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COVER: *It is pretty apparent why the attendance at Display Week 2010 was much higher than last year: the location was ideal, there was no worldwide outbreak of the H1N1 flu, and the economy had picked up. Above all, the strength of the technology at Display Week, both at the technical symposium and on the exhibit show floor, played a dominant role. The headline of a Seattle Times article on the show read: "The Future of Displays Is Here."*

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LCD Issue

- An LCD-TV Powered by a Battery
- New Embedded Functions
- Polarizer Glasses for 3-D Displays
- Improvements in TFT-LCD Performance
- How to Get a Patent Quickly
- *Journal of the SID* September and October Contents

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No-Shows at the Big Show – OLED TVs and Me

Stephen Atwood

Welcome to the July/August issue of *Information Display* and our reviews of SID's Display Week 2010 Symposium and Exhibition. Of all the headlines that came out of the show, one of the most puzzling concerned what people did not see in Seattle in 2010. Many people, including me, expected that after a strong showing at Display Week 2009, and a further strong showing at the Consumer Electronics Show (CES) in January 2010, OLED-TV prototypes would be everywhere at Display Week 2010. This anticipation was in no way dampened by the widely anticipated keynote speech by Dr. Sang-Soo Kim, Executive VP, Samsung Fellow and SID Fellow, Samsung Mobile Display, who painted a very enthusiastic picture for the future of OLED-TV products. His talk, entitled "The Next Big Thing in Displays," described OLEDs as "the next growth driver in the television market."

And yet, I'm told that on the entire exhibit floor there was only a single OLED TV to be seen. I say "I'm told" because sadly I was also a no-show this year. For the first time in over 20 years of attending these events, my business demands took me away at virtually the last minute. I was literally at the airport when I had to re-route myself. But in the case of the companies heavily involved in OLED-TV, I can't imagine this was a last-minute decision. It is a lot more likely that this was part of a strategy to manage the roll-out of this new technology at the right time and under the right economic conditions. There is also much to be done to build out manufacturing infrastructure and establish a level of product performance and maturity that can truly rival the current status of LCD TVs. Certainly, there is no shortage of investment, as analyst Paul Semenza explains in his article this month entitled "Can OLED Displays Make the Move from the Mobile Phone to the TV?" Paul explains that in April of this year, LG announced investments of US$226 million to triple its OLED capacity and in May, Samsung Mobile Display announced that it will invest more than US$2 billion to establish a Gen 5.5 AMOLED line with an ultimate capacity of 70,000 panels per month. These are the moves of major manufacturers serious about the technology and ramping up for big things, just as we saw in the early days of the LCD-TV ramp-up. Part of the added complexity in this case will certainly be product pricing. If it is true that high-volume OLED TVs can be eventually manufactured and sold for less money than LCD TVs, then concern must certainly exist for the erosion of one's own revenue stream and margins – which in turn are paying back the gigantic investments in LCD production capacity already in place. Worldwide competition will no doubt make the eventual side-by-side competition of both technologies inevitable, but I would not blame anyone for wanting to move cautiously and think through all the marketing and product strategies before launching the full arsenal of potential offerings.

Meanwhile, there were plenty of other things at Display Week to see and talk about, including a record 67 exhibitors showing some form of touch-screen technology. Yes, that's right, as author Geoff Walker writes in his Display Week review article on this topic, "There was probably more touch technology at Display Week 2010 than at any other conference worldwide in the last year." And while most of the innovations were more evolutionary than revolutionary in nature, it is really exciting to see how much this segment of the industry has grown. The supply chain for materials and manufac-

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industry news

NEC to Renesas: What's In a Name?

In April 2010, the company formerly known as NEC Electronics Corp. became Renesas Electronics Corp. When a firm with a recognizable name such as NEC changes it, people want to know why. The answer, according to Omid Milani, Director, Display Business Unit, Renesas Electronics America, Inc., is that a merger took place in order to maximize the synergies and business of two large, global semiconductor companies (NEC Electronics and Renesas Technology) and create a leading worldwide microcontroller company. Up until now, NEC Electronics Corp. has sold semiconductors and displays, whereas Renesas Technology has sold only semiconductors. The new entity in the Americas, Renesas Electronics Corp., will sell all those products.

But why Renesas as opposed to NEC? Company officials would not explain exactly why not NEC, but they did say that they had already spent considerable time and effort in branding the Renesas name with regard to microcontrollers. They believe that it is in the best interests of the new entity to continue in that vein in order to underscore the microcontroller emphasis.

As part of the merger, Renesas Electronics America, Inc., now a wholly owned subsidiary of the above-mentioned Renesas Electronics Corp., has been formed through the integration of NEC Electronics America, Inc., and Renesas Technology America. This change has been a point of interest for U.S. vendors who buy NEC's display products, many of which are specialized for the medical and industrial markets. Because NEC Electronics America was the sole supplier of NEC LCD Technologies displays in the Americas, a possible cause for concern was that the change in name might signal other changes. Not so, says Milani: "For the former NEC Electronics America display customers, there is little change – the business cards change; otherwise, everything stays the same." The official announcement from Renesas reiterated this explanation, stating: "A primary aim of Renesas Electronics America is to ensure that customers have easy, rapid access to the complete system solutions they need – semiconductors, hardware/software tools, application assistance, manufacturing – so they can quickly address market opportunities. … In addition, Renesas Electronics America is the sales and marketing channel in the Americas for industrial-type active-matrix LCD modules from NEC LCD Technologies, Ltd."

Renesas Technology, based in Tokyo, was established in 2003 as a joint venture between Hitachi, Ltd., and Mitsubishi Electric Corp. Heading up the newly formed Renesas Electronics America is Chairman Yuichi Kawakami, former President and CEO of NEC Electronics America, and President and CEO Daniel Mahoney, former president and CEO of Renesas Technology America.

– Jenny Donelan

News Brief

Touch International Introduces MulTI-Touch Technology

Touch International, a touch-screen manufacturer specializing in custom touch-screen designs, has announced the release of MulTI-Touch, which the company is claiming is the most advanced multi-touch projected-capacitive technology in the market to date. The Windows-7-compatible MulTI-Touch technology supports up to 10-finger touch and works with water spray, bare and gloved fingers, and pen input, making it useful for many interactive applications.

MulTI-Touch technology is now available in 10.1-in. screen sizes with additional formats expected by Q3 2010. ■

president's corner

SID: Onward and Upward in Seattle

by Munisamy Anandan
President, Society for Information Display

For those unfamiliar with Seattle, one of the city's major tourist attractions is the Space Needle. From the top of the needle-like structure, one can see a panoramic view of the city and the ocean stretching out to the sky. The Space Needle proved to be a good symbol for the upward progress of SID's Display Week 2010. It was clear from the moment SID opened the doors on May 24, 2010, that yes, we had recovered from the Winter of 2009 (it was a sort of economic signaling of Spring – our own "Groundhog Day"). Our attendance was substantially higher compared to the previous year's show. The bottom line is that the rebound in attendance in 2010 confirms that the downturn in 2009 was mostly due to the worldwide H1N1-flu scare and the onset of a very bad economy and not the beginning of a downward trend. (A table farther down in the column supplies more details.)

It is not hard to understand as to why the 2010 attendance was higher: the location was ideal and the economy had picked up. Above all, the power of the technology at Display Week, both at the technical symposium and on the exhibit show floor, played a dominant role. The headline of a *Seattle Times* article on the show read: "The Future of Display Is Here." What one sees at the Consumer Electronics Show and other popular expos as novel display products are those that were intensely researched by SID members and demonstrated at Display Week many years earlier.

A case in point is 3-D. The world is now gearing up for 3-D, but the technology has been growing within the R&D community represented by SID for many years. Consumers now use glasses for viewing 3-D content, but SID member companies have been researching 3-D without glasses for at least 15 years ("New Stereoscopic LCDs without Special Glasses," G. Hamagishi *et al.*, *Conference Record of the 15th International Display Research Conference*, 1995). The current glasses-free research involves the use of parallax barriers, lenticular sheets, special glass substrates, and optical films with LED switching. I see the future of 3-D without glasses.

Similarly, touch technology has recently created a big impact at the consumer level. Touch technology has been a focus of research within the SID community for a decade. An early interesting paper was on "A New Touch-on-Tube CRT Touch Technology," Donald Armstrong, *SID Symposium Digest of Technical Papers*, 2000. More recently, for 'in-cell touch,' SID's Display Week Symposium featured papers in 2005 that described the incorporation of photosensors at every pixel during the TFT process. And there were papers at the 2010 SID Symposium on 'in-cell touch,' including the deployment of Si nanocrystals to serve as photosensors. Although the current touch technology is dominated by 'resistive touch' and 'projected capacitive touch,' I'm persuaded by the trends revealed at Display Week 2010 that the future will be 'in-cell touch.'

One interesting exhibit that is bound to raise the curiosity of the large-screen-display community in the future, and has neither been covered by any media nor been exhibited anywhere else publicly to the best of my knowledge, was the 18-in.-diagonal plasma-sphere display by Imaging Systems Technology. (Plasma-spheres are hollow micro-spheres that encapsulate an ionizable gas and are mounted on rigid or flexible substrates.) One might mistake this display for the three-color LED variety we see in applications such as scoreboards at soccer stadiums. In fact, I saw a 'Post-it' sticker at

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Display Week 2010 Review: Touch Technology

2010 was a year of incremental improvements and continued strong growth for touch technology.

by Geoff Walker

THERE WAS PROBABLY more touch technology at Display Week 2010 than at any other conference worldwide in the last year. That said, 2010 was an evolutionary year rather than a revolutionary one. There were no new technologies, no major breakthroughs, and no shocking surprises. There were, however, more exhibitors (67 *vs.* 59 in 2009), especially in the materials area. This can be taken as a sign of industry maturation, where the focus is gradually shifting from touch screens themselves to the materials and processes that go into manufacturing touch screens.

The 67 touch-related exhibitors can be classified as follows:

- 28 module manufacturers
- 17 materials suppliers
- 7 display manufacturers
- 5 controller manufacturers
- 5 optical bonding suppliers
- 3 haptics suppliers
- 2 market research firms

The primary focus for the 28 module manufacturers was evenly split between projected capacitive (pro-cap) and analog resistive (both single-touch and multi-touch). Other touch technologies [optical, infrared, SAW, EMR (digitizer), *etc.*] were relatively lightly represented. Again, this can be taken as a sign of industry maturation, since, according to market research firm DisplaySearch, well over 90% of industry revenue in 2010 will be produced by resistive and pro-cap technologies.

Geoff Walker *is the Marketing Evangelist and Industry Guru at NextWindow, a manufacturer of optical touch screens. His industry experience includes positions at GRiD Systems, Fujitsu Personal Systems, Handspring, Tyco Electronics/Elo TouchSystems, as well as his own consulting firm (Walker Mobile, LLC). He can be contacted at gwalker@nextwindow.com or 408/506-7556.*

Projected Capacitive (Pro-Cap)

With 18 suppliers exhibiting pro-cap touch screens at Display Week 2010, it was clear that pro-cap touch has fully emerged and should henceforth be considered a "mainstream" touch technology. Besides the number of exhibitors, several other factors point to this emergence. One is that the physical constructions of pro-cap touch screens are starting to fall into well-defined categories (film, glass, on-cell, and wires). Figure 1 (from Sony Chemical) shows a typical film construction.

Another factor is that small quantities of pro-cap touch screens are beginning to be readily available. This is a significant change. Previously, almost all of the pro-cap suppliers were focused exclusively on high-volume consumer-electronics opportunities, and it was very difficult for a small company to find a supplier. Now that pro-cap is spreading into a wide range of devices beyond just smartphones, companies such as RiTdisplay (US Micro Products) can provide samples only 5 weeks after approval of drawings and production in small-quantity batches.

Yet, another factor is that competition has started to shift from simple availability of pro-cap to enhancements in form factor and performance. For example, Wintek showed a 4.3-in. pro-cap touch screen with a 0.6-mm border width on three sides – with the "zero-bezel" (flush design) capability of pro-cap; this exceptionally narrow border width enables products that are literally all screen!

In the performance area, 3M continued to show progress with its exceptional 22-in. pro-cap monitor, reducing response times from 8 to 6 msec for 20 simultaneous touches. 3M pointed out that minimizing response time is important in the big picture because it is part of the overall latency of a touch screen, and latency directly affects user perception of touch-screen performance. In its booth, 3M was using a version of Google Earth that had been enhanced by Perceptive Pixel; the enhancement used a third touch to control panning (two fingers for X-Y zoom and a third finger controlling the altitude of the point of view above the map).

Maxim was also talking about some very exciting controller performance enhancements due in an upcoming product. Although the company was not ready to disclose the details yet, representatives dropped hints about an exceptionally high signal-to-noise ratio that enables the use of any stylus (not just all-metal ones), and an exceptionally low-power-consumption level that equals that of analog resistive.

The 18 exhibitors showing pro-cap included 3M, AMT, EETI (eGalax), LG

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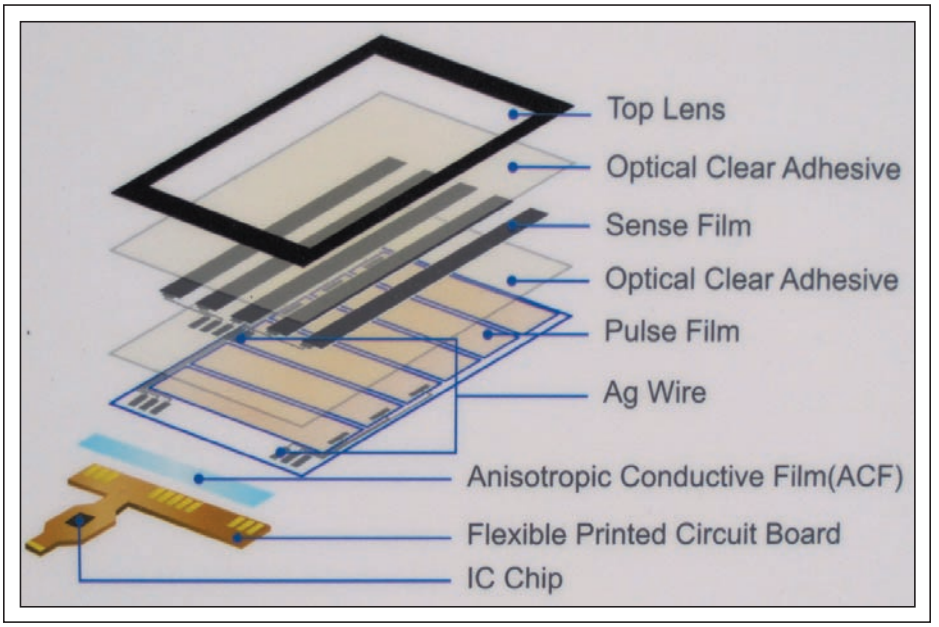

Fig. 1: *This schematic illustration of a film-based projected-capacitive touch screen is typical of one of the two primary forms coming into common use in the touch industry (the other form is glass-based). Source: Sony Chemical.*

Display, Maxim, Microchip, N-trig, Nissha, Ocular, Panjit, RiTdisplay (US Micro Products), Samsung, Sony Chemical, Touch International, Touch Revolution, Wacom, Wintek, and Zytronic.

Analog Multi-Touch Resistive (AMR)

Analog multi-touch resistive touch technology, formerly called "digital resistive," continued its upward trajectory at Display Week 2010. With only one exhibitor in 2008 and three exhibitors in 2009, the total of nine exhibitors this year shows that the technology is beginning to emerge as a serious alternative to projected capacitive. A few suppliers are trying to build their own brand names for the technology (*e.g.*, RMTS by Panjit and MARS by Touch International), but generally the industry seems to be settling on AMR as the name and acronym of choice.

There are actually two different types of AMR, and it is clear from the exhibits at Display Week 2010 that the difference is not yet clearly communicated or even understood. Since neither type has a distinct name yet, perhaps that is not surprising. In the first type, the intersection of each set of conductive (ITO) strips is treated as a switch – it is either making contact or it is not. It is digital. The resolution of this type is therefore typically half of the strip spacing – which is usually quite narrow. For example, if the spacing is 1.3 mm (as in Stantum's very nice demo touch screen shown in Fig. 2), then the resolution is 0.65 mm. This type of AMR could actually be called "DMR" or "digital multi-touch resistive."

In the other type of AMR, the intersection of each set of conductive strips is treated as a miniature four-wire analog-resistive touch screen. Each strip can be considered a type of digital "channel" in this configuration, where contact within one digital channel is always evaluated on an analog basis. While the resolution of this type also depends to some extent on the strip spacing (which is typically wider), the resolution is generally higher than in the first type, sometimes as fine as 0.2 mm. Since a rule of thumb for touch screens is that 1-mm resolution is adequate for most applications, this type is optimum for applications requiring better-than-average resolution. Examples of this type of AMR were shown by EETI (eGalax) and Dawar, among others (see Fig. 3).

The nine exhibitors showing AMR included AMT, Dawar, EETI, Fujitsu, Panjit, Stantum/Sitronix, Techno Print/Nagase America, Touch International, and Wintek.

In-Cell Touch Technology

One of the most surprising aspects of Display Week 2010 was the almost total lack of in-cell touch technologies on display. On-cell touch, where the touch screen is fabricated on top of the color-filter glass, has taken the industry by storm. Exhibitors showing on-cell touch included Samsung (resistive and capacitive), LG Display (capacitive), NEC (surface capacitive), Toshiba (resistive), and Wintek (resistive).

One particularly interesting on-cell demonstration was by NEC, which was showing a very novel version of on-cell surface capacitive (*not* projected capacitive). The demonstration LCD, as described in NEC's Symposium paper, "Touch-Panel-Embedded IPS-

Fig. 2: *Above is Stantum's very-high-resolution (0.65 mm) analog multi-touch resistive (AMR) touch screen, showing extremely fine digital ink. The touch screen uses four Sitronix controller chips around the edge (under the bezel). The left side of the photo is a standard video card used to drive the display electronics on the right.*

LCD with Parasitic Current-Reduction Technique," used as a capacitive sensor the ITO layer (on the color filter) that a standard IPS-TFT display incorporates as an anti-static measure. NEC's enabling technology was a method of minimizing the large parasitic capacitance that exists between the ITO surface layer and the TFT backplane.

