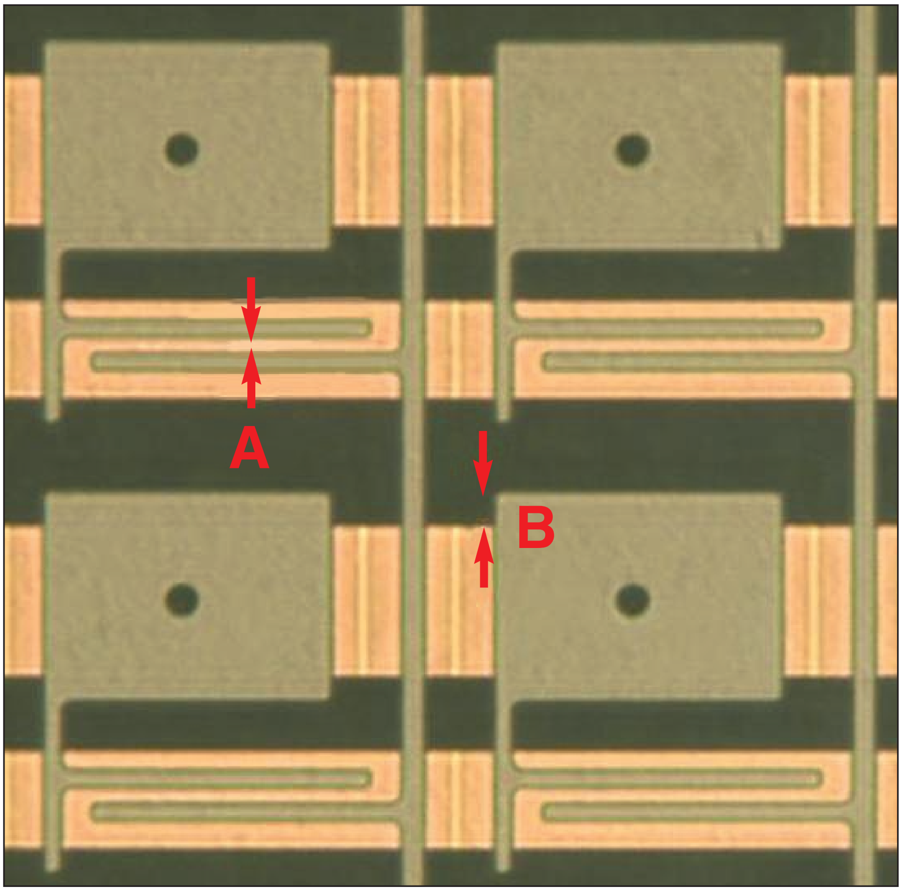

Fig. 1: *An active-matrix backplane array made on a flexible plastic substrate appears in a close-up view. Print-based processes are used to compensate for substrate distortion by locally aligning the print head during a patterning step. "A" is the feature size, which can be as low as 2 μm. "B" is the layer-to-layer registration accuracy, which is typically ±5 μm.*

An active matrix allows displays with a very high resolution that have a comparatively low number of connections. It consists of an intersecting grid of row and column electrodes. At each intersection there is an electrical switch, typically a TFT. The transistor is used to move charge on or off a capacitor, which changes the voltage across the display medium and, in turn, changes the optical state of the medium. An active-matrix display is ideally capable of addressing the display media such that it achieves its optimum contrast ratio and refresh rate, *as though the medium were directly driven.*

In order to meet these requirements for an e-paper device, a number of electrical criteria need to be satisfied. The TFT "ON" current needs to be sufficiently high to move charge on to and off of the pixel during the line address time. This is governed by the transistor mobility. The TFT "OFF" current needs to be low so as to maintain the pixel voltage once the gates are turned off. Achieving a low OFF current requires a stable TFT threshold, which is determined by the purity of the organic semiconductor and dielectric materials. Control of process conditions is vital here. Gate leakage needs to be minimized, along with any other spurious inter-electrode electrical leakage path (*e.g.*, source-to-gate leakage; source-to-common leakage). Pinhole-free dielectric layers with a high dielectric breakdown voltage are a critical requirement to avoid these leakage paths. Again, control of process conditions and the use of a clean manufacturing environment are prerequisites. The gate and source lines need to be sufficiently "fast," *i.e.*, able to transmit changes in voltages quickly, requiring a high conductivity and a low capacitance. Minimizing capacitance requires fine-feature-size definition, as discussed earlier. Another desirable characteristic is to have a low kickback voltage that is consistent across all pixels. The kickback voltage is the voltage offset between the pixel electrode voltage and the data line voltage that is introduced when the gate line turns off. Because it is related to the overlapping area of electrodes, minimizing this parameter again requires a process with fine feature sizes.

The above-described process is capable of making flexible, active displays that are sufficiently large and of sufficiently high resolution to be used in e-paper display applications. The organic semiconductor used is a polyfluorene-based material that is solution-processable and has a typical mobility of 0.03 cm^2/V-sec. This allows for ON currents approaching 1 µA. The ON/OFF ratio of devices made with this process is 10^5–10^6, and the gate leakage is below 10–11 A. The first commercial display modules produced in the Plastic Logic factory have a resolution of 1280 × 960 and a diagonal dimension of 10.7 in. The pixel density is 150 ppi, sufficient for monochrome and gray-scale e-reader applications. The display medium used is Vizplex electrophoretic foil from E Ink Corp. This display is engineered to exploit the full contrast and speed of the medium for monochrome and gray-scale modes. An image of a display made with this process is shown in Fig. 2.

Fig. 2: This flexible display module made with plastic electronics in the Dresden facility in late 2009 has a resolution of 1280 × 960 and 150 ppi. The display media is Vizplex provided by E Ink Corp.

A New Flexible-Display Facility

Plastic Logic built a full-scale manufacturing facility in Dresden, Germany, in order to produce high volumes of display modules cost effectively. Dresden is one of the high-tech hubs in Germany and is host to a large number of electronics companies, among them silicon-wafer fabs. The presence of these companies has ensured the necessary support infrastructure to fabricate electronic devices such as display modules, as well as providing access to an educated and experienced workforce. The equipment for the fully automated line was sourced mainly from the Far East, typically, but not exclusively, from the flat-panel-display industry. In many cases, it was "off-the-shelf" or required only minor customization. The line is housed in a Class-100 clean room. Manufacturing is done by batch processing with the flexible PET substrate mounted on a rigid glass carrier during patterning. The substrate size is equivalent to Gen 3.5. A series of patterning steps are performed to produce nine active-matrix displays per mother substrate. The active matrices are then tested for pixel and line yield prior to lamination with the display media. The yielded displays are then encapsulated to maintain a constant level of humidity throughout product lifetime and ensure consistent display media operation. Flexible encapsulation is feasible because organic TFTs are not highly sensitive to oxygen and moisture, unlike OLED or PLED devices. This is followed by the bonding of high-voltage display drivers and outer lead bonding, in which the connections are made with aniso-tropic conductive film (ACF). Finally, the touch sensor is laminated onto the display module, which also comprises optical coatings and UV barriers.

The QUEproReader

The current generation of e-reader devices can be traced back to the SonyLIBRIé, which was launched in 2004. This was the first e-reader with an electrophoretic display and was considered sufficiently groundbreaking to win the SID/*Information Display* Display Product of the Year Award in 2005. Since then, a plethora of e-reader devices with different sizes, weights, user interfaces, and intended purposes have been introduced. The majority of these devices were designed primarily for reading books, usually with additional functionality for storing, purchasing, downloading, and otherwise facilitating book reading.

***Fig. 3:** The QUEproReader from Plastic Logic was introduced at CES in Las Vegas in January of 2010. The company says it will ship in April 2010.*

Figure 3 shows an image of the QUEproReader from Plastic Logic. QUE is specifically designed as a reader for the business professional. It supports the document formats PDF, GIF, JPEG, PNG, BMP, ePub, text, and printable formats such as Microsoft Office (2003/2007), e-mail, calendar, HTML (*e.g.*, maps), and RTF and can handle a file cabinet's worth of customer-generated documents. It also features powerful tools for interacting with and managing content. In addition, the QUE store allows users to buy and download business and professional newspapers, periodicals, and eBooks, with access to over 1 million eBooks through Barnes & Noble. Books and newspaper content can be downloaded via WiFi or (in the 3G version) via a cellular network.

QUE has been designed to differ from other readers in that it is aimed at the business market, but it's also unique for its shatterproof plastic display, which also makes it ultra-thin and lightweight. It is the size of an 8.5 × 11-in. pad of paper, measuring about 1/3 in. thick. It weighs about 1 pound. Reliability tests have confirmed that the display is more resilient to being dropped and to objects being dropped onto the display than are equivalent glass-based products. QUE also has the largest capacitive touch screen in the industry.

Technology Outlook

Future products that will require more sophisticated displays that fully exploit the rapidly evolving properties of e-paper display media are being developed by Plastic Logic as well as other companies. Most of the companies developing these media are engaged in a color program, and it is expected that full-color e-readers will become available in the next year. Plastic Logic is currently working on a flexible-display platform for a full-color e-reader device.

Color displays have a higher ppi than monochrome displays, requiring a higher performance and higher-resolution display. This, in turn, leads to requirements such as higher-conductivity gate lines, higher-performance TFTs, and finer levels of patterning. Plastic Logic's process development for the next generation of displays is undertaken in the development line in Cambridge, UK. Here, there are programs to improve backplane performance and meet these higher requirements. Next-generation TFT devices use a new organic semiconductor materials set with a mobility approaching that of amorphous-silicon. Displays with a higher number of pixels per inch, required for color and the necessary TFT performance, have been fabricated with these improved processes. Once fully proven on the development line, these materials and processes will be transferred to the manufacturing facility, where they will be scaled up, verified, and ultimately incorporated in the display-making process.

Flexible displays are comparatively an early-stage technology, and their huge potential remains to be exploited from the possibilities of organic TFT devices to the adaptation of more conventional electronics. The plastic substrate can be used to house progressively more of the system electronics, either by directly bonding discrete electronic components or by replacing silicon high-voltage display drivers with printed electronics. The latter was demonstrated in concept in 2004 by Polymer Vision (then Philips Research Laboratories), which integrated part of the gate-driver display circuitry onto a flexible display. Ultimately, it is anticipated that organic TFTs will be powerful and stable enough to drive current-driven media such as OLEDs and PLEDs in consumer products. This, in turn, would make possible a flexible emissive display with integrated high-voltage drivers fully manufactured using printing processes. There are huge challenges that need to be overcome in order to allow this possibility; however, given the pace of development in this field, it is easy to imagine this happening by the middle of this decade.

This is to say nothing of the range of non-display applications that may use printed electronics. RFID is one of the expected applications, in circumstances where a small number of electrical gates are needed, and it is less economically viable to use silicon. Flexible plastic sensors are another possible application, one that resembles an active-matrix display in architecture. There are further opportunities associated with disposable and "on-the-fly" configurable electronics.

Ten years ago, plastic electronics was a nascent field focused on materials research in a handful of universities and corporate research laboratories. This technology has since been shown to be viable for use in cutting-edge display products. In the coming years, we can realistically expect significant further advances in the commercialization of this expanding field. ■

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Keynote Session to Reveal the Next Generation of Displays

The Keynote Session, which officially opens the Symposium on Tuesday morning, May 25, will feature three talks that will describe the next generation of displays.

