DISPLAY WEEK 2014 REVIEW ISSUE

Information DISPLAY

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Sept./Oct. 2014
Vol. 30, No. 5

OLEDs Dominate Awards at Display Week

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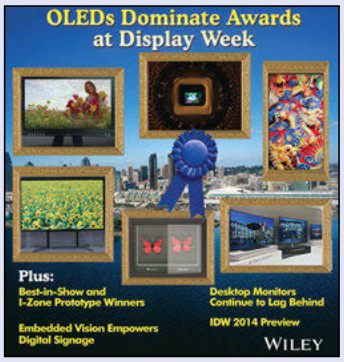
On the cover: *The 2014 I-Zone Best Prototype winner (top center) was Ostendo Technologies' Quantum Photonic Imager. The 2014 Best-in-Show winners are, clockwise from upper right: AUO's WQHD ultra-high-resolution LCD panel, LG Display's UD OLED TVs, GroGlass's AR-coated glass and acrylic that virtually eliminate reflection, BOE's 98-in. LCD panel, and Nanosys's true-to-life display experience with high dynamic range and wide color gamut (made in partnership with Dolby).*



Cover Design: Jodi Buckley

In the Next Issue of *Information Display*

3-D/Holography and Television

- Market Penetration of UHD TVs
- Personal Light-Field Displays
- Group/Immersive Light-Field Displays
- UHD Demands a New TV Infrastruture
- Evolution of OLED TVs

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editorial

Reach Out to the Global Display Community

by Stephen Atwood

Display Week 2014 was a great convergence of people and technology in the friendly and very walkable city of San Diego. It had been many years since I was last there, and I wondered what I would find when I returned. Old memories of the beautiful bayside scenery and cultural diversity were refreshed as I explored the many things to see and do in San Diego. I like to travel but generally avoid large cities in favor of the country when I travel for leisure. It's the call of work and the variety of regular SID activities that have drawn me to so many great cities over the years.

Among the highlights of those trips has been the chance to see many familiar faces as well as make new friends from all over this world. It's amazing to realize that a common interest in a technology can be enough to bring so many diverse people together, but this year in San Diego we had more than 6000 attendees from over 47 different countries, representing almost every continent in the world. While Asia and the U.S. were the regions most significantly represented, it is clear that Europe and even Australia were ably represented at the show. There is no doubt in my mind that we are a society that truly spans the globe.

While the international aspects of SID may seem obvious, given the worldwide nature of the display industry in general, it is still remarkable to me that our industry has such a broad base of feeder technologies and an equally wide range of end-use applications. Each piece of that elaborate eco-system is enabled by people like you and me who hail from literally every developed country. In turn, these countless people with common interests join SID, attend events like Display Week, and form their own chapters to arrange local activities. In major cities all around the world there are SID chapters and local member events, in addition to countless regional conferences and social gatherings – all geared to the common interests of display technologists like ourselves.

I have an assignment for you: While you were in San Diego this year, how many new people did you meet? Take that pile of business cards you brought back out of your bag or desk and look through it. Note the wide range of countries and cities represented. Try to think about some of those faces and remember the ones that made the biggest impression on you. Now take 10 minutes and write an e-mail letter to at least one of those people, preferably from a country different from your own. Do not dwell on any business details; just start by saying "hi" and tell that person something you liked about meeting them. Maybe note a fascinating fact you learned from them or something you were impressed with during your mutual conversation. Tell them something personal about yourself, your interests, and your work. Then wish them well and see what happens. Don't be surprised if they write back very soon and tell you something equally personal and express their pleasure in also meeting you. Before long you could have a new acquaintence and colleague that could become a lifelong friend – all for a few short minutes of effort and the advantage of having been at an SID event. I've done this and it really works.