On-cell resistive moved into greater prominence this year, with three exhibitors showing it. Similar to on-cell capacitive, it uses the color-filter glass as the substrate in a traditional film-glass analog resistive touch-screen. The film layer is placed between the color-filter glass and the LCD's top polarizer, separated from the color-filter glass by spacer dots, exactly like in a standard resistive touch screen. The primary advantages of on-cell resistive are (a) the elimination of one sheet of glass, with resultant reduction in thickness and ambient light reflections and (b) the cost-savings achieved by integrating the touch screen at the time of LCD manufacture.

It is worth noting that some of the on-cell touch screens shown on the exhibit floor were actually labeled as "in-cell" (for example, in the Wintek booth). When questioned, the exhibitors in question all agreed that their technology was actually on-cell. Samsung has started using a new term for both in-cell and on-cell touch, namely, "embedded touch." This is probably a very good idea because it minimizes the temptation for marketers to mislabel their touch technology for perceived marketing advantage. It is also a good idea because it recognizes that from the perspective of the LCD module, both in-cell and on-cell touch technologies are beneath the polarizer and are thus invisible. The side of the color-filter glass on which the touch technology appears is not actually that relevant.

Other Interesting Bits

RPO showed the latest iteration of its waveguide infrared touch-screen technology in the form of a 13.3-in. touch screen with a profile (bezel) height of only 0.5 mm and a border width of 3–5 mm. The reduction in profile height and border width since the company first announced its technology in 2007 is quite significant. RPO also showed a touch screen integrated with an E Ink electrophoretic display, side-by-side with a resistive touch screen. The difference in optical performance was immediately noticeable. The integration with E Ink was unique in that the waveguides were on top of the screen while the light-spreading glass was mounted *under* the screen. The resulting freedom from any overlay produced excellent optical performance. RPO's touch screen also appeared in two other booths – LG Display, where it appeared in a 13.3-in. notebook, and Qualcomm, where it was integrated on top of the mirasol® reflective display. The clear-glass nature of RPO's touch screen is optimum for a reflective display, where ambient light must travel in both directions through the touch screen.

Elo TouchSystems showed an interesting demonstration based on its acquisition of Sensitive Object in January of this year. The demo, which used a large sheet of acrylic with two acoustic sensors clamped to the sheet in arbitrary locations, illustrated how Sensitive Object's "ReverSys" technology uses stored waveforms of acoustic signatures to identify touches at a specific location. Another interesting demo by Elo TouchSystems was of a surface-acoustic-wave (SAW) monitor with zero-bezel (edge-to-edge glass) design. SAW normally has a set of reflectors around the border of the screen that prevents a bezel-less configuration; Elo has figured out how to locate the reflectors (and the piezo transducers) on the back of the glass, leaving the front of the glass as an entirely flat surface. The trick is in shaping the edge of the glass so that the acoustic waves are guided from the back of the glass around to the top surface.

Optical touch technology made a strong showing at Display Week 2010 with exhibits from three companies. NextWindow demonstrated its new 2500-series large-format touch screen aimed at high-volume monitor OEMs; LG Display showed a prototype of a 21.5-in. optical touch screen; and Baanto, a Canadian startup, showed a technology demonstration of a low-cost 19-in. optical touch solution.

E Ink demonstrated a new method of integrating a touch screen with an electronic-paper (e-paper) display, placing a standard analog-resistive touch screen under a flexible

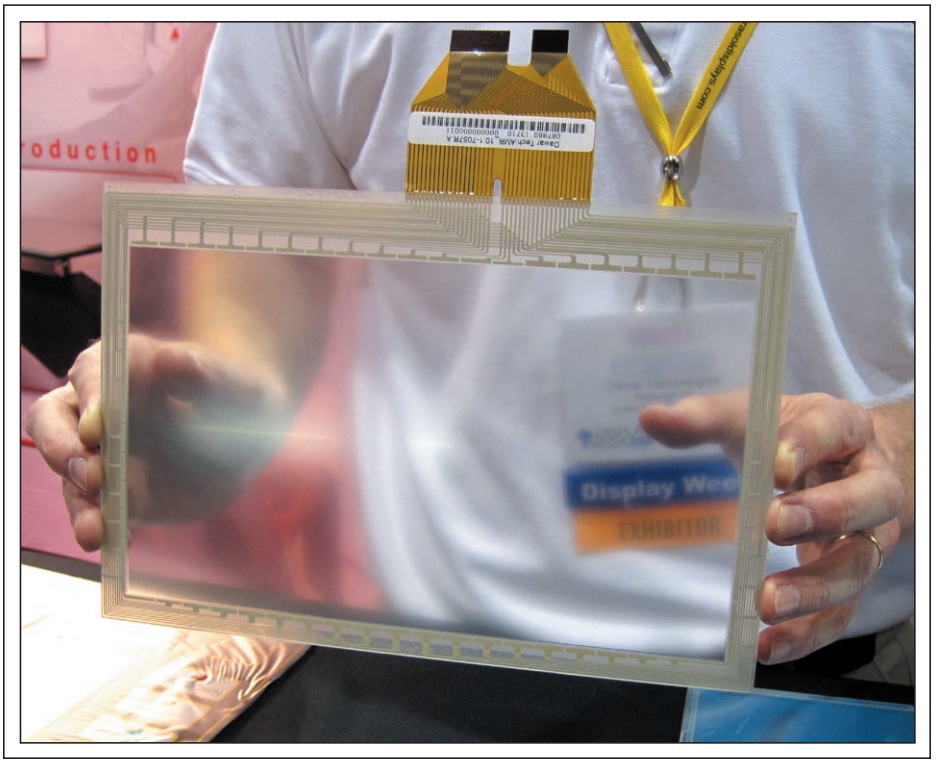

Fig. 3: *Dawar Technologies' prototype analog multi-touch resistive (AMR) touch screen is an example of the type of AMR in which the intersection of each set of conductive strips is treated as a miniature four-wire analog-resistive touch screen. The connections for the 20 relatively wide vertical ITO stripes can be clearly seen across the top of the screen. The relatively large border width of this prototype screen is not typical of production screens.*

e-paper display (*i.e.*, one constructed without a glass substrate). Touch was therefore accomplished by pressing through the e-paper display, which seemed to work surprisingly well.

Kyocera showed a glass–glass touch screen aimed at the industrial market. Glass–glass touchs screens have previously been limited mostly to the automotive market; Kyocera made a fairly convincing argument that glass–glass touch screens are especially appropriate for the industrial market, given their clarity, durability, and ability to be totally sealed.

Other Touch-Related Events

This article has "touched" on only a small fraction of the large amount of information on touch that was presented at Display Week 2010. In addition to the 67 touch-related exhibitor booths, the following activities also took place:

- A 4-hour Short Course on touch technologies on Sunday, attended by over 130 people.
- A panel discussion on touch during Monday's Business Conference and Tuesday's Investor Conference.
- A Symposium keynote speech on the history of touch by Bill Buxton, a world-famous touch researcher currently at Microsoft.
- 14 Symposium technical papers on touch-related topics, covering everything from the history of touch interfaces to driving methods for analog multi-touch resistive (AMR) to in-cell capacitive touch for large LCDs
- Six poster papers on touch-related topics, including one especially interesting paper by Uni-Pixel Displays entitled "Theory, Design, and Production of Fingerprint-Resistant Films for Touch-Enabled Displays"
- Five supplier presentations on touch topics during Tuesday's Exhibitors' Forum; these included talks by 3M, EETI, NextWindow, RiTdisplay (US Micro Products), and Zytronic.
- A 90-minute Applications Seminar on Wednesday on emerging touch applications, attended by about 45 people.
- A full-day Market Focus Conference entitled "The Future of Touch and Interactivity" on Thursday, attended by well over 100 people.

If you are reading this article to see what you missed by not attending Display Week 2010, hopefully it is now clear that from a touch-technology point of view, you cannot afford to miss Display Week 2011! ■

Display Week 2010 Review: LCDs

Liquid-crystal-display technology continues to dominate.

by Alfred Poor

JUST by casually walking up and down the aisles of the exhibit floor at Display Week 2010 in Seattle, it could be plainly seen that liquid-crystal-display (LCD) technology continues to be the dominate technology for many display applications. Obviously, cathode-ray tubes (CRTs) and their related components are long gone, and even the more recent competitors in the marketplace such as OLED displays are doing little to claim turf in terms of actual products. Even the bumper crop of touch-technology demonstrations on the show floor exist primarily to support LCD applications.

So, one might expect that LCD technology has become the established technology, satisfied with its success and enjoying its leading role in the display industry, but that couldn't be further from the truth. Just about everywhere at Display Week – on the exhibit show floor, at the Symposium technical sessions, and even in the awards – it was clear that many people in the display industry are working hard to improve all aspects of LCD technology. This is not an industry content to rest on its laurels. Instead, it recognizes the competition from existing and developing technologies and is striving to maintain its advantages.

Who Needs OLED or Bistable Displays?

For example, although OLED and bistable display technologies continue to garner a great deal of attention in the press, LCD performance is improving rapidly, which is reducing the advantages offered by the new challengers.

Among other advantages, OLED technology has always presented the promise of much thinner flat-screen HDTV sets. But improved light-guide plates (LGPs) and light-management films have made it possible to create edge-lit LED backlight units that may make consumers forget the siren song of thin OLEDs. In the exhibit hall, LG showed off a 42-in. 1080p LCD panel that was a mere 2.6 mm thick (Fig. 1); that's about one-tenth of an inch, or the thickness of a typical sheet of corrugated cardboard.

e-Book applications have been dominated by ultra-low-power display technologies such as electrophoretic and bistable LC. However, conventional LCDs are also making significant inroads in areas that are generally viewed as belonging to bistable solutions. The 2010 SID Display of the Year Silver Award was awarded to the Pixel Qi 3Qi Multimode LCD. It is able to show full-color full-motion video in low light conditions, but can work without its backlight in high ambient light levels,

Fig. 1: *LG's demonstration 42-in. LCD panel is about as thick as a sheet of cardboard. Photo courtesy Alfred Poor.*

Alfred Poor *is an editor and publisher of the HDTV Almanac and a freelance writer covering technology topics with special emphasis on displays. He can be reached at apoor@bellatlantic.net.*

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including direct sunlight. Each pixel has about the same transmissivity as that of a typical LCD panel, but it is also highly reflective. As a result, the reflective mode uses about 80% less power than a typical LCD panel while delivering image quality that is on a par with that of conventional ultra-low-power technologies. This display was developed by Mary Lou Jepson and her team at PixelQi, which is a spin-off from the One Laptop Per Child (OLPC) initiative, for which Jepson developed an earlier generation of the 3Qi screen.

It's Getting Easier to Be Green

Conventional backlit LCDs are inherently somewhat inefficient devices in which much of the backlight illumination is absorbed by the panel, even when displaying a white image on the full screen. Many companies are tackling this problem, aiming to make the displays more efficient by utilizing techniques such as local dimming of LED backlights. By reducing the amount of light in areas where the image is dark, less light is wasted by being absorbed by the LCD panel, which in turn saves energy.

Samsung demonstrated two panels (Fig. 2) that make use of the PenTile® technology from Nouvoyance (formerly Clairvoyance, now owned by Samsung) that makes LCD panels more light efficient by using a different approach to the conventional RGB subpixel design.

This novel subpixel design provides equivalent resolution using fewer components than a standard red-green-blue stripe configuration, which allows more light to pass through, allowing the panel to produce the same amount of light using about half the power. In lieu of a stripe configuration, a white subpixel is added to the red, green, and blue pixels, and they are arranged in a quad formation. The white subpixel provides additional brightness, and the novel arrangement of subpixel components makes it possible to create an equivalent resolution with fewer subpixels than a standard RGB configuration (Fig. 3).

Other components of LCDs, such as the backlight system, are also becoming more efficient. For example, 3M demonstrated its improved Vikuiti™ Dual Brightness Enhancement Films (DBEF) on an unusual display. The company showed an 18.5-in. desktop computer monitor that used only a single USB cable as its connection to the computer. The

Fig. 2: The PenTile® pixel structure of Samsung's demonstration panels uses less power than that of a conventional LCD panel with equivalent resolution. Photo coutesy Alfred Poor.

USB 3.0 connection not only carried the display signal, but also provided the 8 W of power required to run the monitor. This compares with about 14 W required by a typical panel. The lower power demand means that the monitor maker can eliminate the separate AC-to-DC power converter. Of course, the key to this achievement is the higher light recycling efficiency of the new film, but the concept is broadly based. A typical LCD panel absorbs at least 95% of the light emitted by the backlight, even when showing an all-

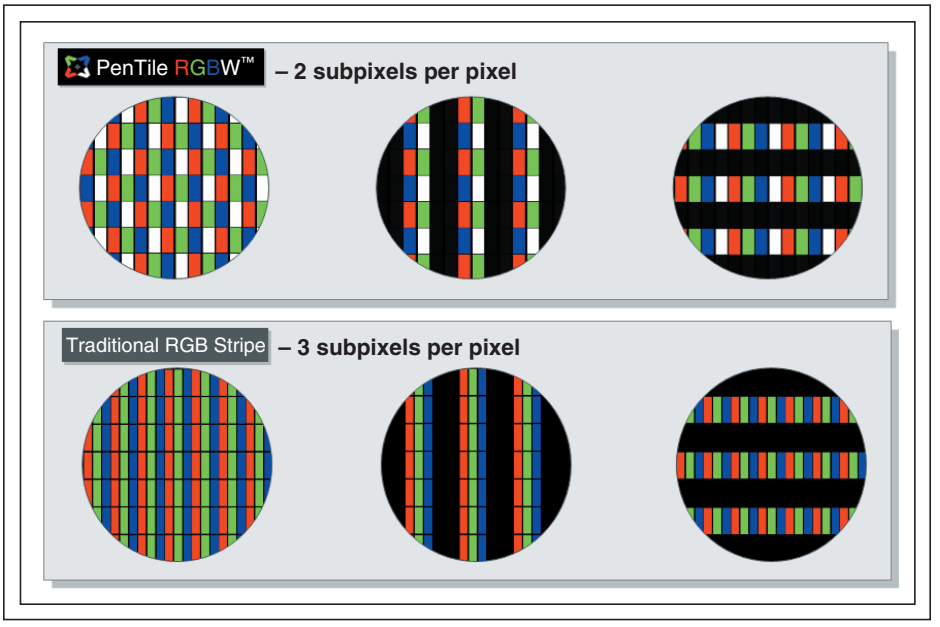

Fig. 3: The PenTile® RGBW design appears above the conventional RGB stripe configuration. Image courtesy Nouvoyance, Inc., and Samsung Electronics Co., Inc.

white screen, so any light that can be recaptured and directed through the panel can result in significant energy savings.

Compare and Contrast

Ambient light can also diminish the image quality of LCD panels despite their ability to show a higher luminance image than some other display technologies. Reflections can be a major source of this problem, thus resulting in anti-glare and anti-reflection solutions getting a lot of attention. Optical bonding processes, while not new, continue to evolve as a result. For example, Toshiba demonstrated its Screen Fit technology that eliminates the air barrier between an LCD panel's top polarizing layer and the cover layer. The optically transparent bonding process eliminates two boundaries, which reduces the internal reflection of ambient light. In its booth, Toshiba showed a 12.1-in. panel with this technology next to another panel based on conventional processes (Fig. 4). The reduction in reflection was striking.

Even more striking was a demonstration of Sharp's new "moth-eye" anti-reflection (AR) technology. The company has already developed effective AR films that rely on nanostructures to reduce ambient reflection. The new technology uses finely patterned holes and "steeples" that are modeled after the structures found in nature – in the eyes of moths. When the surface of the existing AR films is treated with this new structured pattern, the reduction in glare is remarkable. According to a paper presented, "the minimum specular reflectance was reduced to 0.02% and the average reflectance was less than 0.04% in the visible range (380–780 nm) with little wavelength dependence." The panel displayed in the Sharp exhibit had stunning, deep blacks and showed vivid high-contrast images despite high ambient light levels. (Fig. 5).

Big and Small, Short and Tall – and Rugged

If LCD technology demonstrated anything at Display Week 2010, it is how it can be adapted to a wide range of applications. For example, Samsung showed its 84-in. UHD panel with touch. The 3840 × 2160-pixel panel is the equivalent of four 42-in. 1080p panels combined. At the other end of the spectrum, Syndiant showed its tiny LCoS microdisplays intended for use in pocket

Fig. 4: *The panel on the left uses Toshiba's Screen Fit technology to reduce reflections; note how the bright overhead lights are much less visible on the left-hand panel and how much the image on the right is washed out by the ambient lighting conditions. Photo coutesy Alfred Poor.*

Fig. 5: *Using the technology based on moth-eye structures, Sharp has developed a new anti-reflection film that yields impressive results. Photo coutesy Alfred Poor.*

projectors. The company now has a 0.44-in. WSVGA panel with a1024 × 600-pixel resolution.

In between these extremes, all sorts of LCD panels could be found on display. Tannas Electronic Displays, which specializes in resizing LCDs, showed some of its custom resized panels, including one that was 5 × 35.5 in. Another LCD specialist, CheonJo Smart DNC, also had panels with unusual dimensions, including a 32-in. unit with a 1366 × 435-pixel resolution. These displays make it easier to create novel applications for target markets such as military, aerospace, and digital signage.

Many other companies had specialized panels on display. Hitachi had a wide range designed for industrial applications, as did Sony. Rockwell Collins showed a variety of ruggedized panels for industrial and avionics applications, some of which were designed to handle temperature ranges from -55 to 100ºC. Optrex, Vertex LCD, Shanghai Tianma, Bi-Search International, STI, Avnet, and Wintek were among additional exhibitors who showed a variety of panels designed for industrial applications. Product designers should have no problem finding the ideal panel from these combined offerings for whatever product they plan to create.

Display Week 2010 definitely was a showcase for touch-screen and other display technologies, but there is no doubt that LCD technology currently rules the roost. Consequently, many other display innovations not discussed in this article also relate to LCDs. For 3-D LCD news, see the review article on 3-D in this issue, and for news on the proliferation of LED backlighting and other forms of power savings, see the green-manufacturing review article. All in all, manufacturers and researchers clearly recognize that they must continue to improve the technology if it is to hold onto its top spot, and based on the innovation on display this year, it looks as though they are going to enjoy continued success. ■

Display Week 2010 Review and Market Outlook: Can OLED Displays Make the Move from the Mobile Phone to the TV?