Keynote Speakers

Sang-Soo Kim

Mike Sinnett

Steve Bathiche

Dr. Sang-Soo Kim, *Executive VP, Samsung Fellow and SID Fellow, Samsung Mobile Display,* will describe ***"The Next Big Thing in Displays."*** Dr. Kim is responsible for leading the research of large-sized and advanced OLED technology, including flexible and transparent OLED displays, at Samsung. He will address the latest developments in OLED displays and how this technology will result in dramatic changes in the display landscape of the future.

Next, **Mr. Mike Sinnett,** *Vice President/787 Systems Chief Engineer, The Boeing Company,* will speak on ***"Information Displays in Aerospace: Past, Present, and Future."*** Mr Sinnett will explain how information displays have been an integral part of aviation and will continue to play a vital role for years to come. Aviation applications and their environment present significant challenges for display technology. Solutions for both current and future products represent exciting opportunities.

In conclusion, **Mr. Steve Bathiche,** *Director of Research, Applied Sciences Group, Entertainment and Devices Division, Microsoft Corp.,* will discuss ***"Breaking the Fourth Wall: The Next Generation of Interactive Displays."*** In theater, the fourth wall defines the boundary between the audience and the world of the play. When an actor steps out past the scenery and directly interacts with the audience, he is said to be "breaking the fourth wall." In display technology, we have effectively been held hostage to our own fourth wall — the plane of the display. Mr. Bathiche will explain why the next generation of combined sensing and display technologies offers the promise of reaching past this boundary to create truly immersive, interactive experiences. These will redefine the way we compute, communicate, and entertain ourselves. The technologies that will allow us to break through this wall will be explored.

Luncheon Speaker to Describe "Behind the Screens at the Beijing Summer Games"

At the annual SID Luncheon to be held Wednesday, May 26, 2010, **Mr. Terry Schmidt,** *Chief Scientist, Christie Digital Systems, Inc., and longtime SID member,* will reveal what really happened ***"Behind the Screens at the Beijing Summer Games."*** During the 2008 Summer Games in China, the "Bird's Nest" Stadium was aglow with over 2.5 million lumens of high-definition digital video images illuminated by 147 high-power digital projectors. Terry will walk us through the many unique challenges of the high-tech set-up in an outdoor venue of this immense scale and explain how these impressive displays contributed to the overall spectacle of this memorable event.

Special Technology Tracks on 3-D, Green Technology, Solid-State Lighting, and Touch Technology

The four-day (Tuesday, May 25 – Friday, May 28) Display Week 2010 Symposium consists of a record-breaking number of oral presentations allocated into 78 technical sessions across six parallel tracks for 3½ days.

3-D: This year's technical program will be emphasizing the different developments and approaches that are leading the way toward 3-D entertainment in the home and includes 49 papers (36 oral and 13 posters) on advances in 3-D technology.

Session 3: Polarization-Based Stereoscopic Projection Displays

3.1: A Novel Design of a Stereoscopic 3-D Display with a Patterned Retarder
Hoon Kang, LG Display, Gyeonggi-do, Korea

3.2: A New Approach to Dynamic Polarization 3-D LCDs
Hsiang Tan Lin, Chunghwa Picture Tubes, Ltd.,Taoyuan, Taiwan

3.3: Efficient Polarization-Based Stereoscopic Projector with Extended Color Gamut: Combining Two Projectors into One
Lawrence Bogaert, Vrije Universiteit Brussels, Brussels, Belgium

3.4: Simultaneous Projection of Stereoscopic 3-D Left- and Right-Eye Images in Orthogonal Polarization through a Single Lens
Simon Boothroyd, Thetalili, Inc., Ottawa, Ontario, Canada

3.5: Novel Broadband Retarder Evaluation Metrics for 3-D Projection Display
Yu-Hsiun Chang, National Taiwan University, Taipei, Taiwan

Session 10: Crosstalk in Stereoscopic Displays

10.1: Crosstalk Simulation for Polarization-Switching 3-D LCDs
Youngji Ko, Samsung Electronics Co., Ltd., Gyeongi-do, Korea

10.2: Crosstalk Suppression by Image Processing in 3-D Displays
Yu-Cheng Chang, National Chiao Tung University, Hsinchu, Taiwan

10.3: Crosstalk Evaluation of Shutter-Type Stereoscopic 3-D Displays
Cheng-Cheng Pan, Chi Mei Optoelectornics Corp., Tainan, Taiwan

10.4: Measuring Gray-to-Gray Crosstalk in an LCD-Based Time-Sequential Stereoscopic Display
Sergey Shestak, Samsung Electronics Co., Ltd., Gyeonggi-do, Korea

Session 16: Autostereoscopic Displays

16.1: Prototyping of Glasses-Free Table-Style 3-D Display for Tabletop Tasks
Shunsuke Yoshida, NICT, Kyoto, Japan

16.2: Backlight for View-Sequential Autostereoscopic 3-D
Adrian Travis, Microsoft, Redmond, WA, USA

16.3: Directional Backlight Timing Requirements for Full-Resolution Autostereoscopic 3-D Displays
John Schultz, 3M, Saint Paul, MN, USA

16.4: The Optics of an Autostereoscopic Multi-Viewer Display
Eero Willman, University College London, London, UK

Session 23: Autostereoscopic Display Measurements

23.1: Viewing Angle and Imaging Polarization Analysis of Polarization-Based Stereoscopic 3-D Displays
Pierre Boher, ELDIM, Herouville, Saint Clair, France

23.2: Optical-Performance-Analysis Method of Autostereoscopic 3-D Displays
Joo Young Lee, Samsung Electronics Co. Ltd., Gyeonggi-do, Korea

23.3: Characterization of 3-D Image Quality of Autostereoscopic Displays: Proposal of Interocular 3-D Purity
Tsutomu Horikoshi, NTT DOCOMO, Kanagawa, Japan

23.4: Qualified Viewing Spaces for Near-to-Eye and Autostereoscopic Displays
Toni Jarvenpaa, Nokia Research Center, Tampere, Finland

Session 30: 2-D/3-D Switching for Autostereoscopic Displays

30.1: Fast-Switching Fresnel Liquid-Crystal Lens for Autostereoscopic 2-D/3-D Display
Chih-Wei Chen, National Chiao Tung University, Hsinchu, Taiwan

30.2: Autostereoscopic 2-D/3-D Displays by Using Liquid-Crystal Lens
Sheng Liu, Chunghwa Picture Tubes, Ltd., Taoyuan, Taiwan

30.3: Autostereoscopic Partial 2-D/3-D Switchable Display Using Liquid-Crystal Gradient-Index Lens
Ayako Takagi, Toshiba Corp., Kawasaki, Japan

30.4: 2-D/3-D Hybrid System for Digital-Signage Application
Chih-Hong Ding, National Chiao Tung University, Hsinchu, Taiwan

Session 37: Human Factors of 3-D Displays

37.1: *Invited Paper:* 3-D Technology Development and the Human-Factor Effect
Chao-Yuan Chen, AU Optronics Corp., Hsinchu, Taiwan

37.2: New Methodology for Evaluating the Quality of Stereoscopic Images
Cedric Marchessoux, BARCO, Medical Imaging Division, Kortrijk, Belgium

37.3: The Effect of Camera Distortions on Perception of Stereoscopic Scenes
Lachlan Pockett, Nokia Research Center, Tampere, Finland

37.4: Accommodation Response in Viewing Integral Imaging
Byoungho Lee, Seoul National University, Seoul, Korea

Session 44: Volumetric and Integral Imaging

44.1: Volumetric Display Using Scanned Fiber Array
Brian Schowengerdt, University of Washington, Seattle, WA, USA

44.2: An Analysis of Color Uniformity of Three-Dimensional Image Based on Rotating-LED-Array Volumetric-Display System
Xu Liu, Zhejiang University, Zhejiang, China

44.3: Characterization of Motion Parallax on Multi-View / Integral-Imaging Displays
Shin-ichi Uehara, Japanese Ergonomics National Committee, Tokyo, Japan

Session 51: 3-D TV and 3-D Video

51.1: Novel Simultaneous Emission Driving Scheme for Crosstalk-Free 3-D AMOLED TV
Baek-Woon Lee, Samsung Mobile Display, Gyeonggi-do, Korea

51.2: New 240-Hz Driving Method for Full-HD and High-Quality 3-D LCD TV
Dae Sik Kim, Samsung Electronics Co., Ltd., Gyeonggi-do, Korea

51.3: An Ultra-Low-Cost 2-D/3-D Video-Conversion System
Chao-Chung Cheng, National Taiwan University, Taipei, Taiwan
51.4: 3-D Video Framework Design for FVV Realization
Lachlan Pockett, Nokia Research Center, Tampere, Finland

Session 58: Novel 3-D Displays
58.1: 3-D Interactive Display with Embedded Optical Sensor
Pi-Cheng Wu, National Chiao Tung University, Hsinchu, Taiwan
58.2: Spatio-Temporal Hybrid Multi-View 3-D Display
Ching-Wen Wei, National Chiao Tung University, Hsinchu, Taiwan
58.3: Interference-Filter-Based Stereoscopic LCD
Arnold Simon, Infitec GmbH, Neu-Ulm, Germany
58.4: Control of Subjective Depth on 3-D Displays by a Quantified Monocular Depth Cue
Shuichi Takahashi, Sony Corp., Tokyo, Japan

Solid-State Lighting: The 2010 SID technical program will be highlighting the different developments and approaches that are leading the way toward further expansion of the role of LEDs and also OLEDs in solid-state lighting. Six sessions incorporating 26 papers in all are scheduled for presentation.