We have a great Display Week review issue lined up. As our cover states, OLED displays were one of the dominant headlines, with many demonstrations in all manner of sizes and format, including rollable and foldable designs. Alfred Poor's review of OLEDs leads off our coverage, which also includes TVs and 3-D technology by Steve Sechrist, advances in display materials by Ken Werner, and flexible displays plus

(continued on page 35)

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Samsung Confirms It Is Out of the Plasma Panel TV Business

This past summer, numerous news sources began reporting that Samsung was discontinuing its plasma panel business. Shortly after these unsubstantiated reports, Samsung Electronics Corp. issued this statement by way of confirmation:

"We plan to continue our PDP TV business until the end of this year, due to changes in market demands. We remain committed to providing consumers with products that meet their needs and will increase our focus on growth opportunities in UHD TVs and curved TVs."

Earlier this year, Panasonic pulled out of the plasma business. As a result, the last big player making plasma TVs is LG Electronics, and reporters and analysts are taking bets as to how long that will be the case. In the meantime, there are some enticing deals on hundreds of models of plasma TVs via retailers such as Amazon.

Tianma Acquires Full Ownership in Multiple Fab Lines

In a move to strengthen its position as a leading supplier in the LCD marketplace, Tianma Microelectronics Co., Ltd., Shenzhen, China, has completed the acquisition of its five production lines in Japan, Shenzhen, Shanghai, and Wuhan and increased its investment in its Chengdu facility.

After this restructuring, Tianma will own 100% shares of Shanghai Tianma, Wuhan Tianma, Shanghai AVIC, and Shenzhen AVIC (two lines) and 70% shares of Chengdu Tianma. Prior to this, Tianma Microelectronics Co., Ltd., held controlling interests in the six lines. As a result of the stock acquisitions, the combined assets of the company are expected to surpass RMB 10 billion (US $1.6 billion).

According to Tianma, this consolidation of the company's fabrication line assets will optimize product planning and production, increase efficiency, and create more flexibility in customer support, including faster response times and time to market. A major part of Tianma Microelectronics's strategy is to strengthen its position as a tier-one supplier to the American marketplace.

LG Display Unrolls 18-in. Flexible and Transparent OLED Panels

LG Display recently announced that it has developed an 18-in. flexible rollable OLED panel and an 18-in. transparent OLED panel. Both panels are prototypes.

The flexible OLED panel has a high-definition resolution of 1200 × 810 with almost 1 million pixels. The panel's curvature radius is 30R. It can be rolled up to a radius of 3 cm without affecting the function of the display (Fig. 1). LG says that these developments will lead to rollable TVs of more than 50 in. being offered to the market in the not-too-distant future.

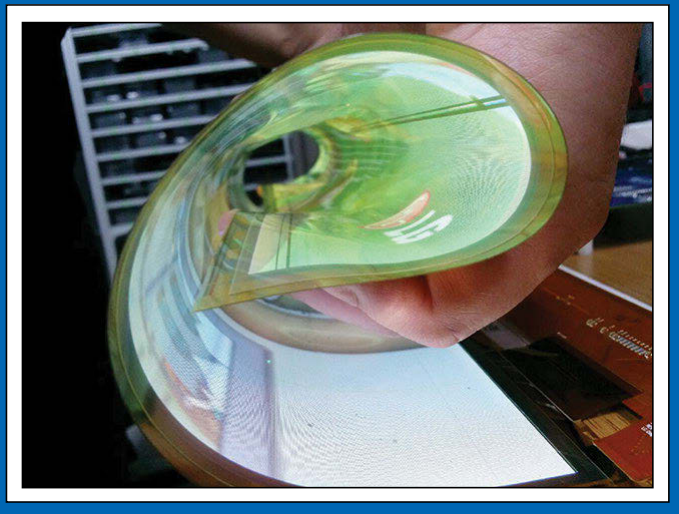

Fig. 1: *LG's rollable, flexible OLED prototype is the foundation for rollable TVs of the future, according to LG Display.*

To enable the flexibility, LG used high-molecular substance-based polyimide film as the backplane of the flexible panel instead of conventional plastic. The polyimide film also helped reduce the thickness of the panel to improve its flexibility.

The transparent OLED panel has 30% transmittance, which was achieved by adopting the company's transparent pixel design technology. LG claims that this is triple the transmittance of existing see-through LCDs.