Recent announcements of advanced-generation active-matrix OLED production are creating the momentum needed to start the transition to large panels for the TV market, but manufacturing challenges remain in scaling up substrate size and driving down costs.

by Paul Semenza

THIS WAS A YEAR in which OLED displays – at least the larger ones – were conspicuously absent at Display Week. Certainly, there was plenty of OLED technology, with over 10 Symposium sessions dedicated to AMOLEDs and OLED devices, materials, manufacturing, lighting, and more. And OLED companies were on the display floor. (See the sidebar from Information Display *roving reporter Mike Moyer). But what were not there (with an exception or two) were the OLED TVs that had been on display just a few months earlier at the Consumer Electronics Show in Las Vegas, a situation even more puzzling in light of a confident keynote address delivered at Display Week by Dr. Sang-Soo Kim from Samsung Mobile Displays. The talk was titled, "The Next Big Thing In Displays," and Kim predicted that Samsung Mobile Display would ship 45-million small–to–medium-sized OLED displays by the end of 2010 and that OLED TV will become the mainstream display technology for TVs by 2015. So, it was a little disappointing that we did not get to see lots of big, beautiful OLED TVs on the exhibit floor in Seattle.* Information Display *asked veteran-market-analyst Paul Semenza for his take on the OLED situation. The answer, in short, involves manufacturing challenges. Read on. — Editors*

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After decades of development, organic light-emitting-diode (OLED) displays are on the verge of becoming a billion-dollar business. In 2009, OLED revenues reached $826 million, up 35% over 2008. DisplaySearch expects continued momentum in 2010, with growth forecasted at 47%, resulting in revenues of more than $1.2 billion. Active-matrix OLED (AMOLED) revenues overtook those of passive-matrix OLEDs (PMOLEDs) in the first quarter of 2009. For the year as a whole, AMOLED shipments passed 22 million, triple that of 2008.

Nearly three-quarters of OLED shipments are used for mobile-phone displays; for AMOLEDs, the share is approximately 90%. Demand for smart phones has driven growth, partially due to Samsung's promotion of AMOLED smart phones. AMOLEDs were also adopted by Nokia in 2009.

While AMOLED growth is due to mobile phones, shipments of PMOLEDs, mainly for mobile-phone sub-displays, are declining as the market shifts to smart phones. During this transition from passive to active matrix, total shipments have been flat, as the growth in AMOLEDs was cancelled out by the decline in PMOLEDs, although quarterly revenues have doubled (Fig. 1).

In 2010, TVs will represent less than 1% of revenues for OLEDs, but going forward, television is the key driver for investments in AMOLEDs. DisplaySearch forecasts that TV will pass 10% of the revenues in 2013 and 30% in 2016. In order to reach – or exceed – these forecasts, there will have to be a significant expansion in AMOLED manufacturing that enables the mass manufacture of large panels while driving down manufacturing cost.

OLED Production: Dominated by One Supplier

The OLED market has undergone consolidation recently, with Eastman Kodak Co. selling its OLED display business to the LG Group, and InnoLux acquiring Chi Mei and TPO (itself the product of a merger between Toppoly Optoelectronics and Philips Mobile Displays), both with OLED businesses. But the most important factor has been the emergence of Samsung Mobile Display (SMD), a joint venture between the OLED business of Samsung SDI and the mobile-display segment of Samsung LCD, which started operations officially at the beginning of 2009.

Samsung has held the lead in revenues since 2007, driven by its dominance in AMOLED production. In 2009, SMD

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accounted for 75% of revenues and 44% of units shipped; for AMOLEDs, the company had a 98% share in units and revenues. RiTdisplay, which focuses on PMOLEDs, had a 22% share in units and a 13% share in revenues in 2009. TDK was third in unit shipments and Pioneer was third in revenues. A key question for the industry is whether there will be strong competitors to SMD in AMOLEDs, as this tends to speed development, drive down costs, and increase adoption – customers feel more comfortable with multiple suppliers.

While Japanese companies had the early lead in OLED development, and specifically AMOLED production, they have been passed by SMD and LG Display (which now has responsibility for OLEDs in the LG Group), as well as Chi Mei EL (CMEL) in Taiwan, and perhaps Chinese firms in the future. Sanyo's joint venture with Kodak failed; Sony is re-setting its OLED strategy, ceasing production of its XEL-1 TV; and Toshiba never made the move to AMOLEDs.

CMEL has been the main AMOLED supplier in Taiwan. Its focus has been on medium-sized consumer and industrial applications rather than mobile phones. TPO has studied AMOLEDs for a long time and its LTPS technology can be applied to both TFT-LCDs and AMOLEDs. CMEL and TPO are now part of Chi Mei Innolux, the product of a merger of InnoLux and Chi Mei Optoelectronics. AUO shipped AMOLEDs with LTPS backplanes in 2005-2006 and is expected to re-launch its AMOLED business in 2010–2011.

In China, Shanghai Tianma broke ground on the first Gen 4.5 AMOLED line in January. It is expected to start mass production in June, 2012. Truly has been shipping PMOLEDs in small volumes for a few years. Visionox has also demonstrated AMOLEDs. Other Chinese companies that have discussed AMOLED production plans include Zhongxian Technologies, IRICO Fushun, and Changhong Electric; TCL and BOE also have OLED development programs.

Making the Move to TV

While TV-class AMOLEDs have been in development for several years, this year has seen a resurgence in activity. At CES in January, Samsung showed 14- and 30-in. AMOLED TVs (Samsung also demonstrated a 14-in. transparent AMOLED). The 30-in.

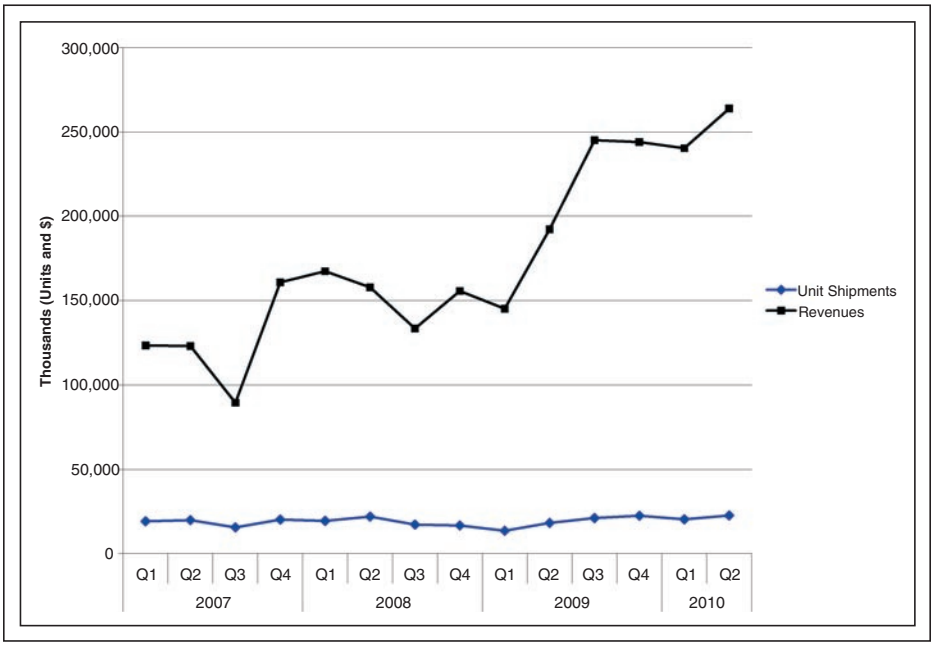

Fig. 1: *As the market has shifted from active- to passive-matrix OLEDs, revenues have increased while shipments have remained flat. Source: DisplaySearch Quarterly OLED Shipment and Forecast Report.*

AMOLEDs were full-high-definition (1980 × 1080) and 240 Hz using active-shutter-glass 3-D technology. LG Electronics released its 15-in. AMOLED TV in Korea in January, at a price of about US$2600. The pixel format is 1366 × 768 and the thickness is 3.2 mm. Meanwhile, Sony stopped selling its AMOLED TV, but sought to demonstrate its technology leadership by showcasing 24.5-in. 3-D AMOLED displays at CES.

These AMOLED-TV demonstrations have indicated the tremendous potential of the technology, showing outstanding colors, black levels, and switching speed, enabling excellent 3-D performance. But, partially in response to the performance of AMOLEDs, TFT-LCDs have greatly improved. With LED-backlit 240-Hz panels featuring greatly improved image quality, contrast, and wide viewing angles, in thicknesses less than 10 mm, the theoretical performance gap between TFT-LCDs and AMOLEDs continues to narrow.[1]

To achieve broad adoption of AMOLEDs in the TV market, cost reduction will be more important than performance improvements. Since AMOLEDs are simpler to manufacture than TFT-LCDs, having no backlight and color filter, and potentially no top glass, yielded costs could be only a fraction of that of TFT-LCDs. But high unit costs for materials, low manufacturing yields, and challenges in developing new manufacturing equipment and processes mean that even coming close to theoretical costs is very difficult. Meanwhile, TFT-LCD costs continue to fall. Thus, 32-in. TFT-LCD prices are forecast to be less than $150 in 2013, while 32-in. AMOLED prices will be more than $350 (Fig. 2).

In order to compete with TFT-LCDs in the TV market, AMOLED production must expand past the current Gen 4 fabs. There have been indications since 2009 that SMD and LG Display will invest in Gen 5 or larger AMOLED fabs. In April 2010, LG invested $226 million to triple its OLED capacity. In May 2010, Samsung Mobile Display announced that it will invest KRW 2.5 trillion (approx US$2 billion) to establish a Gen 5.5 (1300 × 1500 mm) AMOLED line with an ultimate capacity of 70,000 panels per month. This factory is likely to be used to make a range of panel sizes: mainly small–to–medium-sized panels similar to those being currently made on a Gen 4 line, as well as larger panels, including some 6-up 32-in. panels and potentially 2-up 55-in. panels.

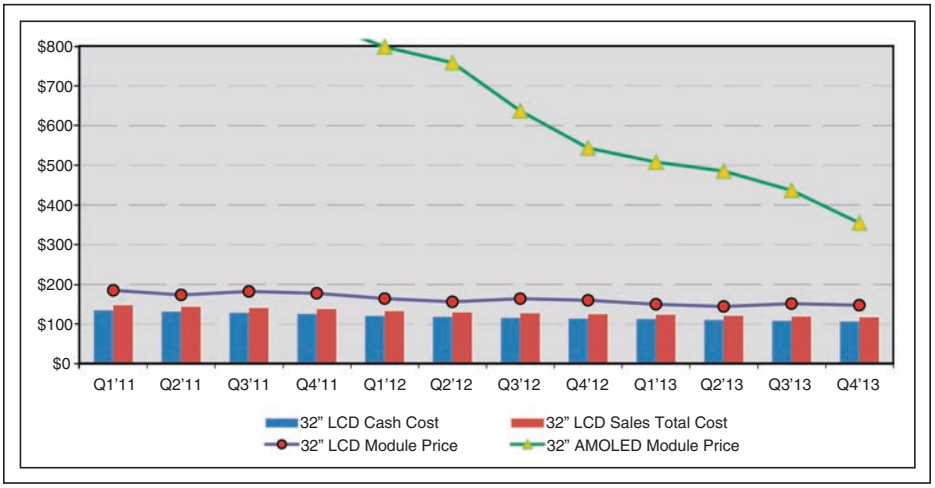

Fig. 2: *The cost and price of TFT-LCD module are a fraction of equivalent AMOLED modules, though the gap will narrow with volume manufacturing of Gen 5+ AMOLED fabs. Source: DisplaySearch Quarterly Worldwide FPD Shipment and Forecast Report and Quarterly Large-Area TFT-LCD Cost Report.*

Paving the Way to Gen 5+ AMOLED Manufacturing

The key challenges for scaling up to larger substrate sizes involve the TFT array, which requires higher performance than devices used for LCDs, and the deposition process for the organic materials. OLEDs require high mobility and tight voltage uniformity for current-driven pixels, currently achieved by adopting an LTPS-based active matrix. The organic devices themselves must utilize low-defect small-pixel uniform organic light-emitting-material deposition, currently achieved by evaporation through a fine metal mask. There are a variety of manufacturing technologies that can enable AMOLED scaling to larger glass sizes.[2]

Currently, most AMOLEDs are produced on LTPS backplanes using excimer-laser annealing (ELA). It is assumed that SMD and other AMOLED makers are considering using ELA or metal-induced solid-phase crystallization plus vertical evaporation. However, there is no Gen 5+ LTPS TFT equipment readily available yet. Alternative TFT-array technologies include oxide TFTs, demonstrated by both SMD and LG Display, and a-Si TFTs with a dual-plate structure (in which the OLED material is deposited on the top glass and the TFT array on the bottom glass), under development by LG Display. For SMD's Gen 5.5 line, LTPS backplanes may be scaled with new tools that could incorporate extended line-beam ELA, high-power ion doping, and large-sized thermal process activation.

Vacuum deposition equipment for OLEDs currently allows only half-Gen-4-sized substrates to be coated. After the full 730 × 920-mm LTPS TFT array is completed, it is cut in half to fit into the vacuum coating chamber to be coated with organic materials. There are several deposition methods under development, including laser-induced thermal imaging (LITI)), nozzle printing, and ink-jet printing. LITI was developed by SMD and 3M, and SMD has a Gen 4 LITI pilot line. DuPont has developed a nozzle-printing process, using equipment developed with DaiNippon Screen. A new approach from Kateeva modifies ink-jet printing by using inks that can be heated by a micro-dryer (called a thermal jet), located between the ink-jet nozzles and the substrate; the heating dries the inks and then vaporizes them so they can be deposited onto the substrate. For SMD's Gen 5.5 line, organic material deposition may be achieved with a line source and evaporation through vertically oriented fine metal masks on full substrates.

SMD has positioned the Gen 5.5 fab as a first step to volume manufacturing of large TV panels on Gen 8. Since novel technologies such as oxide TFTs and ink-jet printing will take time to develop, SMD has suggested a short cut to Gen 8.[3] Rather than simultaneously crystallizing an entire substrate, SMD proposed simply mounting currently available 730-mm line-beam optics on a Gen 8 stage

OLEDs at Display Week

LG was the only manufacturer demonstrating a sizable OLED display at Display Week. This was a 15-in. RGB unit showing clear, bright imagery. There was also a distributor demonstrating a 7-in. OLED from Chimei, though the panel had been discontinued. The Chimei-Innolux Web site claims the company sees "great potential" in OLEDs and that the main market will be high-end mobile-phone and smart-phone sectors. But while the manufacturers of larger OLED displays (Samsung, *etc.*) seem to be holding back just now, there were several other OLED products to be seen at the show.

Among these were products from eMagin Corp., which had an impressive demonstration of OLED-on-silicon microdisplays, including SXGA units. Novaled also had a strong showing of OLEDs for solid-state lighting, with new materials including white top-emitting OLEDs with increased lifetime and power efficiency. UDC had a new light-blue phosphorescent material suitable for both solid-state lighting and displays, which the company claims has significant performance gains and a longer lifetime compared to previous generations of its light-blue PHOLED technology.

DuPont was also on hand to show off its printed OLED technology, which includes a set of solution-based OLED materials that can be printed and coated at high speed using a new process. According to the company, the fabrication of AMOLED displays by solution process reduces material consumption and lowers equipment costs compared to incumbent vapor-deposition processes.

One other interesting development at the show was a paper from Sony on a rollable AMOLED display driven by OTFTs. According to the company, this display is rollable to a radius of less than 4 mm.

– Michael Moyer

and crystallizing the silicon on the large-sized glass in three passes. Typically, this is not a preferred approach because it is very difficult to fabricate a single display over the edge where two ELA scans meet, due to crystallization non-uniformities. But with the multi-scan approach, 6-up 55-in. panels can still be patterned within the boundaries of the scan, and then the finished substrates can be scribed into 55-in. cells for back-end processing.

This approach could enable large-sized AMOLED TV production at Gen 8 while reducing risks associated with novel new equipment/process introduction and also lowering costs with multiple panels per substrate. However, it may limit the number and size of panels produced to ones that fall within the single-pass crystallization zone. Also, the back-end process presumably would still use single-panel evaporation, which does not take full advantage of the large substrate's potential economies of scale.

It may be possible for AMOLED makers to exploit the inherent characteristics of the technology for higher performance. For example, compared to that of TFT-LCDs, AMOLEDs have fast response and true on/off emission, which can be important for 3-D operation. SMD has developed a new frame-by-frame driving scheme that it calls simultaneous emission with active voltage control (SEAV) to take advantage of these characteristics.[3] Most 3-D displays use progressive scanning, in which rows are turned on one after the other. In order to prevent left-right cross talk, either blanking or increased refresh rates are needed; these either reduce brightness or create response-time limitations. The use of SEAV avoids these problems by turning on all the pixels during the emission step and turning them off during the other steps, during which the active shutter glasses are switched. With this frame-by-frame driving, the left image is shown, the pixel is turned off, and the right image is shown and then turned off, for a 240-Hz cycle, providing distinct L/R images without cross talk. The SEAV pixel design is also simpler than in typical AMOLEDs, leading to longer lifetimes, improved yields, simplified peripheral circuits, greater driving margin, and reduced performance demand on the TFT array.

AMOLED Moving Toward TV, but Chasing a Moving Target

The significance of SMD's investment in Gen 5.5, and its indication that it plans to move on to Gen 8, is hard to determine at this time. However, it is very likely that SMD's competitors will follow closely, either with similar substrate sizes or perhaps even trying to leapfrog to larger sizes. Either way, this could be the first step in breaking the stalemate in Gen 5+ AMOLED equipment manufacturing, in which it has been too risky to be the first to develop a new piece of equipment – or the first panel maker to order one. It is likely that there will be a significant increase in momentum for large-area AMOLED manufacturing. However, the path to Gen 8 AMOLED manufacturing is still not clear, and a new wave of Gen 8 TFT-LCD manufacturing investments is on the horizon. Driven by the Chinese market; this is likely to increase the competitiveness of TFT-LCDs in the TV market, mostly driven by price competition.

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[1]For a discussion of TFT-LCD image quality and other performance improvements, see P. Semenza, "Improvements in TFT-LCD Performance: Better Pictures, Thinner, and Lower Power," *Information Display* **26**, No. 9 (September 2010) (to be published).

[2]H. D. Kim, H.J. Kim, B.H. Berkeley, and S.S. Kim, "Emerging Technologies for the Commercialization of AMOLED TVs," *Information Display* **25**, No. 9 (September 2009).