Session 52: OLEDs for Lighting Applications
52.1: Hybrid Tandem White OLEDs with High Efficiency and Long Lifetime for AMOLED Displays and Solid-State Lighting
Tukaram Hatwar, Eastman Kodak Co., Penfield, NY, USA
52.2: *Invited Paper:* **Highly Efficient White Top-Emission PIN OLEDs for Displays and Lighting**
Jan Birnstock, Novaled AG, Dresden, Germany
52.3: OLEDs for Lighting Applications
Hans-Peter Loebl, Philips Technologie GmbH, Aachen, Germany
52.4: Highly Efficient Phosphorescent OLED Lighting Panels for Solid-State Lighting
Peter Levermore, Universal Display Corp., Trenton, NJ, USA

Session 59: Solid-State Lighting
59.1: *Invited Paper:* **On the Recent Progress of LED Lighting in Japan**
Kiyoshi Nishimura, Toshiba Lighting & Technology Corp., Kanagawa, Japan
59.2: Durable Solid-State Flexible LED Devices
Derrick Banerjee, West Virginia University, Morgantown, WV, USA
59.3: Phosphor Modeling for Phosphor-Converted LEDs
Chien Hsiang Hung, National Chiao Tung University, Hsinchu, Taiwan
59.4: LED Drivers: From Displays to General Lighting
Michael Kretzmer, Endicott Research Group, Inc., Endicott, NY, USA

Session 65: Projection Lighting
65.1: *Invited Paper:* **The Physics and Commercialization of Dual Paraboloid Reflectors for Projection Systems**
Kenneth Li, Wavien, Inc, Valencia, CA, USA
65.2: Advanced Laser Module with Intra-Frame-Operating Color-Management for Mobile Projection
Jan Drumm, OSRAM GmbH, Regensburg, Germany
65.3: High-Efficiency Optical System for Ultra-Short-Throw-Distance Projector Based on Multi-Laser Light Source
Michihiro Okuda, SANYO Electric Co., Ltd.., Daito, Japan
65.4: High-Brightness LED-Based Projector with NTSC 120% Wide Color Gamut
Feng-Chuan Tsai, Chi Lin Technology Co., Ltd., Tainan, Taiwan

Session 66: Lighting Materials and Applications
66.1: Application of UV-LEDs to LCD Backlights
Yoshihiko Muramoto, Nitride Semiconductors Co., Ltd., Naruto, Japan
66.2: *Invited Paper:* **Remote Phosphor for Future LED Backlights and Lighting Applications**
Wen-Chi Chang, KISmart, Hsinchu, Taiwan
66.3: Emission Characteristics of ZnO-Incorporated $CaTiO_3:Pr^{3+}$ Phosphor and Its Application for Solid-State Lighting
Seung-Youl Kang, ETRI, Taejon, Korea
66.4: *Invited Paper:* **High-Quality White OLEDs and Resource Saving Fabrication Processes for Lighting Application**
Takuya Komoda, Panasonic Electric Works Co. Ltd., Osaka Japan

Session 68: Lighting Design
68.1: Angular Uniform WLEDs with an Internal Reflector Cup
Ling Zhu, University of Hong Kong, Hong Kong
68.2: Zoomable-Spot Lighting Fixture Using WRGB LED
Lo Hsin-Hsiang, Hsinchu, Taiwan
68.3: High-Power LED Lamp with Efficient Heat Exchange
Sungkyoo Lim, Dankook University, Chungcheongnam-do, Korea
68.4: Optimal Additive Mixing Approach via Multi-Color LEDs Platform
Ming-Chin Chien, National Chiao Tung University, Hsinchu, Taiwan
68.5: A New Light Source: E3 Linear Plasma Lamp
Sungkyoo Lim, Dankook University, Chungcheongnam-do, Korea

Session 75: Displays and Lighting Technologies
75.1: *Invited Paper:* **The Many Roles of Illumination in Information Display**
Lorne Whitehead, University of British Columbia, Vancouver, BC, Canada
75.2: *Invited Paper:* **LEDs: From Displays to Lighting**
Dragan Sekulovski, Philips Research Europe, Eindhoven, The Netherlands
75.3: Is Brighter Always Better? The Effects of Display and Ambient Luminance on Preferences for Digital Signage
Pearl Guterman, York University, Toronto, Ontario, Canada
75.4: Evaluation of Human Reactions on Displays with LED Backlight and a Technical Concept of a Circadian Effective Display
Oliver Stefani, Fraunhofer IAO, Stuttgart, Germany
75.5: Evaluating Procedure of Color-Rendering Property on Reflective LCDs
Yen-Hsing Lu, National Chico Tung University, Hsinchu, Taiwan

Touch Technology: Display Week organizers added this area based on the record-breaking number of exhibitors (54) who displayed touch screens, touch controllers, or touch-related products and services at Display Week 2009, and the record-breaking number of touch-related papers (16) presented at last year's Symposium – surpassed this year with 23 presentations (14 oral, 9 posters).

Session 31: Touch-Technology Development
31.1: *Invited Paper:* **A Touching Story: A Personal Perspective on the History of Touch Interfaces Past and Future**
Bill Buxton, Microsoft Research, Redmond, WA, USA
31.2: Ultra-Thin High-Transparency Projective Capacitive Touch Sensing Film
Chen-Pang Kung, ITRI, Hsinchu, Taiwan
31.3: A System LCD with an Integrated 3-D Input Device
Christopher Brown, Sharp Laboratories of Europe Ltd., Oxford, UK
31.4: Specifying Tactile Performance of Multi-Touch Systems
Gauthier Chastan, Stantum, Bordeaux, France

Session 38: Multi-Touch Systems and Developments
38.1: *Invited Paper:* **What Multi-Touch Is All About**
Jeff Han, Perceptive Pixel, New York, NY, USA
38.2: Direct Display Interaction via Simultaneous Pen and Multi-Touch Input
Ken Hinckley, Microsoft Research, Redmond, WA, USA
38.3: The Structure and Driving Method of Multi-Touch Resistive Touch Panels
Chih-Chang Lai, Wintek Corp., Taichung, Taiwan
38.4: *Invited Paper:* **In-Cell-Embedded Touch-Screen Technology for Large-Sized LCDs**
Seiki Takahashi, Samsung Electronics Co., Ltd., Chungcheongnam-do, Korea

Session 45: Display-Embedded Touch Solutions
45.1: Touch-Panel-Embedded IPS-LCD with Parasitic Current-Reduction Technique
Hiroshi Haga, NEC LCD Technologies, Ltd., Kanagawa Japan
45.2: Novel LCD with a Sensible Backlight
Kwonju Yi, Samsung Electronics Co., Ltd., Gyeonggi-do, Korea
45.3: On-Cell Projected Capacitive-Type Touch Sensor for NBPC
Sang-Soo Hwang, LG Display, Gyeonggi-do, Korea
45.4: Embedded Si-Based Photonic Sensor in TFT-LCD Technology Integrated as a Multi-Function Touch-Input Display
An-Thung Cho, AU Optronics Corp., Hsinchu, Taiwan
45.5: A System LCD with Optical Input Function Using IR Backlight Subtraction Scheme
Kohei Tanaka, Sharp Corp., Nara, Japan
45.6: *Invited Paper:* **Photosensing Circuits Using LTPS TFTs and Photodiode for Smart Functional Displays**
Oh-Kyong Kwon, Hanyang University, Seoul, Korea

Green Technology: Energy efficiency, eco-friendly materials, and recyclability have become key issues in display development. Accordingly, five sessions on different aspects of green technology totaling 20 papers will be presented as part of the 2010 technical program.

Session 9: Green Technologies in Display Manufacturing
9.1: *Invited Paper:* **Green Technology in LCDs**
Jun Souk, Samsung Electronics Co., Ltd., Gyeonggi-do, Korea
9.2: *Invited Paper:* **Green LCD Technologies**
Po-Lun Chen, AU Optronics Corp., Hsinchu, Taiwan
9.3: Power-Efficient LC TV with Smart Grid Demand Response Functionality
Louis Kerofsky, Sharp Laboratories of America, Camas, WA, USA
9.4: *Invited Paper:* **EcoDesign for TV Displays**
Cornelis Teunissen, Philips Consumer Lifestyle, Eindhoven, The Netherlands

Session 15: Low-Power e-Paper and Other Bistable Displays
15.1: Optically Rewritable Liquid-Crystal Technology: A New Green e-Paper Approach
Vladimir Chigrinov, Hong Kong University of Science & Technology, Kowloon, Hong Kong
15.2: Bistable D3 Electrowetting Display Products and Applications
Jurgen Rawert, Adt Deutschland GmbH, Bad Soden, Germany
15.3: Optical Optimization of the Single-Polarizer BiNem Display for e-Reading Applications
Jesper Osterman, NEMOPTIC, Magny Les Hameaux, France
15.4: *Invited Paper:* **Low-Cost Zenithal Bistable Display with Improved White State**
Cliff Jones, ZBD Displays, Malvern, UK

Session 22: Novel Power Reduction Techniques
22.1: Low-Power Driving Scheme for High-Frame-Rate LCD TVs
Hyoungsik Nam, Samsung Electronics Co., Ltd., Gyeonggi-do, Korea
22.2: In-Cell Solar-Display Integration by Embedded-Si-Based Thin-Film Solar Cell
An-Thung Cho, AU Optronics Corp., Hsinchu, Taiwan
22.3: Quantified Evaluation for Clipping Artifact of Local Dimming in LCDs
Hanfeng Chen, Samsung Electronics Co., Ltd., Gyeonggi-do, Korea
22.4: In-Cell Multiple Ambient-Light-Sensor (ALS) LCD Integration Using Si-Based Photonic Sensor by a-Si TFT Technology
An-Thung Cho, AU Optronics Corp., Hsinchu, Taiwan

Session 29: Power-Saving Device Designs
29.1: Power-Savings Design of WLED Backlit LCDs by the Use of Unequal-Area RGB Color Filters
Senfar Wen, Chung Hua University, Hsinchu, Taiwan
29.2: Power Savings: A New Advantage of Multi-Primary-Color Displays Derived by Numerical Analysis
Yasuhiro Yoshida, Sharp Corp., Nara, Japan
29.3: The Luminance Enhancement by Four Primary Colors (RGBY)
Sang Hoon Han, LG Display Co., Ltd., Gyeonggi-do, Korea
29.4: RGBW-LED Backlight System for Ultra-Low-Power-Consumption Field-Sequential-Color LCDs
Chi-Chu Tsai, National Chiao Tung University, Hsinchu, Taiwan

Session 43: Green Technologies in Active-Matrix Devices
43.1: A Novel Multi-Level Memory In-Pixel Technology for Ultra-Low-Power LTPS TFT-LCD
Naoki Ueda, Sharp Corp., Nara, Japan
43.2: New Driving Method for Low Logic Power Consumption in TFT-LCDs
S.C. Yun, LG Display Co. Ltd., Gyeonggi-do, Korea
43.3: Power-Efficient AMOLED Display with Novel Four-Subpixel Architecture and Driving Scheme
Woo-Young So, Universal Display Corp., Ewing, NJ
43.4: Low-Power LCD Using In-Ga-Zn-Oxide TFTs Based on Variable Frame Frequency
Seiko Amamo, Semiconductor Energy Laboratory Co.,Ltd., Kanagawa, Japan