Meko Acquires Insight Media Publishing Operations

Insight Media, publisher of the Display Central news portal, recently announced that it will sell its publishing and advertising operation to Meko, a UK-based news and market research consultancy that has covered the display industry for many years. According to Insight Media, operation of the Display Central news portal, Display Central marketing and promotional programs, the Display Daily email news service, as well as subscription newsletters *Large Display Report* and *Mobile Display Report*, will continue with little substantive changes.

Noted Insight Media President and Founder, Chris Chinnock: "I will continue to be involved with the publishing operation as a Display Daily contributor and sales agent, but much of my focus will now turn toward supporting clients in specific strategic and tactical projects." The Insight Media team of analysts will remain intact to support these other services.

"One of the key reasons this acquisition was appealing to us was the great reputation that the Insight Media team has in the industry for uncovering and analyzing new and exciting technology – a capability we fully intend to continue," said Bob Raikes, Managing Director at Meko. (Raikes is a frequent contributor to *Information Display* and has an article on monitors in this issue.) "This is an exciting opportunity for Meko to expand its coverage areas and Web presence and an area we will be investing in going forward."

The deal was made final on July 31, 2014, and a management transition is fully under way. ■

president's corner

Looking Forward to Serving SID

by Amal Ghosh
President, Society for Information Display

I look forward to serving as the President of SID for the next 2 years. As you may know, our premier society for displays is in its 52nd year of existence and is doing well. An organization such as ours is primarily based on the hard work of many volunteers, without whom SID would not survive. To that end, I would like to thank all the SID volunteers for the countless hours of personal and professional sacrifice they have made to help SID become a better society.

Display Week is SID's main annual event. Display Week 2014 was held in the beautiful city of San Diego and, overall, it was a very successful conference. We had more than 6,000 attendees this year, which is about a 10% increase over last year. We saw attendance improvement in most of the separate areas of the event, including the seminars and short courses. Our technical symposium had an attendance improvement of 10%. The symposium featured many very interesting papers on a wide range of topics, including OLEDs, LCDs, flexible displays, oxide TFTs, and more, and these hot-topic sessions were especially well attended. Finally, our exhibitor booth sales were also better than last year and continue to reflect the optimism of a modestly recovering global economy.

Both the Display Industry Awards and the Best in Show Awards are an important part of Display Week. This year's Display Industry Award Gold winners were Samsung's 5.68-in. curved flexible AMOLED display, receiving the Display of the Year award; Universal Display Corporation's green phosphorescent universal PHOLED material, receiving the Display Component of the Year award; and LG Display's G Flex phone, with the Display Application of the Year award. The Silver winners were LG Display's 55-in. FHD curved OLED TV, Canatu Oy's Carbon NanoBud Film, and Google's Chromebook Pixel. The Best in Show winners, selected at Display Week from exhibitors on the show floor, were Nanosys for its high-dynamic-range wide-color-gamut display experience and GroGlass for its AR-coated glass and acrylic in the small-exhibit category; AUO for its WQHD smartphone displays in the medium-exhibit category; and LG Display for its UD OLED TVs and BOE for its 8K × 4K display in the large-exhibit category.

SID's I-Zone has continued to be popular as a place to experience prototypes first hand. In many cases, these are early versions of products based on technology discussed in the technical symposium and other Display Week events. This year's I-Zone committee gave the Best Prototype Award to Ostendo Technologies, which demonstrated a novel display device it calls a Quantum Photonic Imager (QPI).

This year's show featured our Special Networking Event aboard the *USS Midway*, an aircraft carrier from WWII. We plan on continuing the networking event next year, along with the President's Cocktail Reception before our International Awards Banquet, and three other networking receptions for our Investor's Conference, Business Conference, and Market Focus Conferences. SID intends to continue to offer a host of networking opportunities at Display Week events for many years to come.

I have set some aggressive goals for the 2 years of my presidency. These include increasing the society's individual and corporate memberships. The goal for individual membership growth is about 5% and for corporate memberships about 20%.