[3]S-S. Kim, "The Next Big Thing In Displays," keynote presentation at SID 2010, Seattle, May 25, 2010. ■

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Display Week 2010 Review: Green Technology

Environmentally friendly devices, processes, and materials are growing ever more important in the display world.

by Jenny Donelan

THERE WERE so many shades of green on the show floor at Display Week 2010 that you might have thought it was St. Patrick's Day in May. The green was virtual, of course, but virtually every company had a tale to tell about its environmentally friendly products and processes. It would have been an interesting exercise to ask every exhibitor if it had anything green to say about its products or operations; very few would have answered "no." Not only is green a must-have label these days, it's a fairly easy one to attach: whatever the motivation, most companies are doing at least something less wastefully or more economically than they used to, and almost all of it makes for a green story of some kind.

This is not to say that most of the stories are not true, or important. In fact, the relevance of green was underscored this year by the introduction of the Display Week 2010 Symposium's first Green Technology track, which featured 20 papers covering topics ranging from power-saving components to gas output reduction during manufacturing to newer and more efficient device structures. One way to bring order to all these green initiatives is to sort them into categories, as was proposed in the Symposium paper, "Green Technology in LCD" (Paper 9.1) by Jun H. Souk and Sangwoo Whangbo from Samsung Electronics' LCD Division. The authors separated green technologies in the LCD industry into three areas: green devices, green processes, and green factories, as shown in Fig. 1.

Noting that LCDs continue to be used in more and more applications, and that increased production capacity from Gen 8 or Gen 10 lines in LCD factories is driving the consumption level of chemicals and power higher than ever (while at the same time overall environmental awareness on the part of consumers and governments is increasing), Souk and Whangbo note that LCD manufacturers need to be especially observant. For example, the SF_6 gas used during the dry-etch process has a very high global-warming potential, the authors noted, adding that Samsung had been able to reduce the output of that gas by about 85% through retreatment techniques. CO_2 outgas reduction is also obviously necessary for LCD companies as well as for other types of manufacturers. Out of all the above factors, the most effective areas for change, note the authors, are the reduction of greenhouse gases during the manufacturing process and the creation of power-saving LCD devices that use features such as higher light transmittance panels and local dimming with LEDs.

Keeping in mind that since it is not possible to tell all the green stories from Display Week 2010, a few examples from some representative technology areas at the show are described below.

LCDs

In the paper, "EcoDesign for TV Displays " (Paper 9.4) by Kees (Cornelis) Teunissen, Theo JM Schoenmakers, and Leendert Jan de Olde from Philips Consumer Lifestyle, the authors compare a typical 32-in. CRT television from 1999 with a typical LCD TV of today. The former weighed about 20 kg and consumed 150 W, whereas the latter weighs about 11 kg and consumes less than 90 W. That said, 32 in. was a good-sized TV 10

Green Device	
Power-saving LCD	
LED BLU and local dimming	
High-transmittance panel	
Smart power control	
Green Process	**Green Factory**
Reduced process step	CO_2 and waste reduction
Reduced temperature process	Electricity and energy saving plant
Ink jet printing of color filter and others	Material recycling

Fig. 1: *Green initiatives in the LCD industry fall under the categories of process, device, or factor. Source: J. H. Souk and S. Whangbo, "Green Technology in LCD," SID Symposium Digest* ***40,*** *106-107 (2010).*

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years ago; today, the LCD TVs consumers seem to covet are far larger, and therefore consume more energy than their smaller counterparts. So now that CRTs have been replaced, a further switch is being made from CCFL- to LED-based backlighting for LCDs. This is also a green story. For one, CCFLs contain heavy metals that make them more problematic to dispose of than LEDs. And LEDs, especially in edge-lit formation, are generally more efficient.

However, it was not energy efficiency that drew the most "oohs and ahs" on the show floor. Those reactions went more to products such as LG's 84-in. 3-D TV (read more on the energy-usage implications of 3-D LCDs in our September issue). But in its 'Next-Generation Display Zone' at the show, LG also featured a 15.6-in. notebook LCD product that the company claimed "realizes the world's lowest power consumption levels." According to the symposium paper on this technology, "New Driving Method for Low Logic Power Consumption in TFT-LCDs" (Paper 43.2) by LG Display Company's Sai Chang Yun *et al.*, this was achieved with a new driving rate method that resulted in 53% power consumption compared to a unit using conventional driving methods.

e-Paper

It wouldn't be right to discuss green displays without at least a mention of e-paper and OLEDs, although this issue of *Information Display* features separate articles on these technologies. e-paper and OLEDs each offer some tempting alternatives to LCDs, both in terms of power usage (e-readers based on e-paper can hold a charge for weeks, for example) and display performance. But both also have drawbacks. e-paper is not quite ready to handle full color and video and OLEDs face some manufacturing hurdles. Nonetheless, one of the most impressive sights at Display Week was simply the latest generation of E Ink's monochrome E Ink, "Pearl," which enables visually pleasing imagery with high contrast and sharp definition. It is an example of an evolutionary improvement that could just be what it takes to make more people buy their first e-reader. The Pearl E Ink, which actually increases contrast by 50%, is used in Amazon's newest version of the Kindle DX (the company literature also says Pearl saves more power than the previous generation of E Ink, but does not provide figures) (Fig. 2).

Materials

One of the most visible green proponents at the show was liquid-crystal developer Merck KGaA out of Germany (factory shown in Fig. 3.) Also using the "triple green" theme of materials, processes, and devices, Merck was handing out "Green^3" pamphlets that highlighted the company's green activities, such as CO_2 reductions (Merck's goal is to reduce them by 20% between 2006 and 2020). The literature also focused on advanced LC materials that reduce backlight power, prolonging battery life for mobile units and reducing power consumption for all devices. Merck also makes reactive mesogen materials that can be used to

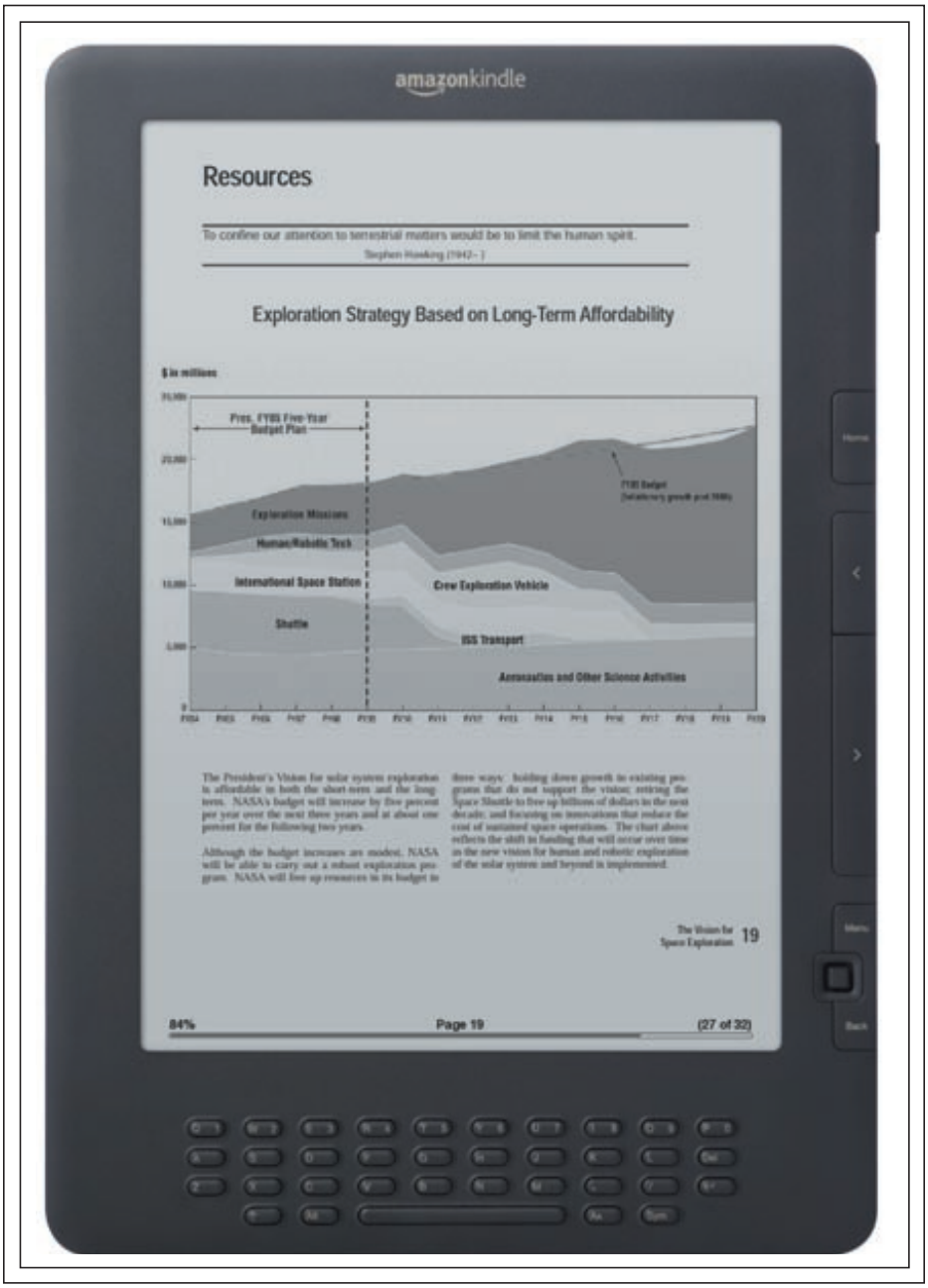

Fig. 2: *The latest e-reader from Amazon, the Kindle DX, features a low-power reflective display based on the latest E Ink technology from E Ink. Image courtesy Amazon.*

Fig. 3: Merck's liquid-crystal production facility in Darmstadt, Germany, is the site of some of the company's green initiatives. Image courtesy Merck KGaA.

improve the brightness of VA-, IPS-, and TN-mode LCDs.

Many other companies were also featuring optical coatings and/or glass designed to brighten or otherwise improve display performance, in many cases reducing power usage. These include 3M, Berliner Glas KGaA, Corning, Dontech, Dupont Display Enhancements, and Sony Chemical, just to name a few.

Packaging

Among all the high-tech green initiatives, it is important to remember that some of the changes with the biggest impact happen at basic levels. Elo TouchSystems, for example, a major developer, manufacturer, and marketer of touch-screen and touch-monitor products, had a packaging and materials story to tell. According to Elo's Keith Pradhan, Director of Product Management, the company has begun using recyclable aluminum and steel chassis. "We've also been looking at recyclable plastic," he says, "but that tends to soften." In addition, the company has redesigned its packaging so as to fit more units on a pallet and thus save shipping costs as well as waste. As is the case with so many green initiatives that actually see the light of day, this one saves money in addition to being good for the environment.

Green Light Ahead

Many of the "greenest" advances are still in the laboratory. Companies such as Merck KGaA are espousing the possibilities of materials such as organic TFT, which does not require the large amounts of chemicals, waste water, gases, *etc.*, that conventional a-Si on glass does. OTFT can be solution–processed by ink-jet printing directly onto plastic substrates. Another promising LC technology, according to Merck, is blue phase, which should reduce the number of required fabrication processes, thereby cutting down on production energy usage and cost. (For more on blue phase, see "Blue Phases for LCDs Based on Isotropic-to-Anisotropic Transitions" in our November 2009 issue.)

Green may seem like the fad of the day. But with environmental awareness becoming increasingly important to consumers and governments, it is unlikely that attention to things green will fade. Even if environmental concerns wane temporarily, as they tend to do, there is always the bottom line. If being green saves money for manufacturers (and does not necessarily cost the consumer more), the greening of displays will continue. ■

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*The MTBF (Mean Time between Failures) is not a guarantee or estimate of product life; it is a statistical value related to mean failure rates for a large number of products which may not accurately reflect actual operation. Actual operating life of the product may not resemble the MTBF.

Navigating through Display Options

When it comes to choosing the right display, engineers must navigate through an obstacle course of options before making the right decision. Once you have scaled the colossal wall of display options to choose from and locked down the environment that the display will be used in, you have to jump though the hoops of system requirements and juggle the projected life cycle for the display – all the while facing the ticking clock of time-to-market pressures. Fortunately, there are resources available to help guide you through the process and make sure you come out on top. Many engineers choose to involve value-added distributors, such as Avnet, in their selection and implementation process – taking full advantage of the additional support they provide. Not only will design engineers have a wide array of products from leading manufacturers to choose from, but they also receive the added benefit of a robust portfolio of services designed to help expedite the product-development process. To make the process feel less like an obstacle course, I have outlined three easy steps to help take the guesswork out of choosing and implementing a display.

Get The Inside Track

Once the display requirements for an application are defined, the next step is evaluating manufacturer offerings to see who provides the solution that best matches your specific requirements. Every brand has its strengths and offers unique features designed to support a particular market or application. Further, the total solution must be considered, including inverters, controllers, cabling, touch screens, and related accessories. To avoid trying to fit a square peg into a round hole, input from a trusted advisor with exposure to a wide range of options is beneficial. Avnet's technical teams, deployed across all local markets, have been trained directly by the manufacturer – attending the same training as the manufacturer's own technical support personnel - and offer a variety of solutions in an unbiased manner and also discuss the various manufacturer product roadmaps. Designers not only benefit from the comparison of today's available solutions, but also get a first-hand look at what technology will be available in the near future. This allows designers to differentiate their product and ensure their competitive advantage is sustained in the future.

Choose the Right Manufacturer

The added information you get from a value-added distributor such as Avnet will help narrow down your search for the right manufacturer whose products will fit the needs of your application. Avnet enjoys strong relationships with many leading display providers - including Optrex, Renesas Electronics (formerly NEC LCD Technologies), Sharp Microelectronics, and Toshiba Electronics. Each of these companies is a recognized leader and innovator in the display technology space. Here are some of the distinguishing characteristics for each of these companies:

OPTREX

Optrex: An LCD manufacturer with over 30 years of experience, Optrex offers:

- Super-high-bright LED and CCFL backlights for outdoor applications, allowing for clear visibility in direct sunlight. Backlighting is available up to 1500 nits with full factory warranty.
- Multiple touch-screen solutions: 4- and 5-wire resistive touch or capacitive touch switch.
- Factory optical / glass bonding options are now available on select modules.
- Long-term product support. Long product life cycle with backward compatibility with new product launches.
- The most complete industrial TFT-LCD line; 2.0-in. QVGA up to 17.5-in. WXGA. Long product life and field-replaceable LED backlights.
- Vivid color. Patented NCM (Natural Color Matrix) technology for a more-true color reproduction.
- Robust design: High performance in any challenging environment; wide temperature range; wide viewing angle; high shock and vibration standard.

RENESAS

Renesas Electronics: A leading provider of high-quality innovative, active-matrix liquid-crystal display (AMLCD) modules for the industrial and high-end monitor markets.

- Modules that range in size from 2.7 to 23 in.
- A variety of resolutions: Quarter video graphics array (QVGA) to quad super-extended graphics array (QSXGA).
- Multiple technologies: transmissive, transflective, SOG, SFT, and more.
- Ideal for a large spectrum of applications, including PDAs, medical equipment, point-of-sale (POS), and gaming.
- Four core technologies:
  - Super-fine TFT (SFT) for ultra-wide viewing.
  - Natural light TFT (NLT) for viewing in a variety of ambient-light environments.
  - Value-integrated TFT (VIT) for compact designs with low energy consumption and multi-functionality adaptive design technology.
  - Adaptive technology.

SHARP®

Sharp Microelectronics: Technology, innovation, and support are the recognized traits of Sharp Microelectronics with products covering the gamut of LCD and panel displays.

- Long-term support of the LCD industrial market with typical life span of 3–5 years. Rugged, high-quality displays for a variety of industrial applications.
- Broad breadth of industrial-application LCDs offering from 1.3- to 28-in.-diagonal sizes.
- Extensive North-American-based technical sales and application support to aid in design-related challenges.

TOSHIBA

Leading Innovation

Toshiba Electronics: The company has been developing its leading-edge LCD technology since 1968, for a wide range of applications which include automotive, industrial, and handheld products, including cell phones, medical products, electronic books, in-flight entertainment, MP3 players, and other mobile devices.

- Low-temperature polysilicon TFT (p-Si) technology.
- 100,000-hours LED-backlight system.
- Low power.
- Wide viewing angles.
- Wide operating temperatures.

As a premier value-added distribution partner for each of these companies, Avnet is ideally suited to offer the correct display for your application. A complete listing of Avnet's display and embedded computing offering can be found at http://em.avnet.com/embedded. We have also just released their online display solutions guide at http://www.displaysolutionsguide.com/landing.php. This guide includes our complete line of supplier panels matched to peripheral part numbers from the manufacturers on our line card, saving time and ensuring that you have the complete solution you need.

Tie It Together With Integration Services

Once the display is selected, making it function in your application is the next critical step in completing the design. Avnet has in-house display-enhancement expertise and industry partners are global leaders and innovators in the field of display enhancement. Regardless of whether the application uses a CRT, LCD, FED, ATM machine, plasma display, touch screen, or projection display, Avnet can help. A custom solution can be tailored to individual requirements, resulting in both time and cost savings.

Panel integration includes cabling and other accessories.