Symposium at a Glance

2010 Display Week Symposium at a Glance – Washington State Convention and Trade Center

Day	Times	Ballroom 6B	Ballroom 6C	Ballroom 6E	Room 608-610	Room 611-612	Room 615-617	Room 618-620	Times
Tuesday, May 25	8:00 – 10:20	SID Business Meeting and Keynote Session (Ballroom 6E)							8:00 – 10:20
Tuesday, May 25	10:50 – 12:10	3 Polarization-Based Stereoscopic Displays (Joint with Projection)	4 Active-Matrix Integration	5 OLED Fundamentals	6 Display Drivers and Interfaces	7 Blue-Phase Devices I	8 Image Quality	9 Green Technologies in Display Manufacturing (Joint with Manufacturing)	10:50 – 12:10
Tuesday, May 25	2:00 – 3:20	10 Crosstalk in Stereoscopic Displays (Joint with Measurement)		11 OLED Devices I	12 Color Sequential (Joint with Systems)	13 Blue-Phase Devices II	14 Contrast and Sharpness	15 Low-Power e-Paper & Other Bistable Displays (Joint with Liquid-Crystal)	2:00 – 3:20
Tuesday, May 25	3:40 – 5:00	16 Autostereoscopic Displays (Joint with Systems)	17 TFT Processing	18 OLED Devices II	19 Multi-Primary Displays	20 Cholesteric Displays	21 Field-Emission Displays and Emitters	22 Novel Power Reduction Techniques	3:40 – 5:00
Tuesday, May 25	5:00 – 6:00	Author Interviews (Exhibit Hall)							5:00 – 6:00
Wednesday, May 26	9:00 – 10:20	23 Autostereoscopic Display Measurements	24 Novel Pixel Design	25 OLED Devices III	26 Driving Electronic Paper	27- Ferroelectric Liquid-Crystal Devices	28 Emissive Displays	29 Power-Saving Device Designs (Joint with Systems)	9:00 – 10:20
Wednesday, May 26	10:40 – 12:00	30 2-D/3-D Switching for Autostereoscopic Displays	31 Touch-Technology Development	32 OLED Material I	33 Electronic Paper I	34 IPS Technology	35 Exo-Emission		10:40 – 12:00
Wednesday, May 26	2:00 – 3:30	Designated Exhibit Time (Exhibit Hall)							2:00 – 3:30
Wednesday, May 26	3:30 – 4:50	37 Human Factors of 3-D Displays (Joint with Applied Vision)	38 Multi-Touch Systems and Developments	39 OLED Material II	40 Electronic Paper II	41 Liquid-Crystal Alignment	42 PDP TV	43 Technologies in Active-Matrix Devices (Joint with Active-Matrix)	3:30 – 4:50
Wednesday, May 26	5:00 – 6:00	Author Interviews (Exhibit Hall)							5:00 – 6:00
Thursday, May 27	9:00 – 10:20	44 Volumetric and Integral Imaging (Joint with Systems)	45 Display-Embedded Touch Solutions	46 OLED Manufacturing (Joint with Manufacturing)	47 Flexible OLEDs (Joint with OLEDs)	48 VA-Mode LCDs I	49 Protective Layer	50 Measuring Contrast and Motion Artifacts	9:00 – 10:20
Thursday, May 27	10:40 – 12:00	51 3-D TV and 3-D Video	52 OLEDs for Lighting Applications (Joint with OLEDs)	53 AMOLEDs I	54 Flexible-Display Manufacturing I (Joint with Manufacturing)	55 VA-Mode LCDs II	56 Novel and Emerging Display Technologies	57 HMDs and HUDs	10:40 – 12:00
Thursday, May 27	1:30 – 2:50	58 Novel 3-D Displays (Joint with Systems)	59 Solid-State Lighting (Joint with Applications)	60 AMOLEDs II	61 Flexible Backplanes I	62 Nanostructure Enhanced Liquid- Crystal Devices	63 Display Manufacturing: Reflective Technologies	64 Novel Near-to-Eye and Heads-up Displays	1:30 – 2:50
Thursday, May 27	3:00 – 4:00	Author Interviews (Exhibit Hall)							3:00 – 4:00
Thursday, May 27	4:00 – 5:20		65 Projection Lighting (Joint with Projection)						4:00 – 5:20
Thursday, May 27	4:00 – 8:00	Poster Session (Exhibit Hall)							4:00 – 7:00
Thursday, May 27	5:40 – 7:00		66 Lighting Materials and Applications (Joint with Emissive)						5:40 – 7:00
Friday, May 28	9:00 – 10:20	67 High Dynamic Range (Joint with Electronics)	68 Lighting Design (Joint with Systems)	69 Oxide TFTs I	70 Flexible-Display Manufacturing II (Joint with Flexible)	71 Projection Components	72 Display Manufacturing: Testing	73 Emerging Display Applications	9:00 – 10:20
Friday, May 28	10:40 – 12:00	74 LED Backlighting	75 Displays and Lighting Technologies (Joint with Applied Vision)	76 Oxide TFTs II	77 Flexible Backplanes II	78 Mobile Projection	79 Display Manufacturing: Processing	80 Digital Signage	10:40 – 12:00
Friday, May 28	12:00 – 1:00	Author Interviews (Exhibit Hall)							12:00 – 1:00

TECHNOLOGY TRACKS KEY

3-D	Active-Matrix Device	Applications	Applied Vision	Electronics	Emissive
FEDs	Flexible	Green	Lighting	Liquid-Crystal	Manufacturing
Measurement	OLEDs	Projection	Display Systems	Touch	

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Ultra-low-Power Technology Round-Up

Government mandates and industry trends are more or less in step with each other when it comes to making more-energy-efficient TVs. This move toward low-power displays is being realized through a variety of technologies, including refinements in the backlighting and edge-lighting of LCDs.

by Steve Sechrist

SOME MAY CONSIDER 2009 the beginning of the energy-conservation era in consumer electronics. That certainly holds for the nation's most populous state, California, and the adoption of its new energy regulations in mid-November 2009 by the California Energy Commission (CEC). The group moved to adopt, at the state level, new energy specifications for TVs and other consumer-electronic devices and gave the new standard teeth by restricting sales of non-compliant products in one of the largest markets in the U.S. Here's how the official proceeding (Docket#09AAER-1C) stated it:

> *"In California, TVs (along with DVRs, DVD players, and cable/satellite boxes) now consume about 10% of a home's electricity. Increasing sales of flat-screen TVs, larger screen sizes, the growing number of TVs per household, and increased daily use of TVs all contribute to greater electricity consumption.*
>
> *"The proposed standards have no effect on existing TVs. … they would only apply to TVs sold in California after January 1, 2011. The first standard (Tier 1) would take effect January 1, 2011 and reduce energy consumption by an average of 33%. The second measure (Tier 2) would take effect in 2013 and, in conjunction with Tier 1, reduce energy consumption by an average of 49%."*

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"Foul," cried electronics organizations, including Californians for Smart Energy (CSE) in-state, as well as bigger guns like the Consumer Electronics Association, producer of the popular CES show in Las Vegas. These groups did not mince words: "Shock and dismay" were used by the CSE, which claimed the results would be catastrophic, significantly contributing to unemployment in the state, *etc.*

But are consumer-electronics makers really so far off from the California compliance numbers – and, more importantly, is the trend toward creating ultra-low-power displays simply on track for the 2011 adoption date anyway?

Off the bat, the CEC's position is this: "The technology to make TVs more energy efficient is available now and currently used in a variety of models. As of late-September 2009, more than 1000 TVs already meet the 2011 standards." Chiming in from the editorial side of the industry, *CNET Reviews*' senior editor David Katzmaier calls the new Californis standards "fairly lenient." He said, "The TVs most in danger of not meeting the California mandates or getting an Energy Star label are the very large PDP TVs, particularly those that are more than 54 in."

In any event, the main culprit behind energy-hogging TVs is not so much the technology they are based on as the ballooning sizes of TVs in general. "TVs consume more power because they are bigger," Katzmaier said. "The California Energy Commission estimates that per square inch, LCDs consume a bit more than CRTs, but most people are also upgrading in size, which means significantly more electricity use." That usage number is growing now to match that of a refrigerator in some cases.

To help get a handle on display size and power consumption of the entire system, we turn to a CNET interactive HDTV Power Consumption chart (Fig. 1) that can be sorted by TV attributes, including power consumed in watts and a host of other factors.

As the CEC suggests, smaller sets (32 in.) deliver the best power numbers, but with some surprises. For instance, nestled among the low-power LCD-TV sets in the 32-in. size, which range between 59.75 and 70.16 W, is a Sharp 46-in. LCD TV (model 46LE700UN) drawing 63.91 W of power (or a slim 0.071 W/sq. in.).

That set beat out a host of 32-in. sizes from the likes of Sony (KDL-32M4000), Panasonic (LCD TC-L32X1 and -LX85), Samsung (LN32A 450), and LG (32LG40) and delivered the best per-square-inch consumption of any LCD TV on the list. Here's how CNET describes the Sharp 46-in. set in its review, "Among HDTVs of its size, the Sharp out-misers the former champ, Samsung's UN46B6000, by 26%, using barely more power after calibration (about 64 W) than a standard light bulb."

Sharp describes its LED-based LCD TV as a "full-array LED-backlight system," meaning

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Model	HDTV type	Screen size	Default setting (watts)	Default setting (watts per square inch)	Default setting (cost per year)	Calibrated setting (watts) ↓	Calibrated setting (watts per square inch)	Calibrated setting (cost per year)
Sharp LC-32D44U	LCD	32	126.25	0.289	$27.91	59.75	0.137	$13.58
Vizio VO32L	LCD	32	104.90	0.240	$22.60	61.14	0.140	$13.17
Toshiba 32CV510U	LCD	32	131.34	0.300	$28.92	61.20	0.140	$13.81
LG 32LG30	LCD	32	117.88	0.269	$26.17	61.70	0.141	$14.06
Sharp LC-46LE700UN	LCD	46	101.58	0.112	$21.94	63.91	0.071	$13.83
Panasonic TC-32LX85	LCD	32	97.79	0.223	$21.99	64.96	0.148	$14.92
LG 32LG40	LCD	32	116.19	0.266	$25.03	67.86	0.155	$14.62
Samsung LN32A450	LCD	32	130.65	0.299	$28.99	68.27	0.156	$15.56
Vizio VO32LF	LCD	32	121.58	0.278	$26.19	69.00	0.158	$14.86
Panasonic TC-L32X1	LCD	32	92.10	0.210	$20.34	70.16	0.160	$15.61
Vizio VOJ370F	LCD	37	145.84	0.249	$31.42	76.64	0.131	$16.51
Sony KDL-32M4000	LCD	32	112.94	0.258	$25.09	78.09	0.178	$17.58

Fig. 1: *An HDTV power-consumption chart compares watts per square inch and other factors for a variety of manufacturers' products in display sizes ranging from 23 to 46 in. Source: CNET.com.*

the light-emitting diodes are not arranged in edge-lit formation similar to those of rival Samsung. But the Sharp sets are considerably thicker than the Samsung sets.

The Insight Media *Green Display Report* (GDR) characterizes edge-lit LED technology in LCDs this way: "In the edge-lit backlight design, separately controlled LEDs illuminate the panel from the top and bottom edges to create 16 zones that can be independently addressed, yielding a 2-D dimming approach. This edge-lit 2-D local-area-dimming LED backlight can reduce power consumption on a 55-in. TV by 35–64% [compared to a cold-cathode fluorescent lamp (CCFL) backlight unit (BLU)], depending upon the type of content. AU Optronics Corp. (AUO) also recently announced a 32-zone edge-lit local-dimming LCD TV."

LG Electronics showed just such a system, with eight zones on the top row and eight zones on the bottom row, using these 16 blocks to achieve the power reduction mentioned above. One other approach, reported by Insight Media publisher and analyst Chris Chinnock, is similar to the 2-D local-dimming strategy that dims color LEDs (R-G-B) individually. This method boosts contrast and expands color – "But do not look to this approach for dramatic power savings," Chinook says.

At the Insight Media Green Display Expo in Washington, D.C., in October of 2009, conference organizer Chinnock reported on a presentation by Bruce Berkoff, chairman of the LCD TV Association: "Berkoff described some of the trends in LCD technology that are helping to reinforce the trend toward lower power consumption. He cited LED backlights as a key driver, as well as local-area dimming and the use of RGBW color-filter architectures.