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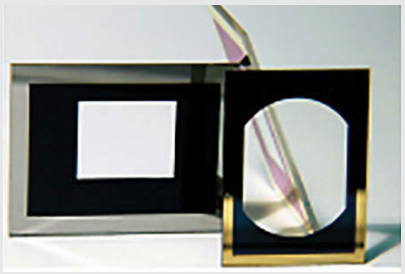

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I-Zone and Best-in-Show Winners

The Society for Information Display honored six exhibiting companies at Display Week 2014 in San Diego last June. These companies were Ostendo Technologies for best prototype in the Innovation Zone and AUO, BOE, GroGlass, LG Display, and Nanosys for Best-in-Show winners on the main exhibit floor.

by Jenny Donelan

THE Society for Information Display created the Best-in-Show Awards, one of the most exciting aspects of Display Week, several years ago as a complement to its Display Industry Awards, which honor commercially shipping products. The Best-in-Show awards shine a spotlight on exhibited products at Display Week that may or may not be ready to ship. These products may even be prototypes, but they represent the immediate future of displays. Best-in-Show winners are chosen during the first day of the exhibition by members of the awards committee, who consider not only a product's significance, but the way it is presented on the show floor.

The Best Prototype Award, also chosen on the first day of the exhibition, goes to the most outstanding product in the Innovation Zone (I-Zone), Display Week's special exhibit area for early-stage technology.

This year's winners, in both the I-Zone and the main exhibit hall, cover a range of sizes, from a tiny chip to a 98-in. TV, and incorporate technologies ranging from OLEDs to LCDs to coatings. We describe them briefly here and congratulate all the 2014 winners!

I-Zone Best Prototype

This year's winner of the I-Zone award for Best Prototype at Display Week was Ostendo Technologies, for a novel display device called the Quantum Photonic Imager (QPI) (Fig. 1). This is a display on a chip that uses LED layers stacked on top of a custom graphics processor. The LEDs incorporate "micropixels," each of which emits multi-color (RGB) light. The display provides a density of about 25 million pixels per square inch and enables power-efficient and ultra-compact displays and projectors, with application potential in mobile (including wearable) displays, automobile head-up displays, and glasses-free full-parallax 3-D light-field displays. A 2-D version of the chip is scheduled to ship by Q4 2015 and a 3-D version sometime later based on customer demand.

Best-in-Show Winners

Five companies – AUO, BOE, GroGlass, LG Display, and Nanosys – won Best-in-Show awards at Display Week 2014. These awards

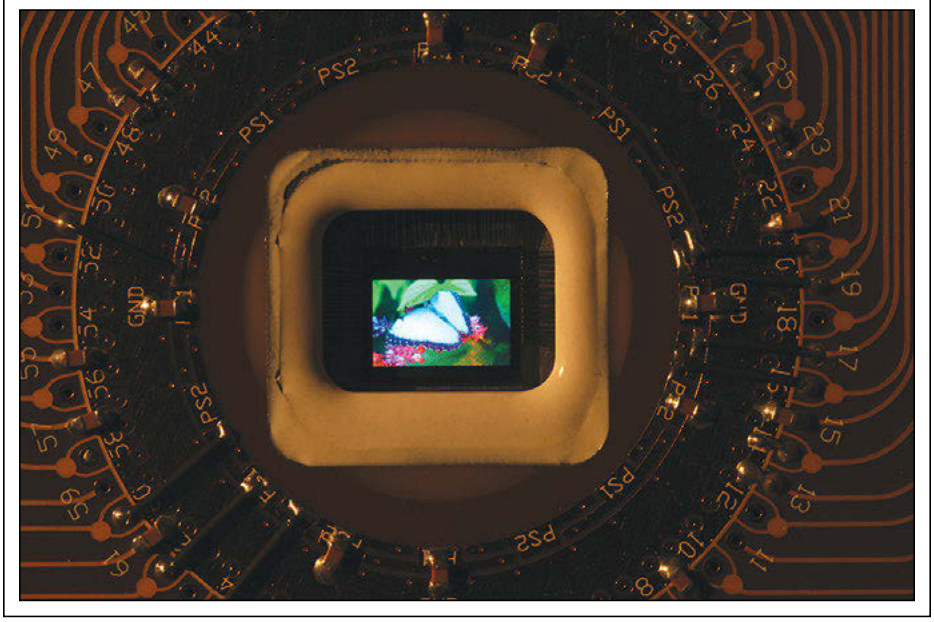

Fig. 1: *Ostendo Technologies' Quantum Photonic Imager (QPI) is designed to enable a multitude of high-resolution applications, both 2-D and 3-D.*

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are presented in three categories: large, medium, and small exhibits.