Panel-Enhancement Offerings:

- Film Enhancements (Passive)
- Backlight Enhancements (Active)
- Glass and Film Laminations
- Optical Bonding
- Heaters
- EMI Shielding
- Night-Vision Image Sensing
- Sunlight-Readable Touch Screens
- Rugged LCD Monitors
- Display Integration (Including Enclosures)
- Custom Electronics (Controller Boards)

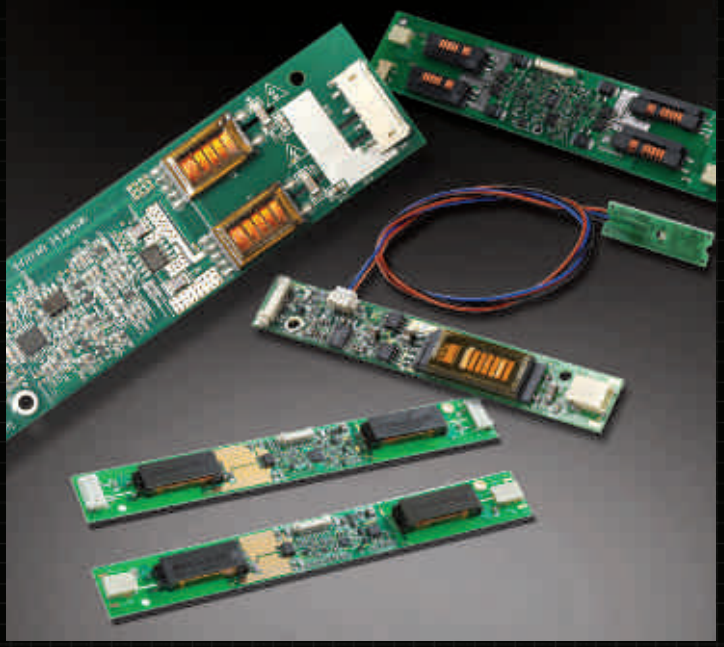
Avnet also provides a high degree of quality assurance through our Global Integration Center located in Chandler, Arizona. In addition to maintaining ISO 9001:2000, 13485 medical compliance and 14001 environmental management system certifications, the Global Integration Center fosters a culture of continuous improvement. In addition, Avnet regularly conducts end-to-end value stream process mapping and improvement and implements numerous quality programs.

While there is no way to side-step the inevitable constraints that come with choosing a display, Avnet can be an invaluable asset in navigating through some of your biggest design hurdles. To find out more, visit http://em.avnet.com/embedded and view a brief video highlighting Avnet's complete portfolio of display products and integration services.

Avnet's state-of-the-art Global Integration Center.

Microsemi Backlight Inverters

CCFL



Microsemi offers a complete portfolio of CCFL system solutions for single, dual and quad lamp CCFL backlit panels with features developed to support safe and robust operations, flexible design in and improved supply chain management. All designs are based on Microsemi patented CCFL drivers IC.

- ***Single CCFL Lamp Panel backlight solutions:***
  - Wide Range Digital Dimming: LXMG1617A-xx-xx
  - Analog Range Dimming: LXMG1618A-xx-xx
  - High Performance – Wide Input/Output Range and Easy Light Sensor Integration: LXMG181x-xx-xx
  - Automotive Grade Solution:LXMG1614E-14-11
- ***Dual CCFL Lamp Panel backlight solutions:***
  - Wide Range Digital Dimming:LXMG1627-xx-xx
  - Analog Range Dimming: LXMG1628-xx-xx
  - Common Lamp Return :LXMG1626-xx-6x
  - StayLIT™:LXMG1626-xx-4x
- ***Quad CCFL Lamp Panel backlight solutions:***
  - Wide Range Digital Dimming: LXMG1643-xx-xx
  - Analog Range Dimming: LXMG1644-xx-xx

LED

High Performance LED System Solutions

Key Features & Benefits

- All products support a Wide Input Voltage Range (4.75V-28V) and Output Voltage up to 35V
- Flexible Design allows matching to a wide variety of panels
  - 1 to 6 Output Strings (strings can also be combined or left selectively unused)
  - Current per string can be easily programmed in steps of 1mA (LXMG1960) or 5mA (LXMG1930)
- 1% typical string-to-string current matching
- Multiple dimming methods such as DC voltage, PWM signal and potentiometer
- Combined analog and digital dimming can provide for greater than 1000:1 ratio
- Multiple Protections including OVP (Over Voltage) and input to monitor and manage LED Over Temperature events

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OPTREX
Flat Panel Display Total Solution Provider

Optrex offers high-bright LED-backlit TFT-LCDs for outdoor use that are very well suited for industrial applications, providing excellent performance, product quality, and long-term support.

Optrex continues expanding their LED-backlit TFT-LCD offering and now offers a full line of high-bright TFT-LCDs with white LEDs for outdoor applications. All the panels are designed for industrial applications, and provide exceptional performance such as high bright or super high brightness, high contrast, wide viewing angle, wide operating temperature range, long LED lifetime, high shock and vibration tolerance, etc. Many of these displays also incorporate Natural Color Matrix (NCM), a color-improving technology for vivid color reproduction.

Available in various sizes and resolutions, including 5.7”, 6.5”, 8.4”, 9.0”, 10.4”, 12.1”, and 15.0”.

Features:

- High brightness up to 1500 cd/m^2
- Long LED lifetime up to 100K hours typical
- High contrast ratio up to 800:1
- Wide operating temperature range up to -30 to 80ºC
- Wide viewing angle up to 85/85/85/85
- High shock and vibration standard
- Anti-glare (AG) surface with anti-reflective (AR) as optional

Benefits:

- High brightness displays ideal for outdoor application
- LED backlights are instantly on, no warm-up time
- Wide dimming ratio
- Lower power consumption compared to CCFL
- Reduce electromagnetic interference (EMI)
- No mercury, environmentally friendly

Applications:

- Portable testing equipment
- Medical applications
- Navigation and avionic systems
- Point of sales and ATM machines
- Outdoor kiosk machines
- Marine applications
- Gas pumps

Part Number	Size	Resolution	Brightness (Nits)	Contrast Ratio	viewing angle	operating temperature	Interface	MP
T-55583GD050J-LW-A-AAN	5.0”	WVGA	800	900:1	85/85/85/85	-20 to 80 C	CMOS	now
T-55629D065J-LW-A-AAN	6.5”	VGA	700	600:1	80/80/60/80	-30 to 80 C	LVDS	now
T-51750GD065J-LW-AON	6.5"	VGA	750	300:1	55/55/60/30	-20 to 70 C	CMOS	now
T-55465D065J-LW-A-AAN	6.5”	VGA	700	600:1	80/80/60/80	-30 to 80 C	CMOS	now
T-55467D084J-LW-A-AAN	8.4"	VGA	800	600:1	80/80/60/80	-30 to 80 C	CMOS	now
T-55562D090J-LW-A-AAN	9.0"	WVGA	800	800:1	80/80/60/80	-30 to 80 C	LVDS	now
T-55532D104J-LW-A-AAN	10.4"	VGA	800	700:1	70/70/65/65	-20 to 70 C	CMOS	now
T-55532D104J-LW-A-ACN	10.4"	VGA	1500	700:1	70/70/65/65	-20 to 70 C	CMOS	now
T-55563D104J-LW-A-AAN	10.4"	SVGA	700	700:1	80/80/60/80	-30 to 80 C	LVDS	now
T-55563D104J-LW-A-ABN	10.4"	SVGA	1200	700:1	80/80/60/80	-30 to 80 C	LVDS	now
T-55586D104J-LW-A-AAN	10.4”	XGA	1000	700:1	80/80/65/65	-30 to 80 C	LVDS	Now
T-55533D104J-LW-A-ABN	10.4”	XGA	1000	700:1	80/80/65/65	-30 to 80 C	LVDS	now
T-55566D121J-LW-A-AAN	12.1”	XGA	1000	600:1	80/80/80/60	-30 to 80 C	LVDS	now
T-55592D121J-LW-A-AAN	12.1”	WXGA	700	700:1	80/80/80/60	-30 to 80 C	LVDS	now
T-55534D150J-LW-A-AAN	15.0"	XGA	800	600:1	80/80/80/60	-20 to 70 C	LVDS	now
T-55534D150J-LW-A-ABN	15.0"	XGA	1500	800:1	80/80/80/60	-20 to 70 C	LVDS	now
T-55519D150J-LW-A-ABN	15.0"	XGA	1100	600:1	85/85/85/85	-20 to 70 C	LVDS	now

Display Week 2010 Review: Flex and e-paper

e-paper technology rebounds with some colorful new possibilities

by Robert Zehner

WHAT A DIFFERENCE a year makes. As I walked the show floor during Display Week 2010, I could not help comparing the state of SID, and of the e-paper industry, against where they both were a year ago in San Antonio. By all measures, Display Week 2010 as a whole has bounced back, with attendance up nearly 100% over last year. e-paper exhibitors who were completely absent from last year's show were back this year with impressive improvements in the performance of their prototypes. Meanwhile, mainstays such as Prime View International (since re-named E Ink Holdings), LG Display, and Samsung continued to show ever more impressive flexible and glass e-paper panels, with features such as in-cell touch and improved color rendition. It's certainly reassuring to see that so many e-paper companies and technologies are weathering the economic storm and are back in growth mode.

On Monday during Display Week, the DisplaySearch Business Conference took place, and Jim Cathey, Vice President of Business Development from Qualcomm MEMS Technologies, compared the current state of the e-reader market to what his company previously experienced in the handset market; as readers evolve from monochrome, static-page viewers through the addition of color, video, and interactivity, the power demands of the devices will skyrocket, while battery technology will continue to improve by a meager 3–5% per year. "When we look at the market for e-readers," said Cathey, "we see history repeating itself." He posits that the only way to break this cycle is by adopting full-color video-rate reflective display technologies with ultra-low static power consumption. Further, Cathey stated that longer battery life will increase average revenue per user (ARPU), the key measure of success for mobile network operators. His reasoning is simple enough: a device with a dead battery cannot be delivering advertising impressions to its owner.

Cathey's comments, while intended to promote Qualcomm's own mirasol® display technology, are clearly influenced by the entry of the Apple iPad into the tablet market in April 2010. In contrast to e-book reading devices from Sony, Amazon, Barnes and Noble, and others that achieve long battery life by using image-stable displays, Apple paired a backlit LCD with a substantially larger and heavier battery to deliver up to 10 hours of use per charge. The common goal for all of the e-paper vendors that I spoke with is to

Fig. 1: *Qualcomm exhibited color and monochrome 5.7-in. XGA displays built with its mirasol® MEMS technology.*

Robert Zehner *has over 10 years of experience in developing and commercializing e-paper displays, most recently as Director of Technical Sales at E Ink Corp. He serves as a member of the flexible displays subcommittee of the SID Technical Program Committee and is a frequent contributor to* Information Display. *He can be reached at rzehner @pobox.com.*

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develop a display with color animation capability, while maintaining ultra-low power consumption and excellent viewability, ultimately combining the performance of a tablet computer like the iPad with the thinness, light weight, and long battery life of an e-reader.

On the show floor, Qualcomm had numerous working samples of its mirasol® displays, including several samples of a 5.7-in. color XGA module. (Fig. 1). These prototypes showed marked improvement in color saturation over demonstrators from previous years, while delivering 23% brightness with an 8:1 contrast. Qualcomm representatives indicated that they expect pilot-scale production to begin in late 2010, with full mass production to follow.

Electrowetting-display manufacturer Liquavista was also represented in the business conference. In his talk, Liquavista CTO Johan Feenstra emphasized that customers expect future e-reading devices to deliver color and video performance, with good power consumption and low cost. Without going into detail, Feenstra explained that Liquavista can vary the addressing scheme for its displays to trade-off power consumption and response speed, which would support both full-speed video at higher power, and static viewing with much lower battery drain. Accordingly, Liquavista exhibited a color-filter-array display showing both magazine pages and simple animations (Fig. 2). A static display with a flashing colored backlight hinted at the company's planned Liquavista-Vivid platform, which will combine a monochrome reflective operating mode for reading and outdoor use with a color-sequential backlit transmissive mode for indoor use.

In the particle-based display arena, Japanese display developer Bridgestone had previously shown high-quality color and monochrome signage products that were limited by a relatively slow update time. Although Bridgestone's quick-response liquid powder (QR-LPD) can be switched in a matter of milliseconds, refreshing the display previously required multiple scans through each line, taking 10 sec or more. At this year's show, Bridgestone demonstrated its AeroBee e-book concept, an A4-sized color reader with pen-based touch and real-time handwriting recognition. According to Bridgestone representatives at the show, the improved response was achieved by only updating the portions of the display that are changing, leading to almost instantaneous transitions for mark-up with the pen. By using the same update method, the AeroBee prototype was also able to show video clips, although the animation was limited to the bottom portion of the display and appeared somewhat blocky.

Fig. 2: *Liquavista's e-reader prototype display achieves color via a color-filter array atop a monochrome electrowetting medium. Future generations may use a color-sequential backlight instead.*

E Ink, a name that has become almost synonymous with e-paper, has undergone some corporate changes over the past year. The Cambridge, Massachusetts-based start-up was purchased in December by Taiwanese display-maker Prime View International. Then, in mid-June (several weeks after SID), Prime View changed its name to E Ink Holdings, in recognition of its commitment to the e-paper business. "The E Ink name is synonymous with the e-paper industry that we pioneered and in which we enjoy a leadership position," said Dr. Scott Liu, Chairman and CEO of E Ink Holdings, Inc., of the name change.

E Ink's technology was represented in multiple places at SID, both in its own booth and in demonstrators shown by display-makers LG Display and Samsung. All three companies showed off their latest generation of color demonstrators on both glass and flexible substrates, in sizes ranging from 6 to 11 in. on the diagonal, consistent with E Ink's plans, announced earlier this year, to commence production of color displays by the end of 2010. E Ink's booth also included a gallery of over 20 different e-reader products from around the world that are currently in production using the company's technology.

It's worth noting for a moment that none of the commercial e-reader products featured in E Ink's booth (or anyone else's for that matter) yet include a non-glass (flex) display module. Plastic Logic pre-announced its Que reader at CES 2010, but is not yet shipping product as of this writing. Rollable-display-developer Polymer Vision declared bankruptcy in 2009, only to be snapped up by Wistron, a major Taiwanese OEM, which has so far been quiet about any possible product launch. Skiff, formerly a division of Hearst Corp., previewed a reader based on LG Display's 11.5-in. stainless EPD at CES – but Skiff's recent sale to Rupert Murdoch's News Corporation explicitly excluded the reader hardware. Nonetheless, with multiple vendors producing increasingly compelling flexible prototypes, one would hope that a volume product launch is still just around the corner.

flex and e-paper

In the display industry, the name Merck (officially called EMD Chemicals here in the U.S.) is synonymous with liquid-crystal chemistry. LCD researchers and manufacturers around the world rely on Merck to supply just the right LC mixture to produce their desired display effect. According to Merck's Mark Goulding, the company may be about to expand its reach into materials for e-paper. In an invited symposium talk delivered as part of Wednesday afternoon's e-paper session, Goulding showed his promising results in synthesizing a variety of brightly colored particles and compounding them into electrophoretic suspensions.

Particle electrophoresis is the core technology behind EPD companies such as E Ink and SiPix Imaging, which to date make up the lion's share of e-paper products on the market. Today, these companies formulate their own materials using closely guarded recipes. In his talk, Goulding suggested that Merck is evaluating whether to offer its own electrophoretic mixtures in the market, which could open up an opportunity for other display companies to experiment with this hot new technology. This probably will not happen tomorrow since Merck's formulas will need more fine tuning before rolling out. As an example, Goulding was not ready to comment on image stability, saying only that it is an area of active research at the moment; image stability is what allows e-readers to keep their image for a long periods of time without requiring a refresh and is critical to ultra-low-power operation of EPDs.

With an established and building demand for reading devices, the e-paper-display business segment is growing and maturing as quickly as ever. While electrophoretic displays have taken an early lead, competitors are redoubling their efforts to bring a variety of competing technologies to market. At the same time, Apple's launch of the iPad with a backlit LCD presents a new set of challenges and opportunities for ultra-low-power displays. All in all, the next year promises to be at least as interesting as the past one for e-paper. ■

Display Week 2010 Review: 3-D

3-D displays go mainstream.

by Alfred Poor

ONE MAJOR REASON to attend Display Week year after year is to see the new technologies as they develop. Some come and go, but some eventually make it to the retail market. This is the year that 3-D displays have really cleared that hurdle and are finding their way into retail channels at last. This does not mean that we are finished with the development of 3-D displays; to the contrary, we've only just begun.

3-D was in evidence throughout Display Week, with many different approaches on the show floor, seven of the 77 technical paper sessions, and a full evening of 3-D cinema demonstrations. Tracking the state of the art and what will likely come next was a full-time occupation at Display Week 2010.

Here and Now

SID drove a stake in the ground, marking the advent of the 3-D television age, with its choice for the Gold Winner of the SID Display of the Year Award. LG's 47-in. LCD panel is 3-D ready, and unlike many designs that rely on active shutter glasses, it works with passive polarized glasses similar to those often used in movie theaters. (The passive polarized glasses do not rely on batteries.) A patterned retarder on the display alternates the polarization of each line in the display, creating a half-resolution image for each eye all the time.

The winner of the Silver Award for Display Component of the Year was RealD for its XL Cinema System, which mounts externally to an existing digital projector. This eliminates the need for a second projector or complex alignment and is a system that can be quickly and easily changed back and forth between 2-D and 3-D modes. It provides frame-sequenced alternate polarization for the left- and right-eye images, and audience members can use passive polarized glasses to see the stereoscopic images.

While its booth was small, Panasonic showed off some of its products that are ready to deliver stereoscopic images for consumers. From a professional dual-lens video camera (vaguely reminiscent of the main character in *Wall-E*) to large plasma screens ready for 3-D images, Panasonic clearly has invested in creating a stereoscopic ecosystem for consumer entertainment (Fig. 1).

The IMS Market Focus Conference TV 3.0 spent most of its first day just on 3-D TV, 3-D cinema, and related topics. From panels and

Fig. 1: *The Panasonic professional 3-D camera can capture stereoscopic images in real time; see the double image of this article's author as he took this photo. Photo courtesy Alfred Poor.*

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components to content delivery, the presenters provided a deep and wide look at the 3-D markets.

Can You Believe Your Eyes?

One of the hot topics about stereoscopic displays is whether or not there is sufficient content available to justify their purchase by consumers. (For more on this topic, see this month's Display Marketplace article, "Broadcast and Production Embrace 3-D.") One school of thought states that nothing less than content captured in native 3-D is worth watching (and even then there are many pitfalls to be avoided that could ruin the shoot). Others concede that when performed carefully by experts, it is possible to extract depth information from 2-D original content and obtain results that are worth watching. Still others contend that real-time conversion of 2-D to 3-D content may not be as good as native 3-D content, but is adequate for most viewers.

Those who attended the special Display Week 3-D Cinema Event on Tuesday evening had the opportunity to judge stereoscopic content quality for themselves as dozens of short films and trailers were displayed on a 30-ft. silver screen. The images were shown using an NEC three-chip DLP digital cinema projector with a RealD XL stereoscopic system. Clips included commercials, movie trailers, animated sequences, and converted 2-D content. There was even a short clip from the 1947 Russian film *Robinzon Kruzo* that was converted to modern 3-D image files.