"Berkoff expanded this discussion of local dimming to describe a concept edge-lit 1-D system that illuminates the panel from top and bottom to create 16 zones that can be independently addressed (really a 2-D dimming approach). This can reduce power consumption of a 55-in. TV by 35–64% (compared with a CCFL BLU), depending upon the type of content. Interestingly, AUO announced a 32-zone edge-lit local-dimming LCD TV at Flat Panel Display International during the same week. Another variation on the 2-D local-dimming approach is to dim the red, green, and blue LEDs individually. Compared with using a white LED, the RGB LEDs improve contrast, expand the color gamut, but do not provide as much power savings."

Light-Guide Technologies

There are, however, new light-guide technologies that allow for direct LED backlighting and thin design. Insight Media covered this approach recently in its *Large-Display Report* (July 9, page 26.) in which analyst Ken Werner noted a "distinguished paper" (No. 48.1) delivered at the 2009 SID Symposium, where James Gourlay of Design LED Products (Livingston, UK; product shown in Fig. 2) and Ian Miller of ITI Techmedia (Glasgow, Scotland) described such a structure in detail.

According to Werner, "The thin device structure, which incorporates side-emitting LEDs distributed in a two-dimensional array across the BLU, is embedded in a multi-layered printed and integrated light guide. Containing 0.6-mm-high LEDs, the substrate/light-guide structure is 1.5 mm thick. A prototype 40-in. design produced a BLU thickness of 15 mm, and the authors believe less than 10 mm is possible. The light-guide structure incorporates micro-structure surface extraction, which provides a controlled beam angle for the extracted light."

Readers may find it interesting to do an Internet search on "Sharp LED light Guide" to see the patent activity around this subject. Clearly, there is something big brewing in this area.

Samsung Popularizes "LED TV"

Are power savings alone enough to get consumers excited about LED backlit units – or paying more for them? In fact, LED-backlit TVs are some of the best selling (and highest priced) LCD TVs available today. Last year, Samsung made a lot of hay (OK, dollars too) over its new "LED TVs" that also captured some of the lowest power-draw numbers in the industry using edge-lit technology.

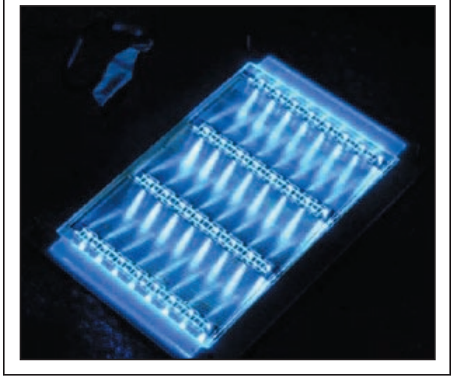

***Fig. 2:** The new Sharp LED-based LCD TVs will sport "direct backlighting," perhaps with the use of a new light guide similar to this one from Design LED Products to improve light uniformity and reduce on-screen hot spots.*

Spurred on by a bold marketing campaign in the spring of 2009, the company launched a line of new, pricy LED TVs with an ultra-thin low-power-consumption message that hit a chord with consumers despite a worldwide pull-back in spending.

While LED illumination for TVs is not new, Samsung made a strategic decision to launch a "new class" of TV it labeled simply "LED TVs," creating confusion at the retail level and drawing the ire of some analysts. But the gutsy recession-bucking plan that included higher-priced LCD TVs paid off in spades as Samsung dominated the high-end premium market with an 83% share of sets costing $3K or more each, up from just 4% a year earlier, according to Pt. Washington, NY, based NPD Group. Samsung sold 500,000 "LED TVs" in the first 100 days after the mid-March launch and reported a fivefold increase in earnings for Q2 over Q1. Some industry analysts attributed up to 80% of that growth to the LCD-TV performance.

Samsung showed that the green message could pay off in the market and that consumers would be willing to pay a premium for the LED-based LCD TVs. But interestingly, it was not the power savings as much as the ultra-cool thinness factor (and perhaps the idea of the "new" LED technology) that made the Samsung panels so popular.

Alternative Technologies

The *Green Display Report* also identifies other display technologies that could lead to reduced power consumption. These include time-multiplexed optical shutter (TMOS), a technology from UniPixel that the company claims significantly reduces complexity in manufacturing. Here is the technology description given in the company's report: "UniPixel's TMOS display technology promises to deliver displays with very low power consumption by combining a linear array of RGB LEDs at the edge of a two-dimensional array of electrically addressed pixels that couple light to the viewer utilizing frustrated internal reflection (FIR). When a polymer film, initially not in contact with the underlying polymer substrate, is deflected downward electrostatically and comes in contact with the illuminated polymer substrate, light is coupled outward from that pixel toward the viewer." On the production side, the company claims it needs just six layers and far fewer manufacturing steps when compared to LCD technology, and the front plane can move to a very efficient roll-to-roll process.

A second, temporal-based technology involves field-sequential-color (FSC) LCDs that, according to the *Green Display Report*, "operate by flashing the red, green, and blue LEDs in a rapid time sequence to create a full-color display. In an FSC LCD, each individual pixel is illuminated with red, green, and blue (RGB) light in sequence to produce a full-color image rather than relying on three individual, spatially separate RGB subpixels. FSC LCDs must be operated at more than three times the frame rate of non-FSC displays because each of the R, G, and B frames must be loaded and flashed in sequence."

This approach would allow display-panel designers to eliminate the light-absorbing color-filter arrays that add cost, thickness, and power consumption to LCDs. Along with other advantages, the FSC-LCD pixels can have larger aperture ratios leading to higher light transmission and lower power consumption.

Other (next-generation) technologies include a Pentile-type approach to pixel arrangement, using a unique RGBW-colored pixel configuration that more closely supports the way the human eye discerns colors.

Conclusion

So, as the state of California drives toward reducing the energy consumed by our most popular displays, LCD-TV makers will respond in kind. But the truth is the industry is marching in that direction – government mandate or not. Samsung proved earlier this year that low-power (sexy, thin) displays could sell for a premium and enrich the company coffers by taking bold moves in that direction. Sharp responded with its brand of direct-backlit displays using light-guide technology that blew away the low-power numbers of even the most efficient sets previously on the market. And as we continue the move toward next-generation displays, the industry will continue to re-invent itself with units that use fewer components and provide greater efficiency. ■

What's Next for e-Readers?

E-readers are not yet commodity items, although they are selling briskly. This year's unit sales are predicted to be twice those of last year. And, in many ways, e-book technology is still in its early stages. E-book file compatibility is still being sorted out, and future versions of e-readers will offer many features not widely seen today, including color displays, video capability, ruggedness, and flexibility.

by Jenny Donelan

NO SOONER does a super-cool device find success in the marketplace than people – both those that do the buying and those that do the manufacturing – want it to be even cooler. A case in point is the e-reader, such as Amazon's Kindle or Sony's Reader. These devices are great to look at, both in terms of physical design and their easy-on-the-eye text display. They allow a person to carry more than a year's worth (as in hundreds of titles) of best-sellers, mind-enriching classical literature, or both, in a briefcase or purse. They operate for a long, long time (more than a week) on a single charge. Last, for many people at least, they have that indefinable "gotta have it" quality. During the 2009 holiday season, e-readers seem to have helped numerous individuals solve the perennial problem of what to buy for that certain someone. Amazon, which steadfastly refuses to divulge sales figures, including number of units sold, did claim that last season, Kindle became its top-selling gift of any kind, ever. On Christmas Day 2009, presumably as a result of all the Kindles found under the tree, Amazon sold more electronic books than physical ones for the first time in its history.[1]

The e-Reader Market

According to market-research-firm iSuppli, unit sales for e-readers should top 10 million by the end of 2010 and reach over 20 million by 2013 (see Fig. 1). Of those particular e-readers, it is hard to say which brands hold sway.

Even though one has to guess at Amazon's figures, it is widely presumed to be the market leader. In 2008, iSuppli estimated that Amazon held 40% of market share, Sony 35%, and the remainder 25% (Fig. 2).

iSuppli does not have 2009 statistics, but it may be safe to assume that the shares did not change drastically from 2008. Says Vinita Jakhanwal, principal analyst with iSuppli, "I think that market share in 2009 would have favored Amazon and increased their share slightly." She added that the "Others" portion of Fig. 2 may also have increased, as various Asian companies in the e-reader space did well last year.

Anatomy of an e-Reader

There are a number of e-reader technologies on the market, but the most widespread probably involves electrophoretic imaging film combined with an LCD backplane. Devices

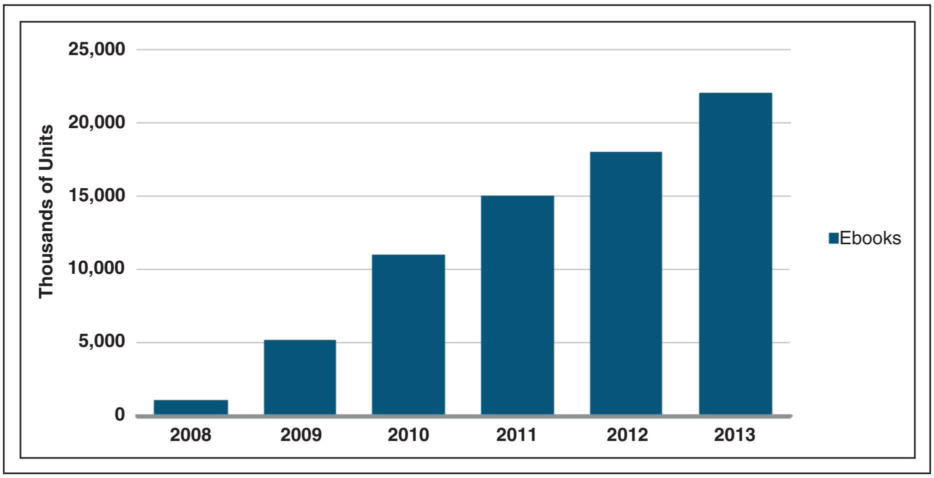

Fig. 1: *Between 2009 and 2010, unit sales for e-readers of all kinds are predicted to more than double, from slightly more than 5 million to about 11 million units. Source: iSuppli Corp.*

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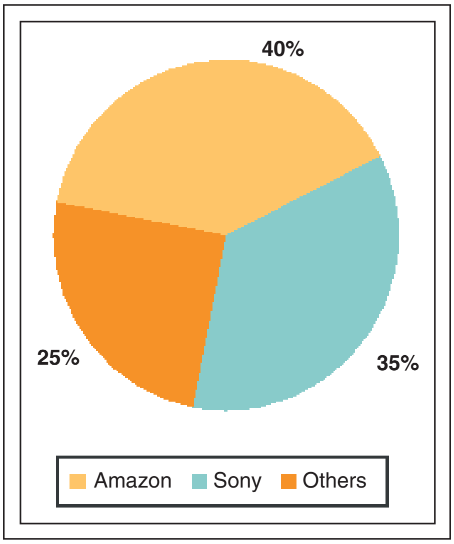

Fig. 2: iSuppli estimates that Amazon held a 40% market lead in 2008. Source: iSuppli Corp.

from Amazon, Sony, Barnes & Noble, and many others rely on the above electronic-ink technology from E Ink Corp., the Massachusetts-based company that was bought by Prime View International (PVI) late last year. For more about what PVI is up to, see this issue's Industry News article, "Prime View International, HYDIS Technologies, and LG Display Announce Comprehensive Cooperation Agreement."