Large Exhibit Category: BOE Technology Group won an award in the Large Exhibit Category for its 8K × 4K QUHD (quad ultra-high-definition display) (Fig. 2). This 98-in. LCD has a resolution of 7680 × 4320 and a brightness of 500 nits. This panel is designed to provide a very-high-quality immersive experience for viewers, based on its size, image quality, and color reproduction.

LG Display also received a Best-in-Show award in the Large Exhibit Category for its UD OLED TVs (Fig. 3). LG has shown a real commitment to OLED TVs, as commented upon by roving reporter Steve Sechrist in his Display Week Review on TVs in this issue. Said Sechrist: "LG is expanding its OLED TV line-up and showed 65- and 77-in. curved UHD sets and non-curved OLED sets in its large booth at Display Week." At the show, LG said the two larger sets were slated for commercial shipment later in 2014. The company also said it was moving to a more efficient curved AMOLED 55-in. set with a new FHD model (55EB9600) that incorporates a low-power approach. At press time, LG had just launched the new 55-in. set.

Medium Exhibit: AU Optronics Corp. (AUO) won a Best-in-Show award in the Medium Exhibit Category for its WQHD ultra-high-resolution smartphone LCD panels (Fig. 4). AUO's 6-in. WQHD smartphone display employs AHVA (Advanced Hyper-Viewing Angle) technology and LTPS production and has a resolution of 1440 × 2560 with 490 ppi. Also adopting AHVA technology and LTPS production, AUO's 5.5-in. WQHD smartphone display has a pixel density of 538 ppi, allowing for a more accurate presentation of Web content and sharper character display. The WQHD displays are designed especially to handle high-resolution video.

Small Exhibit Category: GroGlass won an award in the Small Exhibit Category for its AR-coated glass and acrylic that virtually

Fig. 2: *BOE's 98-in. LCD panel sports a resolution of 7680 × 4320.*

Fig. 3: *LG Display featured a family of curved OLED TVs at Display Week, adding a 65- and 77-in. model to the 55-in. TV it had introduced earlier.*

Fig. 4: *AUO's WQHD ultra-high-resolution LCD panel, in both 5.5- and 6-in. formats, is designed to empower the next generation of high-performing smartphones.*

Fig. 5: *GroGlass's coating (left) for glass or acrylic provides an exceptionally clear, non-reflective view.*

Fig. 6: Quantum Dot Enhancement Film from Nanosys is being used to enable Dolby Vision, a new content platform that will be commercially available later this year.

eliminate reflection. The company's exhibit at Display Week was a real attention-getter. The left-hand section of the display that incorporated the GroGlass product, as shown in Fig. 5, was so transparent it seemed like there was no glass whatsoever covering the butterfly. GroGlass offers its anti-reflective coating in sheets up to 124 × 88 in. The coating is made of multiple metal oxide layers that are applied to glass or acrylic. In addition, there is a special top coating that makes the glass or acrylic highly durable, more scratch resistant, and easier to clean.

Nanosys also won for its true-to-life display experience with high dynamic range and wide color gamut (made in partnership with Dolby). For Display Week, the two companies teamed up to create a first-of-its-kind 32-in. display that demonstrates the impact of Dolby Vision content by using Quantum Dot Enhancement Film from Nanosys (Fig. 6). The award winning display from Nanosys and Dolby features 16 F-stops of dynamic range, peak light output of 2000 nits, and DCI-P3 color-gamut coverage – all without drawing significantly more power than a standard TV, thanks to the quantum-dot-enhanced backlight. TVs featuring Dolby Vision technology are expected to be available for retail purchase later this year. ■