This content was presented without commentary, other than that the selections were chosen to represent a cross-section. As a result, some of the pieces were stunning, such as certain car commercials in which the depth effects greatly enhanced the experience of viewing beautiful designs. In other cases, however, some of us gasped and took our glasses off as quickly as possible when the depth data was poorly rendered. This happened most frequently in title sequences where the text and graphics were presented as an overlay in front of a live-action background. The conflict between visual cues was painfully disruptive. And "negative Z" effects, in which objects appeared to be between the viewer and the screen, were the ones most likely to offend one's viewing systems.

Autostereoscopic

One limitation of stereoscopic images is that they typically only have two images: one for the left eye and one for the right eye. This is sufficient for creating the impression of depth in the combined image, but it does not let you see motion parallax in the image. In other words, you cannot move your head to "look around" an object in the foreground to see what is behind it. A new photo frame shown by Newsight Japan solves this problem with some clever processing. It can start with either a native stereoscopic image or just a 2-D digital photo. It then synthetically creates five different views of the scene and displays it on the special autostereoscopic panel (Fig. 2). It really works best for a single viewer, for whom the effect is surprising. By moving your head from side to side, you can see what is behind objects in the image. For now, the processing is done on a PC, but the next version is slated to do real-time conversion using on-board processing.

Both LG and Samsung showed a variety of stereoscopic and autostereoscopic displays. LG stole the show with its 84-in. UHD LCD television, having the resolution of four 42-in. 1080p sets combined. Fraunhofer HHI demonstrated the Free2C, a single-viewer autostereoscopic system that uses head tracking to steer the images toward the user's eyes. It relies on a fast real-time subpixel sorter with a parallax barrier to adjust the image.

Both Toshiba and 3M showed an improved autostereoscopic single-viewer mobile display. Based on the same technology that the companies demonstrated last year, this frame-sequential system relies on a pair of LED edge lights with an OCB-LCD panel. When the left light is on, the right-eye image is displayed, and a special film directs the light just to the right eye. Then the left light turns off and the right light turns on, and the left image is directed just to the left eye. The "sweet spot" for the stereoscopic effect is rather large, making it easy to use. However, if you get too far off to one side or the other, the effect fails gracefully; you simply see just one image at a lower brightness. The film that makes this possible is just 0.1-mm thick.

None of the autostereoscopic demonstrations indicated that these will be viable options for anything but single-viewer displays any time in the near future. Even the complex head-tracking system was limited to a single viewer. Based on what was exhibited, multi-viewer autostereoscopic displays are still a long way off.

So with a little old news, a bunch of current news, and a whole lot of just-over-the-horizon news, it is clear that the stereoscopic 3-D industry has been well-launched and thriving,

Fig. 2: *The autostereoscopic photo frame by Newsight Japan creates five views of a scene so that you can "see around" objects in the foreground. Photo courtesy Alfred Poor.*

and the autostereoscopic industry is still developing. The displays on exhibit provided reinforcement for the position that mainstream 3-D displays for multiple viewers – especially at home – are likely to require either active or passive glasses for many years to come. So, 3-D is now an established part of the commercial display landscape, but we are still looking forward to Display Week 2011 to find out how it will develop next. ■

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Broadcast and Production Embrace 3-D

Content providers and consumer-electronics companies are already behind the move to 3-D. Now, professional broadcast and production vendors are joining in to help provide critical mass.

by Chris Chinnock and Matthew Brennesholtz

IN APRIL, the National Association of Broadcasters (NAB) held its annual exhibition in Las Vegas. The NAB show is geared to the latest technology in mobile, terrestrial, cable, satellite, and Internet broadcasting, and encompasses the creation of content, post-production, live-broadcast events, and the management and delivery of content to consumers' homes. Stereoscopic 3-D was certainly the most visible technology innovation at this year's show. As a result, it now seems clear that the current wave of interest in 3-D for consumers will continue. All hardware and software suppliers to the broadcast and production communities are now on-board and offering products to serve the 3-D segment.

The change in attitude toward 3-D from last year's event to this year's was profound. In 2009, a handful of companies showed 3-D products and many noted that they were studying 3-D. But a year later, every aisle at NAB had 3-D products and services and nearly every company was talking 3-D (see Fig. 1). Some of this seemed more talk than fact, but the fever has taken hold. As one of Insight Media's analysts, Bernard Mendiburu, noted, "It seemed like 5 NAB years had passed in a single year." That's how rapid and dramatic the shift has been.

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Factors Behind the Rise of 3-D in Broadcasting and Production

There seem to be multiple factors for the sudden change in emphasis. One is that 3-D content is being created and pushed by the major Hollywood studios, and this effort is meeting with great success (and profits) in theaters. Studios are also pushing to move this same 3-D content into the home because a large percentage of Hollywood revenue comes from non-theatrical sources. More and more 3-D content will also come from ESPN, Discovery, and a host of new channels and content producers. The 3-D pipeline is filling, so this piece of the infrastructure is maturing rapidly.

Next, TV makers have introduced 3-D TVs with many advanced features – Internet connectivity, LED backlights, Widgets, Skype video conferencing, and more – not just 3-D capability. Consumers will buy these TVs for 3-D and the other features, creating a growing installed base of 3-D-capable TVs. The Blu-ray 3-D specs have been established, as have specs for delivering 3-D over HDMI cables. So the pieces are in place for 3-D in the home. Pricing is at the high end of the range for these products, but the premium for a 3-D-capable TV compared to the premium for an HDTV over a standard-definition TV 10 years ago is significantly lower.

Finally, it is vitally important to be able to deliver 3-D content via cable and satellite services. Having made a costly investment in upgrading the infrastructure to support digital and high definition, this part of the chain does not want to make a similar investment for 3-D. For cable and satellite service providers, squeezing 3-D into the existing infrastructure is a must if early 3-D rollouts are to be enabled. Fortunately, this is possible and exactly what is being done. The two high-resolution stereo images are filtered (sampled or decimated) and then packed as side-by-side or top/bottom images in a standard video frame. This is the so-called frame-compatible approach. This signal can be processed, compressed, transmitted, and decoded like any other 2-D video signal. For the most part, some minor firmware upgrades are all that are needed to enable transport and delivery of 3-D signals to a consumer's 3-D TV. Only when the content gets to the TV does the TV recognize it as 3-D and process it to display a 3-D image. For an overview of the flow of 3-D content into homes or movie theaters, see Fig. 2.

There are two main disadvantages to this approach, however. First is the obvious fact that this decimation of the image significantly reduces image quality. With some types of proprietary encoding, such as that provided by Sensio or RealD, the image-quality reduction is not really significant, but then you need the proprietary decoder at the receiver. If you do not have the right decoder in your 3-D TV, the signal will still be viewable in 3-D, but there will be a significant loss in image quality. And, as we have seen from some early demonstrations such as the Master's

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Tournament in HD 3-D, the bit rate devoted to the 3-D signal is important, with 18–20 Mbps clearly being the best choice for HD image quality.

The second problem is that the frame-compatible approach doubles the required bandwidth – but in a not-so-obvious way. Since this frame-compatible 3-D image is not viewable as a 2-D image on a 2-D set (a side-by-side or top/bottom image is seen), the cable company must have a second channel to deliver the 2-D signal. For the near future, broadcasters are planning only a few 3-D channels to go along with their many 2-D HD channels so we do not see separate 3-D channels as a major issue for now. If 3-D broadcasting becomes common, it may be more of an issue, but alternative solutions are being developed now.

Business Model

The bottom line is that all of the pieces of the value chain to create and sustain a 3-D TV service for consumers are in place. But is there a business model to support this? It would appear that there is.

For example, TV is supported ultimately by subscription fees and advertising. While consumers might pay more for a 3-D video on demand of a pay-per-view event, as they do in the theaters for a 3-D movie, advertisers must also embrace 3-D. Panasonic and others are helping to prime the advertising pump by injecting some big bucks to sponsor the establishment of 3-D services from DirecTV. This allows DirecTV to help pay the bills while it figures out the service and gets advertisers onboard, and while consumers buy 3-D TV sets. This is a brilliant risk-reduction strategy that jump-starts the market.

Companies in the content creation and broadcast arenas can also manage risk. One theme we heard at NAB from the equipment vendors is that the broadcast industry is not buying 3-D equipment. Companies are buying digital HD production, post-production, and broadcast equipment – but requiring that it be 3-D ready or field-upgradable to 3-D with software or firmware changes. In some cases, vendors describe their 3-D path as adding a second identical piece of equipment to handle the two signal paths. But vendors with only 2-D HD equipment not suited for upgrade to 3-D seem to have been getting the cold shoulder. This shows that the infrastructure upgrade to support 3-D is dovetailing

Fig. 1: *The 3D Hero camera from GoPro belongs to a line of professional-level, wearable, HDTV and action-sports cameras. It is expected to be available later this year.*

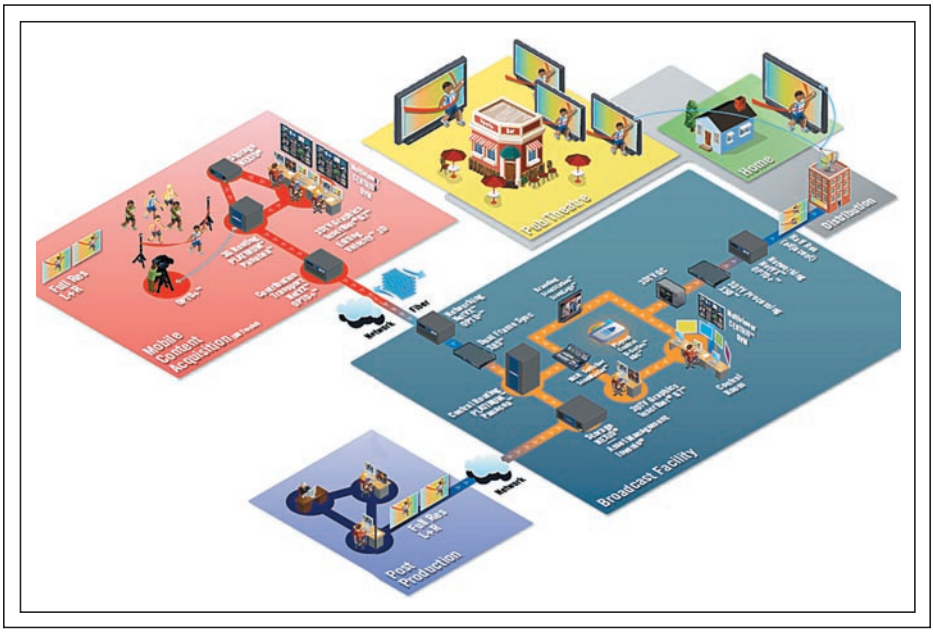

Fig. 2: *3-D content flows from acquisition though post-production and broadcast formatting to delivery in homes and theaters. Image courtesy Harris.*

well with digital HD production and broadcast needs, lowering the risk of support. And adding 3-D capability to most equipment is not such a big deal, as most vendors have been able to do this in 1 year. Future proofing, editing, and broadcast control suites for 3-D is nowhere near as intensive an investment as was the HD upgrade.

3-D Production and Broadcast Equipment

There are areas that do require dedicated 3-D equipment, however, including cameras, camera processors, and displays. For example, stereoscopic 3-D cameras typically use two sensors and two lenses to capture the left/right image pair. These cameras can be configured in a side-by-side manner or in a beamsplitter arrangement with a precision optical element positioned between the two cameras, which are orthogonal to each other. These 3-D rigs need to perform all the 2-D camera functions, plus some 3-D ones. The distance between the cameras usually needs to be varied to obtain the right 3-D perspective. The cameras may have to be "toed in" just as our eyeballs toe-in to look at closer objects. In addition, the camera motion, stability, and matching of lenses and other parameters are all very important for good 3-D acquisition. Last year, there were perhaps a half-dozen 3-D camera-rig models available worldwide. At NAB this year, there must have been close to two dozen and at a wide variety of price points. This is a needed part of a healthy ecosystem.

For 3-D displays, two types are being used by the professional community: one is the beamsplitter type, in which two flat-panel displays are positioned at right angles to an image combiner. These are often boxy monitors but are popular for monitoring 3-D images during movie or event shooting. Passive polarized glasses allow both images to be seen simultaneously, but by different eyes.

The second type is the X-pol or Micro-pol. This display features a sheet of retarders that is laminated over a flat-panel display. The sheet converts the polarization of the panel such that even rows have one circular polarization state and odd rows have the opposite state. Passive polarized glasses then allow the viewing of the 3-D image. These specialized 3-D monitors are not likely to be used for 2-D work, so they are an investment upgrade.

Note that both of these approaches use passive polarized glasses (see Fig. 3) and not the active shutter glasses favored for home-based TVs. For the home environment, TV manufacturers did not want to put the 3-D cost into the display, but into the glasses that the consumer buys, thereby making the TV pricing more competitive. In the professional world, long hours of use and fears about interference in the image quality by the shutter glasses mean passive approaches are preferred. In addition, in the professional production, post-production, or broadcast environment, there are likely to be multiple 3-D displays visible at a time. Passive glasses bypass the issue of synchronizing all these displays so the operator sees the correct image on all displays at all times. These users will pay more for the display and less for the glasses because this technology better suits their needs.

It should be noted that anaglyph glasses are also used in editing and broadcast suites and will continue to be in use for some time, we suspect. There are two reasons for this. First, any 2-D display can be used to view 3-D with anaglyph glasses. Second, it provides an easy and effective way to monitor the 3-D image even without the glasses on. When a red/blue anaglyph 3-D image is viewed without glasses, it provides a quick and accurate indication of parallax. If the blue fringe is to the left and the red fringe is on the right, parallax is positive and the object will appear safely behind the screen. If the colors are reversed, parallax is negative and out-of-screen effects are occurring, potentially causing viewer eyestrain.

We do not see 3-D monitors being used for critical activities such as color correction or even for editing. For the most part, editing of 3-D content will be done in 2-D and checked in 3-D. Color grading will also be done using Grade-1 2-D monitors for the foreseeable future. However, editing and color-correction software and hardware are coming to market to make it easy to replicate the edits and color correction from one image to other images, thereby reducing the production/post-production time for 3-D content.

3-D Workflow

"Workflow" is a key buzz word in the post-production and broadcast industries. It refers to how content flows from one stage of the process to the next – ideally easily and seamlessly. While 3-D workflow is not yet as seamless as 2-D workflow, it is getting there.

New processors and encoders may be needed to support 3-D. The processors can manage things such as camera metadata, which include zoom, focus, position, toe-in, convergence, and color space. Some of these

Fig. 3: *This viewfinder from Miracube for a 3-D camera system is based on micropolarizer technology and passive glasses.*

parameters are all needed by 2-D workflows, but new parameters are needed by the 3-D workflow to help assure a well-aligned and well-composed 3-D shot. Encoders will need upgrading to support the two high-quality 3-D images and to filter and pack them for transport in various parts of the distribution chain. There may also be proprietary encoders involved to improve image quality.

Digital Production and Digital Products Are Aligning

In conclusion, NAB 2010 was not the NAB show at which 3-D became common. Rather, it was the NAB show at which everyone recognized the need to be ready for the arrival of 3-D broadcasting in the near future. One of the promises of digital systems is their easy upgradability for new applications. The dramatic 1-year growth of available 3-D equipment and 2-D equipment future-proofed for 3-D is a sign of the industry making good on this promise.

Comparing NAB 2010 to CES 2010 is an interesting exercise. CES provides insight into what consumer-electronics companies are thinking, especially with regard to 3-D TVs, which were a major theme of CES 2010. NAB reflects the views of broadcast, production, and post-production. These views from both areas of 3-D are now aligning. Insight Media and others are forecasting strong sales of 3-D TVs, and it appears the content and infrastructure will be there to support those sales. It now seems clear from NAB that more 3-D content will be created and the production and distribution mechanisms will be in place to support a ramp up of 3-D. However, the last and most important issue is consumer acceptance of 3-D. We think 3-D will be accepted by consumers for event-driven viewing, but realistically, it is too early to know the answer to how much other such viewing they will accept. The first 3-D TVs and 3-D services are starting to roll out now, so the answer will become clearer in the coming months and years. ■

Display Technology at the 2010 North American Auto Show

Modern automobiles contain a great deal of electronics, including a significant number of information displays. At the North American International Auto Show in Detroit last January, a showcase for the latest in autos and automotive electronics, there was no shortage of great examples of display technology at work.

by Alan Sobel

AS ANYONE WOULD EXPECT, the show had plenty of glitz – shiny cars; fancy configurations of lamps, fenders, and wheels; and pretty women – but also impressive technology. For example, instrument cluster and "infotainment" gadgetry are part of manufacturers' quests to differentiate one auto from its competitors, but there are also some sound technical reasons for at least some of the devices. The space behind the dashboard is very crowded with instruments, controls, wires, and ventilating ducts. Removing the mechanical gauges and replacing them with flat-panel displays can save space as well as enable easy changes of the instrument panels among different car lines. It is even possible for drivers to change the configuration, moving around temperature and pressure indicators, warning lights, and so forth to suit their convenience. Of course, this can lead to confusion if different drivers of the same car have different preferences.

Currently, most electronic displays are flat, but curved and flexible displays are coming, giving designers even more freedom to locate and configure the displays. One trend in this direction is the use of compact projectors rather than direct-view displays. While these can require greater volume behind the dash than flat panels, they make possible even more freedom to display the information on warped surfaces.

Another possibility is the use of head-up displays (HUDs), which project the information onto the windshield. These can be particularly useful in conjunction with night-vision systems. In daylight, though, symbology

Fig. 1: *The navigation screen (top, center) pops up on the dashboard of a Volvo.*

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superimposed on the outside world may be a source of driver confusion. Although HUD technology has been around for many years and is widely employed in aircraft, it has been too expensive for much use in civilian autos. The only HUD actually seen at the show was in a Mercedes.

Most navigation displays in vehicles at the show were located in the center of the dashboard, requiring the driver to look away from the road to see and interpret the information. Volvo had a display that popped up in front of the windshield but still in the center of the dash, to the side of the driver's forward view (see Fig. 1). The small GPS that I can attach to my windshield with a suction cup is much more convenient; I put it at the bottom left of the windshield where I can read it easily, but it does not obscure the outside world.