E Ink's technology consists of millions of tiny microcapsules, each containing positively charged white particles and negatively charged black particles suspended in a clear fluid. According to E Ink's literature[2]: "When a negative electric field is applied, the white particles move to the top of the microcapsule where they become visible to the user. This makes the surface appear white at that spot. At the same time, an opposite electric field pulls the black particles to the bottom of the microcapsules where they are hidden. By reversing this process, the black particles appear at the top of the capsule, which now makes the surface appear dark at that spot." The electronic ink is incorporated into a sheet of film that is attached to a thin-film-transistor (TFT) backplane or other surface.

The resulting device produces a display that is often described as "paper-like." While "the reading experience" is not quantifiable, it is generally understood that for the average person, e-paper offers a more agreeable long-term reading experience than does, for example, a backlit LCD. E-paper can also be read outside, even in bright sunlight. Of course, such displays cannot be read in darkness without an external light source, any more than can paper itself. Sony's PRS 700BC e-reader came out in 2008 with a frontlighting option that met with mixed reviews online, and there has been on-and-off talk of some kind of built-in illumination for e-readers. But today, if you want to read your e-book in the dark, generally you employ a miniature book light, just as you would with a physical book.

Features on the Horizon

At present, users and manufacturers are focused mostly on the following features for e-readers: color, video capability, flexibility, ruggedness, size, file format, and price. Some of the above capabilities – color and especially price – will likely be the factors that convince the next round of customers who are not quite ready to buy yet.

Color

Of all the desirable new features for e-books, color is probably top of list. The first E-Ink-based color products, manufactured by the Beijing-based Hanvon (Hanwang) Technology, should go into production by the end of 2010, according to Sri Peruvemba, Vice President of Marketing for E Ink. These devices will not use colored electronic ink, but will employ RGBW filters over the monochrome display. A prototype device using E Ink's color technology appears in Fig. 3.

A color device already on the market is the Fujitsu FLEPia, which began selling in Japan last year at prices in the $1000-and-up range. The FLEPia uses cholesteric-LCD technology (not electronic-ink technology) and runs Windows CE, so it is also Web and e-mail capable.

Qualcomm has shown prototypes of a color e-reader based on its reflective mirasol® technology (already in use for mobile devices). Release dates for such a device are uncertain, but a 2010/2011 time frame is likely. And there are additional color technologies under development. Generally speaking, e-reader color to date is of the subdued, muted variety – not brilliant as, for example, an OLED display. So it's safe to assume that most companies, even those that already have color, are searching for the ultimate solution to the best-looking low-power readable, color display. It is an evolution. Consider the case of smartphones and PDAs, notes Peruvemba. "They all started monochrome, then went to color."

Video

E-paper technology is generally not fast enough to handle video yet. This is an edge that a MEMS-based e-reader would presumably have because that technology can display video. Some manufacturers have tackled the issue by creating dual-mode devices, combining an e-paper display for reading with an LCD for Web browsing, video watching, *etc.* One such device is the eDGe reader from Entourage Systems, which opens like a book to reveal an e-paper display on the left and an LCD on the right, as shown in Fig. 4.

E-Ink-based video displays are at least 2 years out, says Peruvemba, adding that it is already possible to do a certain amount of pop-up-type animation with the technology.

Size, Flexibility, and Ruggedness

Among the many e-readers on display at CES in January 2010, two in particular caught people's attention. Both Plastic Logic's QUEproReader (see "Flexible Displays Made with Plastic Electronics" in this issue) and the Skiff announced by Hearst feature displays that are first of all, large, and, second, flexible. The 8.5 × 11-in. QUE uses E Ink technology atop a plastic substrate, and the Skiff

Fig. 3: E Ink Vizplex color displays will employ an RGBW color filter. Image courtesy E Ink.

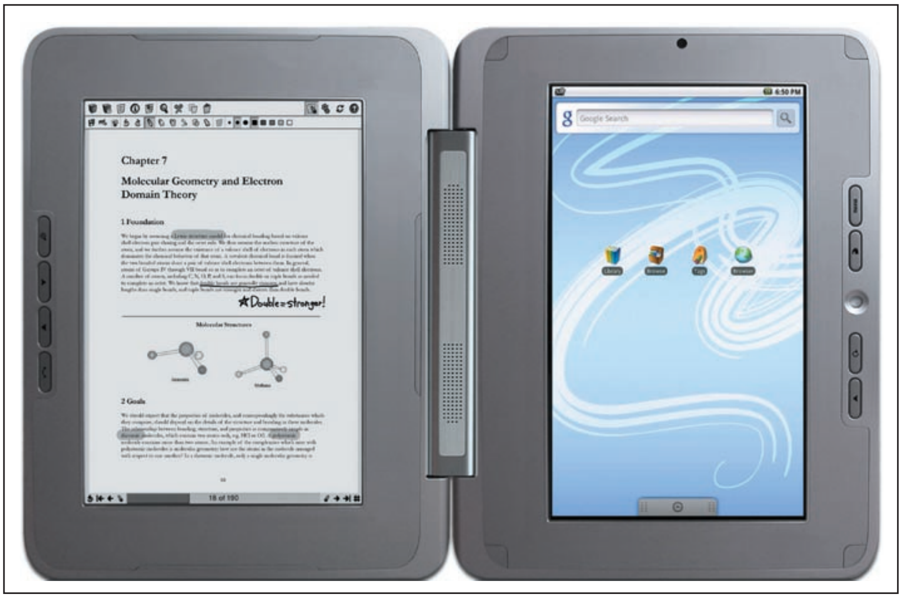

Fig. 4: The eDGe reader, which maker Entourage Systems calls a "dualbook," features a 9.7-in. E-Ink-based screen on the left and a 10.1-in. LCD touch screen on the right. Users can call up a virtual keyboard for typing. It weighs about 3 pounds and is scheduled to ship in March 2010 at a cost of $490. Image courtesy Entourage Systems.

is also large (final size to be announced) and is made with E Ink's Vizplex film on flexible stainless steel. However, as this issue's guest editor Rob Zehner remarks in his guest editorial note, "A New Breed of Display Starts to Flex Its Muscles," both the QUE and Skiff technology may be flexible, but the form in which you will purchase it is not; both displays are enclosed in a rigid housing. There are still advantages to such flexibility: ruggedness (steel and plastic are presumably less susceptible to breakage than glass) and lack of weight. "Once you get to tablet size," says Peruvemba, "weight becomes an issue and flexible displays weigh less than glass." And big just keeps getting bigger. On January 14, LG announced a 19-in. digital ink-on-steel prototype that is clearly aimed at the newspaper industry.

File-Compatibility Issues

File compatibility is not a display problem per se, yet the way this issue plays out will have some effect on display makers. According to a recent article in *The Christian Science Monitor*,[3] there are more than 10 existing e-book formats. Amazon has a proprietary format for its e-books, although the Kindle can also read plain text, Microsoft Word documents, and Adobe Portable Document Format (PDF) files. Sony's Reader cannot read Amazon titles; it uses the ePub format, which at this writing seems to be gaining popular momentum. Sony announced a move to ePub in August 2009, and several other readers, including the Barnes & Noble Nook and devices from iRex Technologies, can also read the ePub format. Both Google and Project Gutenberg (www.projectgutenberg.org) offer free ePub titles, books whose copyrights have expired. The number of books available from Gutenberg alone is 30,000. As you might expect, the Kindle cannot read the ePub format. A voracious reader is likely to want to choose from the titles available from all of these catalogs, and at this writing, there is no "one device reads all."

Price

It is not necessary to consult a market analyst or a product manager to know that price plays a big part in e-reader adoption. Just ask your neighbor. Many people are waiting for prices to drop to within their comfort level. However, notes Peruvemba, deep discounting is not the whole future. "Price is going in both directions. E-newspaper and e-textbook devices are priced higher, whereas the entry-level e-books are priced lower. "Certainly this seems to be true in the case of the recently announced Kindle DX, which is $489, and the QUE, which ranges from $649 to $799.

As for the low end, how low is low? Right now, the basic 6-in.-diagonal-screen Kindle is $259. Will the magic figure that causes vast numbers of people to click "Order now" on their computer screens be $239, $219, $199, or less? Display makers may find the latest e-reader data from Forrester Research discouraging. As reported by Forrester analyst Sarah Rotman Epps in her September 2, 2009, blog,[4] the price at which most consumers surveyed would consider an e-reader expensive but still purchase it is in the $50–98 range. So, it would look as if the e-reader will only find full absorption when it becomes priced as a commodity – or maybe not. It was not too many years ago that the average parent would have considered a music device considerably smaller than a pack of playing cards and costing $150 or more to be an outrageous extravagance for a teenager. Now, iPods are near-regulation equipment for U.S. teens and are often replaced annually, regardless of need.

In any case, all of the above advances, and some of them in conjunction with price, will eventually cause many people to reach their personal tipping point when it comes to paying for an e-reader. Some may buy because they really want color or because they want to watch videos as well as read. Others will be enticed by a larger screen or the prospect of a really rugged device that can stand up to a lot of mishandling. Confidence in the long-term viability of e-book formats will compel others. Last, there is the factor of time. There are those – call them the late adopters – who simply prefer to wait until a new technology becomes less new before they open their wallets.

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Patent Licensing in the Display Industry: A Primer

Especially in the fast-changing environment of display technology, companies should know the facts when it comes to intellectual property. What is IP, whose is it, and how can it be protected? Although the legal language can be daunting, this is vital information for anyone doing business in the display arena. Information Display *will be offering articles throughout the next several months from several intellectual property experts. This is the first article in a series of four from law firm McKenna Long & Aldrige, written to provide an overview of patent licensing for the perspective of information-display managers.*

by Song Jung and Adrian Mollo

THE DISPLAY INDUSTRY is a good model for a discussion of patent license agreements. First, the industry has multiple categories of companies, each with different, and often divergent, business interests. As discussed below, those interests may vary for a number of reasons, including both business concerns (*e.g.*, the natural disinclination to enforce patents against potential customers) and legal issues (*e.g.*, the fact that the new patent exhaustion doctrine limits the ability of a patent owner to implement a multi-tiered licensing program).

Further, the electronics and display industries are very competitive. Consider a 2005 survey published by the Licensing Executive Society (USA & Canada), which reported that the "digital information communications and electronics" industry group, more so than any of the other industry groups surveyed, responded that improving their patent bargaining position and managing litigation risk are key motivations for developing IP assets.[1] The LES survey also confirmed that the communications and electronics industries have an above-average number of in-bound and out-bound license agreements, *id.* at p. 150 (Exhibit 4), confirming the prevalence of licensing activity in the electronics industry.

Later articles in this series will address issues arising in the negotiation and drafting of patent licenses (*e.g.*, types of license grants and covenants not to sue), recent legal developments of note to the licensing executive (in areas including antitrust law, patent exhaustion, and patent enforcement), and a checklist of issues to consider when preparing to negotiate and draft patent licenses and related agreements. This first article, however, is intended to provide an introduction to the forms of intellectual property, an understanding of why businesses license, and a discussion of licensing considerations in the display industry.

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Forms of Intellectual Property

The most common forms of intellectual property are listed in Chart 1.