Vehicular displays do not have to be particularly fast (except for camera readouts used to see the back or blind spots), but they do have to be bright enough for daylight use and dimmable for night operation. The driver's instrument panel need not have a very wide viewing angle but a navigation display located at the center of the dash must be readable by both driver and passenger.

Major controls – shifters, mirrors, and door and window controls – are located in the same places on most automobiles, a substantial convenience for those of us who frequently drive different vehicles. There are SAE (Society of Automotive Engineers) standards regarding permissible locations for displays relative to the view of the outside world, and the distances the driver must reach to operate controls. I believe that these standards are, for the most part, being followed by manufacturers.

On a similar note, the various auxiliary devices – navigation systems, satellite radios, and voice-controlled cell phones – all have the ability to distract the driver from his primary tasks of driving the vehicle and avoiding accidents. There is already much evidence – more than just anecdotal – that the use of cell phones while driving is a substantial contributor to accidents. While some of these devices may be disabled when the vehicle is in motion, for many drivers this functionality will be viewed as merely a pious notice not to use the gadget while driving – something easily ignored. We are seeing some clamor to forbid texting while driving, but texting is now only one of a number of electronic distractions competing for the driver's attention.

Technology can improve safety: anti-collision radar, automatic stability control, and automatic headlamp dimmers are just a few examples. However, some of the possible and advertised gadgetry can have dangerous consequences. We have recently seen major problems with electronic technology applied to automobiles; Toyota's recent difficulties are perhaps the outstanding example. There are, I think, two major areas of concern. The first involves mission-critical systems such as speed control that must function with complete reliability and in a fail-safe manner. Then there are the auxiliary systems, such as entertainment and navigation devices, which must be designed so that they do not interfere with the primary considerations of safety. Engineers, as well as marketers, must bear all these factors in mind. All in all, electronic displays can be used in vehicles to significantly improve the driver's operating experience and improve safety – if properly deployed and tested and if they do not distract the driver from the primary task of driving. Based on this year's exhibits, the auto industry is at least paying lip service to the idea that infotainment displays should not be driver-distracting displays. ■

Intellectual Property Issues at Trade Shows

Trade shows play a vital role in conducting business effectively, but it pays to do the homework first to see how to protect your intellectual property and to avoid conflicts with the intellectual property rights of others.

by Y. Jae Kim

IF YOU WORK in any industry, chances are good that you have attended, displayed at, or worked at a trade show for that industry. And while trade shows are invaluable sources of exposure, education, contacts, and business deals, certain intellectual property (IP) issues can arise at trade shows that anyone involved should keep in mind. While your specific job function – be it engineering, marketing, or manufacturing – may not be related to the law, you would be surprised by the various IP issues that can arise at trade shows and that could directly impact you and your company.

Patent Perils

IP can broadly be defined as subject matter that covers patents, trademarks, trade secrets, and copyright. While trademarks, trade secrets, and copyright issues may certainly come up at trade shows, this article focuses primarily on patent issues. In extreme cases, certain actions conducted at trade shows could cause your company to lose patent rights or may negatively impact your company's ability to protect its new and unpatented invention(s).

So what type of patent issues can arise at trade shows and how would they affect you or your company? For starters, your goods can be raided by the police if they believe you are displaying an allegedly infringing product. Further, your company may be sued for patent infringement by selling or offering to sell allegedly infringing products at a trade show. (For purposes of patent infringement, it does not matter where the sale or offer for sale occurs in the U.S. But trade shows are particularly of interest because of their general nature and purpose: to show and market goods.) And, if that is not enough, your company may be sued for merely bringing allegedly infringing products to a trade show.

What Constitutes Patent Infringement?

In general, you can be held liable for patent infringement in the U.S. if you, without the proper authorization:

1. Manufacture or make any patented product within the U.S.;
2. Use any patented product within the U.S;
3. Sell or offer to sell any patented product within the U.S.; or
4. Import, *i.e.*, bring into, the U.S. any patented product.

True-Life Situations

For example, assume that you are a non-U.S. company, "Anywhere Co.," attending the annual Widget Expo as an exhibitor. Let's also assume that this is your first and only contact within the U.S. for which you are exhibiting, for the first time, your new Display Widget (DW). Lastly, let's assume that Acme Display Co. holds a valid and enforceable U.S. patent for a display widget that your DW infringes.

In this scenario, since the DW is an infringing product, Anywhere Co. can potentially be liable for patent infringement merely by bringing the DW into the U.S.; *i.e.*, Anywhere Co. imported into the U.S., without authorization, a product covered by a U.S. patent held by Acme Display Co. This appears to fall within the letter of the law for patent infringement. But it may seem a little unfair to Anywhere Co. Can Anywhere Co. actually be hauled into a U.S. court and be forced to litigate a costly patent infringement case merely because it brought its DW product into the U.S.?

Apparently so, and that is essentially what happed to one Brazilian company by the name of G.M. Reis. G.M. Reis has no offices, employees, or assets in the U.S. and had only episodic contacts with the U.S. prior to being sued by Synthes, a U.S.-based company. In 2007, G.M. Reis purchased a booth at an orthopedic trade show in San Diego, California, to display (not sell or offer for sale in the U.S.) several of its bone-plate products that it brought into the U.S. At the trade show, Synthes served a complaint on G.M. Reis for patent infringement at its booth. The case went all the way to the United States Court of Appeals for the Federal Circuit, where the

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Court held that, yes, even with G.M. Reis's very minimal contacts with the U.S., jurisdiction by a U.S. District Court is reasonable and fair.[1]

Consider also the fairly recent raids and confiscation of goods from trade show exhibitors by the police in Germany. In March of 2008, more than 180 German police officers, customs officials, and prosecutors raided 55 exhibitors' booths for allegedly displaying infringing products at the CeBIT trade show.

Protecting Your Own IP in Public

Besides patent infringement issues, patent issues also arise at trade shows in the context of public disclosure. If your company is like most, you will be displaying some of your latest and greatest products at a trade show. However, by doing so without initially taking the proper measures, you may potentially forfeit your patent rights in any such disclosed product. This can occur because an invention can become publicly disclosed by being merely displayed as a device that embodies the invention at a trade show or is discussed with a potential customer at a trade show. This public disclosure starts a 1-year clock running on a statutory bar in the U.S. in which to file for patent protection on the invention. Outside the U.S., your patent rights can even be forfeited entirely by your public disclosure.

Your Trade Show To-Do List

Here are a few things to keep in mind before going to a trade show:

(1) If you are a foreign entity bringing products into the U.S. for a trade show, remember that such actions can constitute importation of the product. Do your homework and be mindful of the patent landscape in your industry. Defending a patent litigation is potentially very expensive.

(2) Assuming you are not importing a product into the U.S., patent infringement can also arise when there is a "use," a "sale," or an "offer for sale" of an allegedly infringing product without the proper authorization of the patent holder. However, there is some good news in that the Courts have held that "the mere demonstration or display of an accused product, even in an obviously commercial atmosphere"[2] does not give rise to an act of patent infringement. Further, in order for there to be an offer for sale of an allegedly infringing product, such activity must include pricing terms. Thus, to avoid falling under the realm of an "offer for sale," you should avoid discussing pricing as much as possible. As for a sale of an allegedly infringing product, that is pretty straight forward; no sale, no act of infringement.

(3) While you may not be directly involved in protecting your company's intellectual property at a trade show, speak to your company's IP representative or IP counsel to confirm that your activities and the products you are showing will not jeopardize any potential intellectual property rights. If you are displaying or would like to display a new product, discuss it with your IP counsel and take the proper measures. For example, your company may want to file a patent application to cover any new product designs before a public disclosure is made. An ounce of prevention can be worth several million dollars when it comes to patent rights and patent litigation.

(4) Trade shows are often a venue in which violations of IP rights are discovered. Since enforcement of IP rights is a self-policing activity, you should keep an eye out for what may be a violation of your company's patent, trademark, copyright, and even trade secret rights.

(5) If you come across potential infringement of your company's product at a trade show, you must also be mindful of declaratory judgment actions; *i.e.*, if a party is threatened or believes that it may be sued for infringement, that party may have the right to file suit first, which may provide it with certain advantages in litigation, such as choice of forum (*i.e.*, where the suit will be tried). Thus, it is best to discuss the potential infringement with your company's IP representative or IP counsel before confronting a potential infringer at a trade show.

(6) Lastly, if you are a U.S. entity attending or displaying at a trade show outside the U.S., remember that your U.S. patent and other U.S. intellectual property rights are only valid in the U.S. Someone else, or nobody, may own intellectual property rights that cover your products outside of the U.S. So again, do your homework and work with your IP counsel or IP representative to see what measures need to be taken to avoid conflicts with the IP rights of others. The U.S. Department of Commerce also provides valuable information and strategies for handling IP issues outside the U.S. And do not forget that international trade shows offer excellent opportunities for monitoring international infringement of your IP rights.

Be Forewarned *and* Forearmed

None of the above is meant to discourage anyone from attending or exhibiting at trade shows. As you are likely aware, trade shows represent an opportunity for companies to see and be seen, to share information and discover synergies, that is really unparalleled by any other platform. But it is a good idea to be aware of the potential pitfalls before you or your company sets foot on the trade-show floor. Armed with all the pertinent facts and necessary prep work regarding your IP and the IP of others, you can then relax and enjoy all that the show has to offer.

References

[1] *Synthes* (U.S.A.) *v. G. M. dos Reis* Jr. Ind. Com. De Equip. Medico, No. 2008-1279 (Fed. Cir. April 17, 2009).

[2] *Medical Solutions, Inc. v. C Change Surgical LLC*, 541 F.3d 1136 (Fed. Cir. 2008). ■

continued from page 4

the bottom of this display that read 'Not an LED display.' This technology may be a challenger to LEDs for outdoor and indoor digital-signage applications.

A major advancement in display technology reported during Display Week 2010 was the progress of oxide technology for the thin-film transistors (TFTs) used in AMOLED panels. AUO demonstrated progress in this area with a 32-in. LCD panel driven by oxide TFTs. Sony also reported on oxide TFTs. Can oxide TFTs be a solution to the problem that is plaguing the manufacture of large-sized OLED displays? Most AMOLED development uses low-temperature polysilicon (LTPS) technology for the TFTs. When scaling up to large-area panels, the uniformity of the threshold voltage over a large area is poor, although the stability is good. Generally, it takes four or more transistors per subpixel to drive each cell, and the process to make these transistors involves a minimum of five and up to 11 discrete steps. Because of this, cost is high and the yield is low. When using oxide technology instead, designers have found that the uniformity of the threshold voltage is much better, they can reduce the total number of transistors to two, and the process can be reduced to as little as 4–5 steps, resulting in lower cost and much higher yield.

Considerable progress also seems to have been made in organic TFTs, as demonstrated by Sony's rollable OLED display driven by organic TFTs.

A Successful Show

Attendees are the key to the success of any event, and SID is grateful to the attendees of Display Week 2010 in Seattle. As is clear from the chart below, we enjoyed considerable success.

Attendees	Display Week 2009	Display Week 2010
Total Symposium	1282	2132
Total Seminar/ Tutorial/Short course	702	1100
Display Business events	441	980
Total attendees for all events	3604	5679
Exhibits	Strong recovery in 2010 compared to 2009	

One of the reasons for the increased attendance was that the show was widely covered by the media. *The Seattle Times* ran a full-page article on Display Week 2010 in the business section. Brier Dudley, the technology columnist for *The Seattle Times*, wrote extensively on the spectrum of display technologies presented at Display Week 2010. Local TV channels Q13 Fox News and KOMO 4 News broadcast directly from the exhibit show floor. Q13 Fox News threw a spotlight on LG's ultra-high-definition 3-D TV, measuring 84 in. on the diagonal. Flexible OLED display technology was another topic the channel disclosed to its viewers. The KOMO 4 News channel focused on Panasonic, LG Display, Qualcomm, and other companies exhibiting products based on touch technology or 3-D TV.

SID's *Information Display* magazine covered and commented in great detail, day by day, on many of the technical and exhibit events, from the keynote addresses that kicked things off to the poster session presented on late Thursday afternoon (http://informationdisplaysid2010.blogspot.com/). Editor Jenny Donelan, with help from our experts, one among them being our Past-President Paul Drzaic, published in *Information Display Online* many details of the technology at the show that were not covered by any other media.

Behind the Scenes

As is well-known, SID is a non-profit volunteer organization. Numerous volunteers worked behind the scenes to enable the success of this event. SID is grateful for their dedicated and sustained service. As usual, the technical symposium drew great attention and I thank the general chair and program chair, Tom Fiske and Helge Seetzen.

I also want to mention the several event organizers for this event, including Palisades Convention Management (PCM), Display Search, IMS, Cowen-Elliott, DVD recording firm Bluesky, and public relations firm MCA. (I hope I may be excused for any omissions.) SID thanks all the organizers and appreciates the hard work done by our contractor PCM.

The SID Symposium, Seminar, and Exhibition occupy the top spot in the world of display technology, due to the technical strength SID has built over the last 48 years. This event continues to evolve, with organizers continually adding new technologies that show promise for the consumer. Last year, Display Week brought to its fold non-traditional subjects such as solid-state lighting. Keeping up with the galloping pace of display technology and display systems, SID also added a focus on 3-D displays. Interactive displays have caused lots of excitement recently, and hence SID placed emphasis on touch systems as well. These hot topics drew big crowds in the technical sessions as well as on the exhibit floor.

SID's goal is to promote the science and technology of displays, as well as the business of displays, and thus serve its members, both sustaining and regular, regardless of their affiliation and size. I am confident that Display Week 2010 has accomplished this goal. I look forward to even more progress, excitement, and continuous waves of attendees at Display Week 2011 in Los Angeles. ■

SID 2011 honors and awards nominations

On behalf of the SID Honors and Awards Committee (H&AC), I am appealing for your active participation in the nomination of deserving individuals for the various SID honors and awards. The SID Board of Directors, based on recommendations made by the H&AC, grants all the awards. These awards include five major prizes awarded to individuals, not necessarily members of SID, based upon their outstanding achievements. The **Karl Ferdinand Braun prize** is awarded for ***"Outstanding Technical Achievement in, or contribution to, Display Technology."*** The prize is named in honor of the German physicist and Nobel Laureate Karl Ferdinand Braun who, in 1897, invented the cathode-ray tube (CRT). Scientific and technical achievements that cover either a wide range of display technologies or the fundamental principles of a specific technology are the prime reasons for awarding this prize to a nominee. The **Jan Rajchman prize** is awarded for ***"Outstanding Scientific and Technical Achievement or Research in the Field of Flat-Panel Displays."*** This prize is specifically dedicated to those individuals who have made major contributions to one of the flat-panel-display technologies or, through their research activities, have advanced the state of understanding of one of those technologies. The **Otto Schade prize** is awarded for ***"Outstanding Scientific or Technical Achievement in the Advancement of Functional Performance and/or Image Quality of Information Displays."*** This prize is named in honor of the pioneering RCA engineer Otto Schade, who invented the concept of the Modulation Transfer Function (MTF) and who used it to characterize the entire display system, including the human observer. The advancement for this prize may be achieved in any display technology or display system or may be of a more general or theoretical nature. The scope of eligible advancement is broadly envisioned to encompass the areas of display systems, display electronics, applied vision and display human factors, image processing, and display metrology. The nature of eligible advancements may be in the form of theoretical or mathematical models, algorithms, software, hardware, or innovative methods of display-performance measurement, and image-quality characterization. Each of these above-mentioned prizes carries a $2000

SID honors and awards nominations

Nominations are now being solicited from SID members for candidates who qualify for SID Honors and Awards.

- KARL FERDINAND BRAUN PRIZE. Awarded for an outstanding *technical* achievement in, or contribution to, display technology.
- JAN RAJCHMAN PRIZE. Awarded for an outstanding *scientific* or *technical* achievement in, or contribution to, research on flat-panel displays.
- OTTO SCHADE PRIZE. Awarded for an outstanding *scientific* or *technical* achievement in, or contribution to, the advancement of functional performance and/or image quality of information displays.
- SLOTTOW–OWAKI PRIZE. Awarded for outstanding contributions to the education and training of students and professionals in the field of information display.
- LEWIS & BEATRICE WINNER AWARD. Awarded for exceptional and sustained service to SID.
- FELLOW. The membership grade of Fellow is one of unusual professional distinction and is conferred annually upon a SID member of outstanding qualifications and experience as a scientist or engineer in the field of information display who has made widely recognized and significant contribution to the advancement of the display field.
- SPECIAL RECOGNITION AWARDS. Presented to members of the technical, scientific, and business community (not necessarily SID members) for distinguished and valued contributions to the information-display field. These awards may be made for contributions in one or more of the following categories: (a) outstanding technical accomplishments; (b) outstanding contributions to the literature; (c) outstanding service to the Society; (d) outstanding entrepreneurial accomplishments; and (e) outstanding achievements in education.

Nominations for SID Honors and Awards must include the following information, preferably in the order given below. Nomination Templates and Samples are provided at *www.sid.org/awards/nomination.html.*

1. Name, Present Occupation, Business and Home Address, Phone and Fax Numbers, and SID Grade (Member or Fellow) of Nominee.

2. Award being recommended:
   Jan Rajchman Prize
   Karl Ferdinand Braun Prize
   Otto Schade Prize
   Slottow–Owaki Prize
   Lewis & Beatrice Winner Award
   Fellow*
   Special Recognition Award
*Nominations for election to the Grade of Fellow must be supported in writing by at least five SID members.

3. Proposed Citation. This should not exceed 30 words.

4. Name, Address, Telephone Number, and SID Membership Grade of Nominator.

5. Education and Professional History of Candidate. Include college and/or university degrees, positions and responsibilities of each professional employment.

6. Professional Awards and Other Professional Society Affiliations and Grades of Membership.

7. Specific statement by the nominator concerning the most significant achievement or achievements or outstanding technical leadership that qualifies the candidate for the award. This is the most important consideration for the Honors and Awards committee, and it should be specific (citing references when necessary) and concise.

8. Supportive material. Cite evidence of technical achievements and creativity, such as patents and publications, or other evidence of success and peer recognition. Cite material that specifically supports the citation and statement in (7) above. (Note: the nominee may be asked by the nominator to supply information for his candidacy where this may be useful to establish or complete the list of qualifications).

9. Endorsements. Fellow nominations must be supported by the endorsements indicated in (2) above. Supportive letters of endorser will strengthen the nominations for any award.

E-mail the complete nomination – including all the above material by **October 8, 2010** – to fan.luo@auo.com or sidawards@sid.org or by regular mail to:
Fan Luo, Honors and Awards Chair, Society for Information Display,
1475 S. Bascom Ave., Ste. 114, Campbell, CA 95008, U.S.A.

stipend sponsored by AU Optronics Corp., Sharp Corporation, and Samsung Mobile Display, respectively.

The **Slottow–Owaki prize** is awarded for ***"Outstanding Contributions to the Education and Training of Students and Professionals in the Field of Information Display."*** This prize is named in honor of Professor H. Gene Slottow, University of Illinois, an inventor of the plasma display and Professor Kenichi Owaki from the Hiroshima Institute of Technology and an early leader of the pioneering Fujitsu Plasma Display program. The oustanding education and training contributions recognized by this prize is not limited to those of a professor in a formal university, but may also include training given by researchers, engineers, and managers in industry who have done an outstanding job developing information-display professionals. The Slottow–Owaki prize carries a $2000 stipend made possible by a generous gift from Fujitsu, Ltd., and Professor Tsutae Shinoda.

The fifth major SID award, the **Lewis and Beatrice Winner Award,** is awarded for ***"Exceptional and Sustained Service to the Society."*** This award is granted exclusively to those who have worked hard over many years to further the goals of the Society.

The membership grade of **SID Fellow Award** is one of unusual professional distinction. Each year the SID Board of Directors elects a limited number (up to 0.1% of the membership in that year) of **SID members** in good standing to the grade of **Fellow.** To be eligible, candidates must have been members at the time of nomination for at least 5 years, with the last 3 years consecutive. A candidate for election to Fellow is a member with ***"Outstanding Qualifications and Experience as a Scientist or Engineer in the Field of Information Display who has made Widely Recognized and Significant Contributions to the Advancement of the Display Field"*** over a sustained period of time. SID members practicing in the field recognize the nominee's work as providing significant technical contributors to knowledge in their area(s) of expertise. For this reason, five endorsements from SID members are required to accompany each Fellow nomination. Each Fellow nomination is evaluated by the H&AC, based on a weighted set of five criteria. These criteria and their assigned weights are creativity and patents, 30%; technical accomplishments and publications, 30%; technical leadership, 20%; service to SID, 15%; and other accomplishments, 5%. When submitting a Fellow award nomination, please keep these criteria with their weights in mind.

The **Special Recognition Award** is given annually to a number of individuals (membership in the SID is not required) of the scientific and business community for distinguished and valued contribution in the information-display field. These awards are given for contributions in one or more of the following categories: (a) ***Outstanding Technical Accomplishments,*** (b) ***Outstanding Contributions to the Literature,*** (c) ***Outstanding Service to the Society,*** (d) ***Outstanding Entrepreneurial Accomplishments,*** and (e) ***Outstanding Achievements in Education.*** When evaluating the Special Recognition Award nominations, the H&AC uses a five-level rating scale in each of the above-listed five categories, and these categories have equal weight. Nominators should indicate the category in which a Special Recognition Award nomination is to be considered by the H&AC. More than one category may be indicated. The nomination should, of course, stress accomplishments in the category or categories selected by the nominator.

While an individual nominated for an award or election to Fellow may not submit his/her own nomination, nominators may, if necessary, ask a nominee for information that will be useful in preparing the nomination. The nomination process is relatively simple, but requires that the nominator and perhaps some colleagues devote a little time to preparation of the supporting material that the H&AC needs in order to evaluate each nomination for its merit. It is not necessary to submit a complete publication record with a nomination. Just list the titles of the most significant half a dozen or less papers and patents authored by the nominee, and list the total number of papers and patents he/she has authored.

Determination of the winners for SID honors and awards is a highly selective process. Last year less than 30% of the nominations were selected to receive awards. Some of the major prizes are not awarded every year due to the lack of sufficiently qualified nominees or, in some cases, because no nominations were submitted. On the other hand, once a nomination is submitted, it will stay active for three consecutive years and will be considered three times by the H&AC. The nominator of such a nomination may improve the chances of the nomination by submitting additional material for the second or third year that it is considered, but such changes are not required.

Descriptions of each award and the lists of previous award winners can be found at *www.sid.org/awards/indawards.html*. Nomination forms are available at *www.sid.org/awards/nomination.html* where you will find Nomination Templates in both MS Word (preferred) and Text formats. Please use the links to find the Sample Nominations, which are useful for composing your nomination since these are the actual successful nominations for some previous SID awards. Nominations should preferably be submitted by e-mail. However, you can also submit nominations by ordinary mail if necessary.

Please note that with each Fellow nomination, only five written endorsements by five SID members are required. These brief endorsements – *a minimum of 2–3 sentences* to a maximum of one-half page in length – *must state why clearly and succinctly, in the opinion of the endorser, the nominee deserves to be elected to a Fellow of the Society. Identical endorsements by two or more endorsers will be automatically rejected* (no form letters, please). Please send these endorsements to me either by e-mail (preferred) or by hardcopy to the address stated in the accompanying text box. Only the Fellow nominations are required to have these endorsements. However, I encourage you to submit at least a few endorsements for all nominations since they will frequently add further support to your nomination.

All 2011 award nominations are to be submitted by October 8, 2010. E-mail your nominations directly to fan.luo@auo.com or sidawards@sid.org. If that is not possible, then please send your hardcopy nomination by regular mail.

As I state each year: "In our professional lives, there are few greater rewards than recognition by our peers. For an individual in the field of displays, an award or prize from the SID, which represents his or her peers worldwide, is a most significant, happy, and satisfying experience. In addition, the overall reputation of the society depends on the individuals who are in its 'Hall of Fame.'

When you nominate someone for an award or prize, you are bringing happiness to an individual and his or her family and friends, and you are also benefiting the society as a whole."

Thank you for your nomination in advance.

– Fan Luo
Chair, SID Honors & Awards Committee

SID Elects New Leadership Team

During Display Week 2010 in Seattle, the Society for Information Display announced the election of a new leadership team composed of display-industry veterans from around the globe. Dr. Munisamy Anandan assumes the role of president, while Brian Berkeley will serve as president-elect. Dr. Amal Ghosh is the new treasurer and Prof. Yong-Seog Kim has been elected as the new secretary. In addition, three regional vice-presidents have also been elected: Dr. Tolis Voutsas (Americas), Dr. Ian Sage (Europe), and Prof. Hoi-Sing Kwok (Asia).

In addition to his role as SID president, Dr. Anandan is also the managing member of Organic Lighting Technologies LLC. Prior to founding Organic Lighting Technologies, he was the director of the organic light-emitting-diode (OLED) process and packaging engineering at eMagin Corp., where he developed and oversaw innovative organic deposition processes for microdisplays and new packaging applications. He has also worked at companies such as Panasonic Technologies and Bell Communications Research and has more than 30 years of extensive experience in various display technologies, including LCD, plasma, FED, OLED, MEMS-based displays, and LCD backlighting.

Working alongside Dr. Anandan as the president-elect is Brian Berkeley, who is vice-president of the OLED R&D Center at Samsung Mobile Display. Berkeley, who has been with Samsung since 2003, is also a 20-year veteran of Apple Computer, where he led all display development activities. Along with authoring more than 50 technical papers and patents, he is well-recognized for numerous accomplishments, including his current work in large-area OLED displays. The new SID treasurer is Amal Ghosh, who also serves as senior vice-president of research and development at eMagin Corp. With more than two decades of industry experience and numerous publications and patents to his credit, he is a recognized expert in the areas of OLED and field-emission displays (FEDs). SID's new secretary, Prof. Yong-Seog Kim, is a professor at Hongik University in Seoul, Korea, and leads the plasma-display research at the university.

For more information about the new officers, see the full press release at http://www.sid.org/pressroom/100524.html. ■

continued from page 2

turing technology is finally maturing in a way similar to that of other mainstream technologies. The rate of adoption of touch screens into almost every personal-display application is truly exciting, at least for someone like me who worked in that field for many years.

Without a doubt, the gorillas in the room at Display Week were the LCDs. But despite their relative maturity and high rate of adoption in just about every application imaginable, there was still plenty of new innovation in the LCD space, as described by author Alfred Poor. Packaging innovations enabled by LEDs, better light efficiency enabled by innovative pixel structures, advancements in bistable and transflective modes enabled by many discoveries, and striking improvements in high-ambient contrast are just part of what Alfred saw as he surveyed the exhibition in Seattle.

While not quite as colorful as other technologies, the field of flexible displays and e-paper offerings was well represented in Seattle as well. As author Rob Zehner commented, it was exciting to see so many of the key innovators in the field back after last year's brief absence. Themes for innovation included color, faster response time, and further improvements in image quality. This is a unique space because while everyone assumes great energy efficiency as a baseline, they also assume that image quality will never rival active-matrix displays. I happen to think this is wrong, and some of the things that Rob describes lead me to think I'm right – that someday we really will have handheld, lightweight, full-color video-rate displays for a fraction of the energy consumption that is needed today. What I am not so sure about is the flexibility part. Several years ago there was much fanfare over the promising products based on rollable and foldable reflective displays. Well, these products have materialized much more slowly than promised and I think we might be a few more years away from widespread availability and consumer adoption.

However, something that has materialized in a big way is 3-D technology. In author Alfred Poor's second article he reviews the myriad of different embodiments of 3-D being demonstrated, including the ones with glasses (stereoscopic) and the ones without (autostereoscopic). As we announced in our May issue, both Gold and Silver DYA awards (in different categories) went to 3-D technologies: LG's 47-in. LCD 3-D-ready panel and the RealD XL Cinema 3-D projection system. So, of course, people were anxious to see these and other innovations live at the exhibition and as I'm told, they were not disappointed. In Alfred's article he raises the concern about the availability of enough original 3-D content to make the value proposition play out. Well, analysts Chris Chinnock and Matthew Brennesholtz take this subject to task in our second Display Marketplace feature entitled "Broadcast and Production Embrace 3-D." Based on what they saw at the April 2010 National Association of Broadcasters (NAB) conference and their own follow-on research, they believe critical mass for the complete content chain is almost here.

One aspect of display technology that has earned its own category is environmental friendliness or "Green." We have been covering the green aspect of displays for many years now, but only recently has the moniker evolved to mean much more than just energy efficiency or recyclability. Green now refers to the entire life cycle of a display product, including the environmental footprint of the manufacturing process and the environmental impact of all the materials and processes involved. In her Display Week review article on this subject, Managing Editor Jenny Donelan captures the highlights, including the first-ever Symposium Green Technology paper track, which further underscores how seriously the manufacturers themselves are taking this topic. What is not clear to me is how much consumers (at least those in North America) really value the "green" over the big, bright, and beautiful. We may find out soon, or we may be watching this one for many years to come.

This is a huge issue for us, and I have not even mentioned the rest of the articles, which include another great chapter in our series on Intellectual Property Issues by Jae Kim, our monthly Industry News, a review of the 2010 North American Auto Show by longtime contributor Alan Sobel, and a note from SID President Munisamy Anandan.

I want to thank our excellent staff at *ID* for the incredible amount of work over the past 2 months to put this Display Week review issue together. I also want to thank all our contributing authors who served as roving reporters during the event and all the team at Palisades Convention Management for their hard work and meticulous attention to details every year managing Display Week. For all the colleagues I didn't see this year at the show, I truly missed you. I wish you all success and prosperity for the remainder of 2010 and you can be sure I'll be back for 2011 in Los Angeles. ■

Journal of the
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The following papers appear in the August 2010 (Vol. 18/8) issue of *JSID*.
For a preview of the papers go to sid.org/jsid.html.

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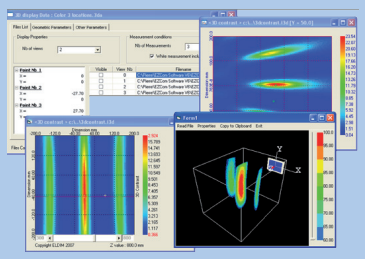

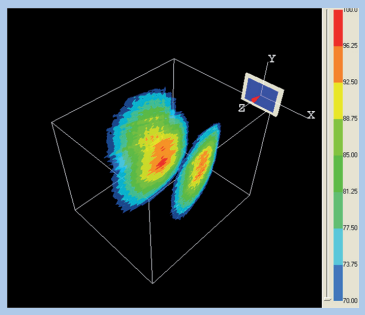

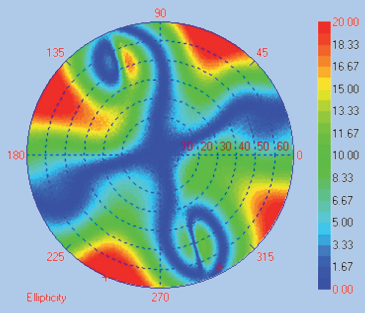

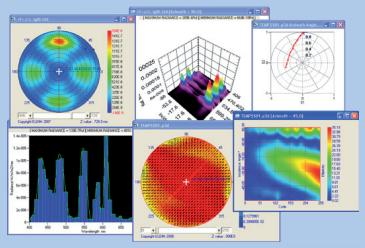

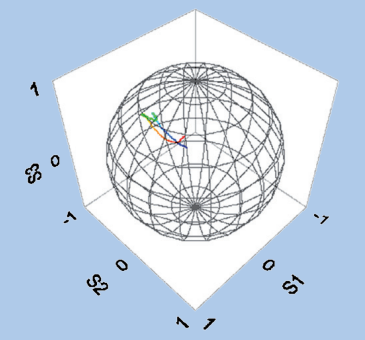

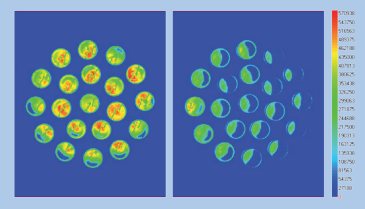

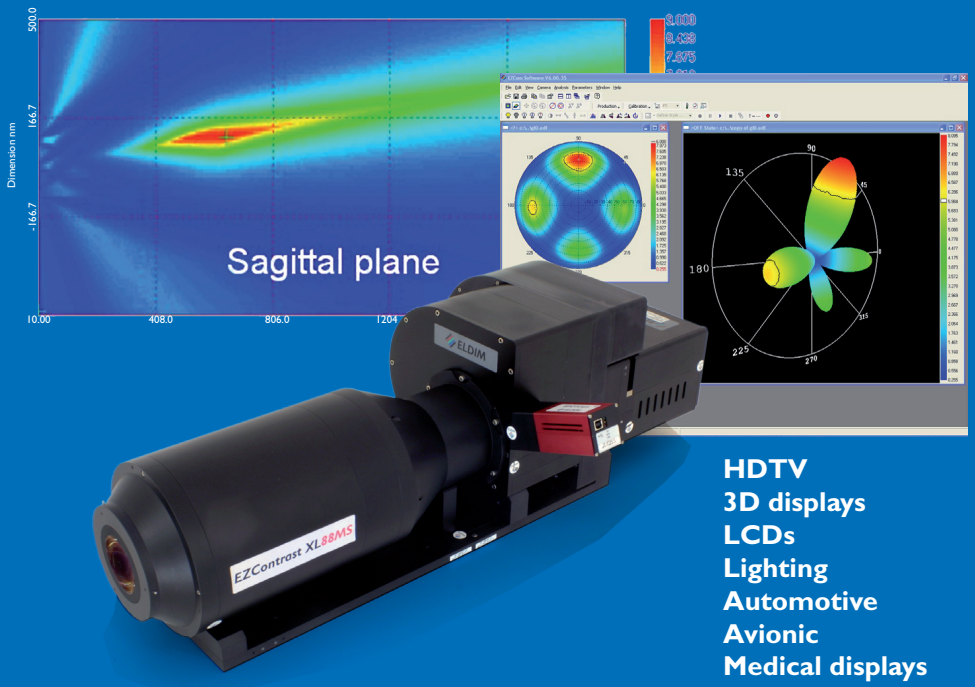

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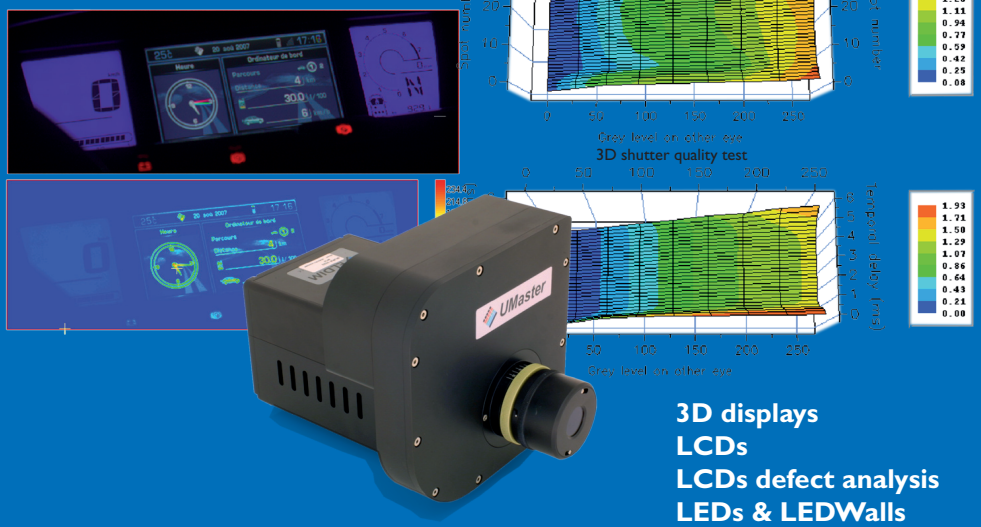

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PROFESSIONAL INFORMATION

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, QC, 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)*

_____

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
321 ☐ Computer Monitors /Peripherals
322 ☐ Computers
323 ☐ Consulting Services, Technical
324 ☐ Consulting Services, Management/Marketing
325 ☐ Education
326 ☐ Industrial Controls, Systems, Equipment, Robotics
327 ☐ Medical Imaging/Electronic Equipment
328 ☐ Military/Air, Space, Ground Support/Avionics
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)*

_____

4. What is your purchasing influence?

410 ☐ I make the final decision.
411 ☐ I strongly influence the final decision.
412 ☐ I specify products/services that we need.
413 ☐ I do not make purchasing decisions.

5. What is your highest degree?

510 ☐ A.A., A.S., or equivalent
511 ☐ B.A., B.S., or equivalent
512 ☐ M.A., M.S., or equivalent
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)*

_____

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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