The intellectual property laws, generally speaking, provide the owner the right to prevent unauthorized use of the intellectual property. Unauthorized use of a patent, copyright, or trademark is generally referred to as infringement of the intellectual property. Obtaining or using a trade secret without permission is referred to as misappropriation of the trade secret.

It is common for a license to address two or more forms of intellectual property. For example, a license agreement might license the right to practice a particular group of patents, license a trademark under which the goods will be distributed, and license the copyright to a software program needed to operate the product. Although this series of articles focuses on patent license agreements, it is important to remember that patent rights may sometimes present the best value when coupled with other forms of intellectual property or assets.

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Furthermore, although this article focuses on U.S. law, licensing in the display industry is, by its nature, an international effort. As such, the practice requires careful consideration of the law of the U.S. states (whose law governs the interpretation and enforcement of contracts), one or more nations (depending on the domicile of the parties and the place for performance of the agreement), and international treaties.

Why Do Companies License?

More important than "what" is being licensed, of course, is the question of "why." As noted above, the unauthorized use of a patented invention constitutes infringement of the patent, which triggers a number of potential remedies under the Patent Act, ranging from a reasonable royalty (the minimum recovery afforded a patent owner, *see* 35 U.S.C. § 284) to a permanent injunction and an award of lost profits and attorneys' fees.

A license, in turn, is the right to do something that, but for that grant, would constitute infringement. In other words, the patent owner may elect to barter away the exclusive right as against a certain party in return for some negotiated compensation. That compensation can take various forms, including a monetary payment (lump sum or a running royalty), a return grant of rights under the licensee's patents (a cross-license agreement), or some other type of non-monetary consideration (*e.g.*, shareholdings in a joint venture).

The strategy underlying how to value a license is complex. Considerations include the relevance of the patented invention to the licensee's business activity, the availability of non-infringing alternatives, the relationship between the licensor and licensee, the length of the proposed license, and the breadth of the licensed rights, whether the license may benefit the licensee's affiliates, the scope of any grant-back rights, the licensee's profitability and ability to pay, the relevance of the licensee's own intellectual property, and whether the licensor may provide additional rights (*e.g.*, know-how pertaining to use of the patented invention).

A patent license, therefore, is much more than a negative right. It is a tool for accomplishing larger business objectives, whether securing relationships with suppliers, extracting a fee from competitors, or creating new alliances and ventures.

Chart 1: Common forms of intellectual property

Type of IP	Nature of Right[2]
Patents	Patents protect the owner's rights in a novel process or product, by allowing the patent owner to prevent others from practicing the claims of the patent.
Copyright	Copyright law allows the owner to control the reproduction, use, or transformation of an original literary (including software), dramatic, musical, or artistic work.
Trademark	Trademark law protects symbols, designs, words, colors, or sounds that represent a particular brand or source of goods, by allowing the owner to prevent others from engaging in confusing or misleading use of the same or similar marks.
Trade Secret[3]	Trade secret law addresses the misappropriation or wrongful acquisition of trade secrets (which may include confidential manufacturing "know-how")

Licensing in the Display Industry

Some businesses develop technologies, others use them to make products, and yet more assemble and sell finished goods to end-users. The concerns and objectives of a party vary, depending on the party's place in the system.

For perspective, consider Chart 2, which attempts to categorize members of the display industry and characterize each category's likelihood to grant or take patent licenses (also referred to as either in-licensing or out-licensing patents).

Chart 2: Comparison of licensors and licensees as categories of industry members.

Categories of Industry Members	Licensor	Licensee
Universities	Yes	Less likely to take licenses, except for R&D purposes
Tech. Developers	Yes	Less likely to take licenses, except for R&D or JV purposes
Component Mfrs.	Yes, often to competitors	Yes
Chemical Cos.	Less commonly a licensor	Less commonly a licensee
icEquipment Mfrs.	Yes, often to competitors	Yes
Display Mfrs.	Yes, horizontally to competitors and occasionally to upstream component manufacturers	Yes, commonly from competitors and non-practicing entities (*e.g.,* universities, tech. developers, and other non-practicing entities ("NPEs"))
OEMs	Less commonly a licensor	Occasionally a licensee
"Brands"	Traditionally less likely to grant IP licenses	Less likely, due to patent exhaustion, indemnity, and other limitations on a brand's direct liability for patent infringement
NPEs	Yes	No
Patent Pools	Yes	Yes, a patent pool license agreement commonly contains grant-back licenses, often for the benefit of both pool members and other licensees

The foregoing chart may be divided into three general categories of licenses: (a) upstream and downstream licenses, (b) licenses by and between competitors, and (c) licenses by non-practicing entities.

(a) Upstream and Downstream Licenses

The first category includes licenses within the value chain for a product, either upstream (*e.g.*, a display manufacturer to a component manufacturer), or downstream (*e.g.*, a component manufacturer to a display manufacturer). The nature of such licenses is significantly influenced by the business relationship between the licensor and licensee and related constraints.

Downstream licenses are uncommon for at least two reasons. First, a component manufacturer will naturally wish to avoid adversity with its potential customers. Second, sales of patented components to downstream customers likely "exhaust" the manufacturer's patent rights in the component, obviating the need by any downstream user for a license to use those components.

Upstream licenses are also uncommon, although they are seen more frequently than downstream licenses. On one hand, the upstream license presents a revenue generation opportunity without the direct threat of alienating existing or potential customers.

On the other hand, if the asserted patent claims apply equally to both upstream commercial activity (perhaps by a component manufacturer, a chemical company, or an equipment manufacturer) and activity by the patent owner's competitor, the patent owner may opt for horizontal enforcement of the patent, rather than an upstream license.

Why? First, any upstream patent licenses pose the threat of inadvertently exhausting patent rights against downstream use by competitors, particularly following the U.S. Supreme Court's 2008 decision in Quanta Computer Corp. *vs.* LG Electronics, Inc. (as discussed more fully in a later article). Second, a horizontal license may result in additional non-monetary benefits, such as a cross-license to a competitor's own patent portfolio. Third, if the patent owner is entitled to calculate royalties due based on the value of the downstream combination rather than the value of the upstream component or chemical, the horizontal license may be far more lucrative than an upstream license.[2]

(b) Licenses to Competitors

The second category of licenses involves those between competitors.

Why, some may ask, would the patent owner forfeit the right to exclude others from practicing the invention, particularly competitors? In some instances, admittedly, it doesn't make sense. Consider Coca-Cola, which zealously protects the trade secret rights to its formula. Likewise, pharmaceutical companies understandably investigate all available means to extend the duration of their patent monopolies over valuable medications and drugs. The right to exclude others and protect a valuable formula or design is a powerful tool.

On the other hand, the potential benefits of out-licensing patent rights often outweigh the value of excluding others from competition. For example, licensing new display technologies, on fair and reasonable terms, might not only disincentivize competitors from designing around your invention, but could help establish an industry standard.

Likewise, patent licenses can be used to manage and resolve threats from others, reduce the cost to acquire or design around new technologies, and acquire rights for both the licensing party and its affiliates and subsidiaries, thereby creating efficiencies for a family of companies. Further, presuming the owner and its licensee have roughly equivalent materials, manufacturing, and labor costs, the license fee adds an incremental cost to the competitor's operations.

(c) Licenses by Non-Practicing Entities

The third category of licenses encompasses those made by non-practicing entities (NPEs).

An NPE is a company that does not itself commercially use the claimed invention. Examples may include technology development companies, universities, and "patent trolls." "Patent trolls," in particular, have received the ire of industry and have been described as " . . . patent licensing firms that often end up taking legal action . . . [and] seldom ever create any inventions worthy of patents themselves."[3] Licensing programs by NPEs are noteworthy because they are not subject to the business constraints imposed on conventional licenses, whether upstream, downstream, or among competitors (*e.g.*, concerns regarding alienating a customer base, licensing a component manufacturer that may supply a competitor, *etc.*).

Conclusion

For a variety of reasons, most licensing activity in the display industry appears to be agreements or conflicts between competitors or out-bound licenses by non-practicing entities, such as technology companies and universities. This pattern is influenced by the underlying business relationships between the entities (such as the nature of a company's business and its customers) but also by strategic legal considerations. The remaining articles in this series will touch on those legal considerations, such as the differences between types of license grants, the interplay of standard-setting organizations and the antitrust laws, and the patent exhaustion doctrine. The series will conclude with a checklist of issues to consider when preparing to negotiate and draft patent licenses and related agreements.

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[1]R. Razgaitis, "U.S. Canadian Licensing in 2004: Survey Results," les Nouvelles, December 2005, p.152 (Exhibit 7).

[2]The U.S. Patent Act can be found at Title 35 of the U.S. Code, the Copyright Act at Title 17 of the U.S. Code, and the Lanham Act (the U.S. trademark statute) at Title 15 of the U.S. Code. Trade secret law, in turn, is governed by state law. Approximately 46 of the U.S. states have adopted a form of the Uniform Trade Secrets Act ("UTSA"), thereby providing a measure of uniformity in trade secret law. There are also numerous international treaties that touch on each area of patent, copyright, trademark, and trade secret law.

[3]The UTSA defines a "trade secret" as including any formula, pattern, compilation, program, device, method, technique, or process, that (i) derives independent economic value, actual or potential, from not being generally known to, and not being readily ascertainable by proper means by, other persons who can obtain economic value from its disclosure or use and (ii) is the subject of efforts that are reasonable under the circumstances to maintain its secrecy.

[4]Whether the patent owner will be able to recover patent damages based on the value of the downstream combination (for example, a laptop computer), rather than the value of the patented component (for example, a microprocessor), will turn on application of the "entire market value rule." Typically, a patent owner is limited to a recovery based on the value of

the patented component. If, however, the patentee shows that the patented component is the source of demand for the downstream combination, the patent owner may seek damages based on the entire value of the downstream combination, including the value of any accompanying unpatented components. *See*, *e.g.*, Rite-Hite Corp. v. Kelley Co., Inc., 56 F.3d 1538 (Fed. Cir. 1995).

[5]Investors Business Daily (May 29, 2008). ■

continued from page 2

world. In the article "Flexible Displays Made with Plastic Electronics" by Seamus Burns, the Plastic Logic technology for making flexible e-readers is described and we get a good view into the workings of the QUEproReader that was just shown at CES 2010. In addition to flexibility, this device uses organic TFTs from a proprietary process developed by Plastic Logic.

Back in the June 2005 issue of *ID*, we published articles written by Peter Smith and Prof. Gregory Crawford discussing numerous issues and opportunities in both the materials for flexible substrates and the technologies under research for TFTs. It's really exciting to look back now from where have come to see how much innovation has occurred and how fast it has happened. There is not enough space here to describe it all, but for energetic readers, it's a fun exercise and all back issues through 2005 are available on our website at www.informationdisplay.org.

Of course, in order for all this technology to get utilized, it needs a killer application and I think it could be argued that e-readers are certainly coming close to being one of those. This month our managing editor Jenny Donelan surveys the product space for eBook readers and discusses market growth along with upcoming product enhancements such as color, video capability, and of course, flexibility. This, along with the entrenched applications such as HDTV and mobile devices in a number of configurations makes it clear to me the people working in the flexible and low-power space will have no shortage of customers in the coming years. ■

president's corner

continued from page 6

680 abstracts submitted, based on the review of industry experts to ensure that SID papers meet our high-quality standards. In the program, we will have three days of papers on 3-D technology, as well as featured sessions on touch technologies, solid-state lighting, and green manufacturing – over 20 sessions in all, plus posters, just on these hot topics.

Keep an eye on the SID 2010 Web site, http://www.sid2010.org. There, you can learn about the mix of seminars and business conferences, the SID exhibition, our special event, and the symposium as the details become finalized. We have several additional surprises in store, so stay tuned! ■

Journal of the Society for Information Display

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The 2010 award winner will be selected in December 2010 by the JSID Awards Committee. It will be awarded to a published paper on the basis of: originality, significance of results, organization and clarity. ***The award consists of a plague and a $2000 US Dollar prize***, to be shared among all the student authors of the paper selected. It will be presented to the winner(s) at one of the international conferences sponsored by the Society for Information Display. All manuscripts published in JSID during 2010, for which the ***first author is a student***, are eligible. The plaque and prize is given to the student author(s) only. Manuscripts are to be submitted to the Editor, Journal of the Society for Information Display. The Journal publishes all manuscripts in full color. Detailed instructions for the submission of manuscripts may be found at www.sid.org, or authors may contact the Editor for additional information by sending e-mail to editor@sid.org.

Display Week 2010 to Feature New Special Topics of Interest

In order to address the recent rapid growth in certain areas of information display, the Society for Information Display has added four new tracks of special topics of interest to the upcoming Symposium at Display Week 2010. These topics include touch technology, 3-D, solid-state lighting, and green technology.

3-D: The momentum for home 3-D has been building recently as more and more TV manufacturers announce new 3-D products. This year's technical program will be emphasizing the different developments and approaches that are leading the way toward 3-D entertainment in the home and includes 48 papers on 3-D technology. Among this year's topics will be polarization-based stereoscopic displays, crosstalk in stereoscopic displays, autostereoscopic displays, autostereoscopic display measurements, 2-D/3-D switching for stereoscopic displays, human factors of 3-D displays, volumetric and integral imaging, 3-D TV and 3-D video, and novel 3-D displays.

Solid-State Lighting: Solid-state lighting, with its promise of saving energy and providing design flexibility, has been continually gaining acceptance over conventional lighting. It is already well-established in areas such as backlights for displays, digital signage, and small specialty lighting applications and is expanding into mainstream markets including home, office, and street lighting; automobile headlamps; and other applications. The 2010 SID technical program will be highlighting the different developments and approaches that are leading the way toward further expansion of the role of LEDs and also OLEDs in solid-state lighting. Four sessions on lighting technology and one session on human factors, incorporating 22 papers in all, are scheduled for presentation.

Touch Technology: Display Week organizers added this area based on the record-breaking number of exhibitors (54) who displayed touch screens, touch controllers, or touch-related products and services at Display Week 2009, and the record-breaking number of touch-related papers (16) presented at last year's Symposium – surpassed this year with 19 presentations. Among the topics that will be addressed in this year's technical sessions are touch-technology development, multi-touch systems and developments, and display-embedded touch solutions.

Green Technology: Due to both government regulations and public opinion, energy efficiency, eco-friendly materials, and recyclability have become key issues in display development. Accordingly, six sessions on different aspects of green technology totaling 22 papers will be presented as part of the 2010 technical program. Sessions include low-power e-paper and other bistable displays, novel power-reduction techniques, power-saving device designs, smart grid and power recycling, and green technologies in active-matrix devices and display manufacturing.

With these new topics of interest, plus a wealth of papers on numerous other areas that are key to the display industry, this year's Symposium will be a vital source of information for anyone in or interested in the display industry. To find out more, visit www.sid.org/conf/sid2010/sid2010.html. ■

Official SID Housing Request Form: Display Week

Seattle, Washington May 23 - 28, 2010

The official housing closing date is April 23rd, 2010. If you have not made reservations by this date, contact Globetrotter Travel, and every effort will be made to secure accommodations for you.

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SID HOUSING GUIDELINES

In order to keep facility fees down, the Society for Information Display arranges contracts that combine rental of convention facilities and guarantee of a certain number of hotel room-nights at convention hotels. SID Symposium participants can help keep registration fees down this year and in the future by registering and staying in hotels listed in the SID registration information. Nevertheless, in response to the current economic situation, SID has relaxed its deadlines for hotel reservations to provide its attendees flexibility in scheduling their participation.

IMPORTANT DATES

April 23, 2010 - Name receipt deadline	Globetrotter must have received the names of the occupants for each room reservation. Name changes are permitted, without charge up to the date of check in. Room reservations without named occupants will be cancelled.
April 30, 2010 - First night guarantee deadline	Up to this deadline, reservations may be cancelled without penalty. Reservations still in force on this date will be charged a one night, non-refundable deposit of room rate plus tax.
72 hour - Full reservation guarantee deadline	For any cancellations or date changes made within 72 hours of the checkin date, a full charge for all reserved room nights plus tax will be applied. The one-night deposit previously charged will be credited against this charge.

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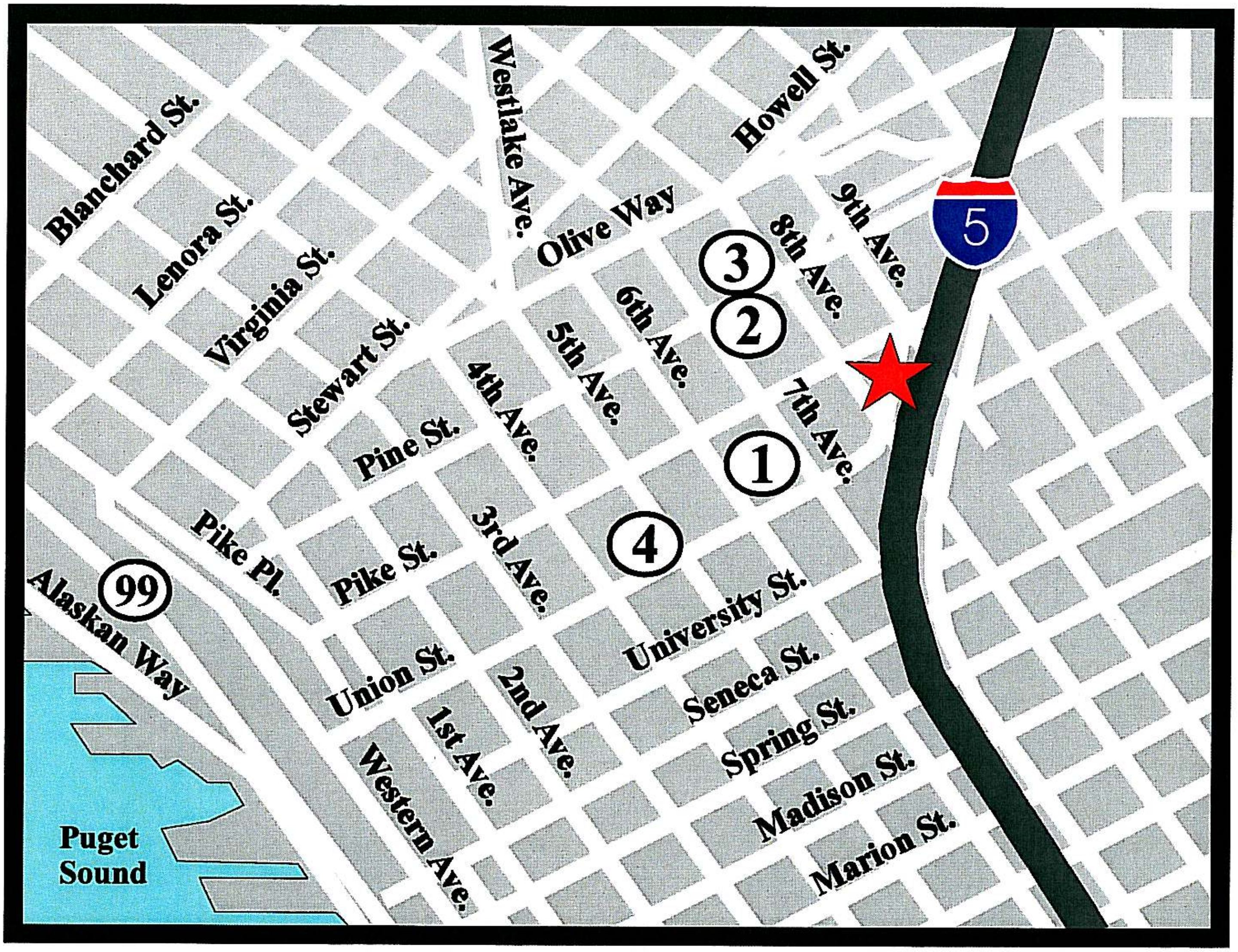
Society for Information Display 2010 Seattle Hotel Map



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PROFESSIONAL INFORMATION

1. Are you professionally involved with information displays, display manufacturing equipment/materials, or display applications?

110 ☐ Yes 111 ☐ No

2. What is your principal job function? (check one)

210 ☐ General /Corporate /Financial
211 ☐ Design, Development Engineering
212 ☐ Engineering Systems (Evaluation, OC, Stds.)
213 ☐ Basic Research
214 ☐ Manufacturing /Production
215 ☐ Purchasing /Procurement
216 ☐ Marketing /Sales
217 ☐ Advertising /Public Relations
218 ☐ Consulting
219 ☐ College or University Education
220 ☐ Other *(please be specific)*

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3. What is the organization's primary end product or service? (check one)

310 ☐ Cathode-ray Tubes
311 ☐ Electroluminescent Displays
312 ☐ Field-emission Displays
313 ☐ Liquid-crystal Displays & Modules
314 ☐ Plasma Display Panels
315 ☐ Displays (Other)
316 ☐ Display Components, Hardware, Subassemblies
317 ☐ Display Manufacturing Equipment, Materials, Services
318 ☐ Printing/Reproduction/ Facsimile Equipment
319 ☐ Color Services/Systems
320 ☐ Communications Systems / Equipment
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327 ☐ Medical Imaging/Electronic Equipment
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329 ☐ Navigation & Guidance Equipment/Systems
330 ☐ Oceanography & Support Equipment
331 ☐ Office & Business Machines
332 ☐ Television Systems/Broadcast Equipment
333 ☐ Television Receivers, Consumer Electronics, Appliances
334 ☐ Test, Measurement, & Instrumentation Equipment
335 ☐ Transportation, Commercial Signage
336 ☐ Other *(please be specific)*

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4. What is your purchasing influence?

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5. What is your highest degree?

510 ☐ A.A., A.S., or equivalent
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513 ☐ Ph.D. or equivalent

6. What is the subject area of your highest degree?

610 ☐ Electrical/Electronics Engineering
611 ☐ Engineering, other
612 ☐ Computer/Information Science
613 ☐ Chemistry
614 ☐ Materials Science
615 ☐ Physics
616 ☐ Management/Marketing
617 ☐ Other *(please be specific)*

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7. Please check the publications that you receive personally addressed to you by mail (check all that apply):

710 ☐ *EE Times*
711 ☐ *Electronic Design News*
712 ☐ *Solid State Technology*
713 ☐ *Laser Focus World*
714 ☐ *IEEE Spectrum*

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