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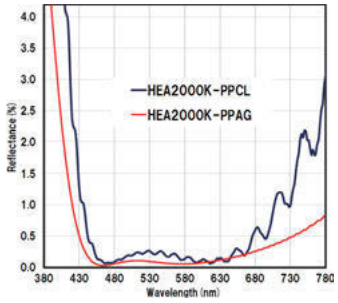

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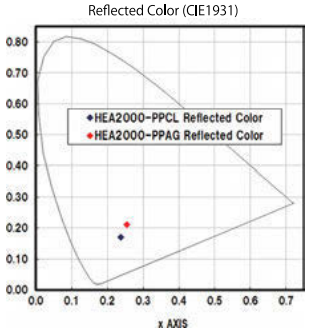
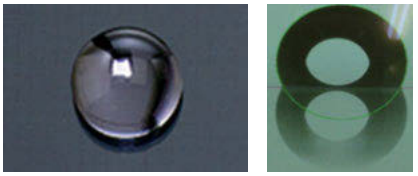
HEA2000K-PPAG: Anti Glare film.





Contact Angle 117°

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Display Week 2014 Review: OLEDs

OLEDs are no longer on the way; they're here. At Display Week 2014, not only did we get to see how they have become established in some markets, we also saw how the technology is advancing rapidly in ways that can only expand their appeal in the future.

by Alfred Poor

IN 2014, we can finally stop making hopeful pronouncements about how it's going to be "The Year of the OLED." OLEDs have arrived. This technology has established a solid footing in the display industry and shows signs of continuing growth. OLED TVs are shipping in small numbers, but they are shipping at last. They are curved and thin and beautiful. At the same time, OLED technology dominates the markets for high-end smartphones, tablets, and other portable display devices. And at Display Week 2014, we saw new applications made possible by certain expanded capabilities of OLEDs that LCD technology is hard pressed to match. From wearable technology to solid-state lighting, OLED technology is poised to launch new products on several fronts.

Award-Winning Technology

While LCDs continue to dominate the show floor at Display Week and the display industry at large, one need look no further than SID's own Display Industry Awards to see how OLEDs have become an integral part of this industry. Four out of the six award winners this year were based on OLED technology, including Samsung's 5.68-in. OLED panel, LG's 55-in. OLED TV panel, Universal Display Corp.'s green phosphorescent OLED (PHOLED) material, and LG Displays's G Flex smartphone. (For more information about these products, see the Display Industry Awards article in the May/June 2014 issue of *Information Display*.)

OLEDs on Display

These award winners were but the tip of the OLED iceberg in the Display Week 2014 exhibit hall. For example, Tianma/NLT was showing a demonstration panel that was 5.5 in. on the diagonal with a 1280 × 720 high-definition resolution and rated at a luminance of 200 nits. AU Optronics Corp. (AUO) showed a 5.7-in. OLED panel with an

Fig. 1: *AUO's 5-in. OLED panel has a pixel resolution of 2560 × 1440 for an impressive 513 ppi. It is rated at 300 cd/m^2 and produces imagery that looks almost as if it is printed on paper. Photo courtesy Alfred Poor.*

Alfred Poor *is a Senior Member of the Society for Information Display and a well-known speaker and analyst in the display industry. He can be reached at apoor@verizon.net or 1-215-453-9312.*

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amazing 2560 × 1440 pixel resolution (quad 720p high-definition resolution) rated at 300 nits; this works out to a pixel density of 513 ppi (Fig. 1). This was probably just a demonstration to show off what the company can do with OLED technology, but it was impressive. The image looked almost as if it were a high-quality print on paper.

Perhaps the most impressive small OLED panels were the flexible ones. In addition to LG and Samsung's award-winning curved panels, AUO showed a 5-in. panel with high-definition resolution (1280 × 720 pixels) built on a plastic substrate with a thin-film barrier for encapsulation. The active-matrix panel was just 0.2 mm thick – equivalent to about two sheets of paper – and could be bent to a radius as small as 1 cm. Not all the flexible panels were active-matrix OLEDs, either. It's great to have a high-resolution color display, but there are times when a lower information density will suffice in order to have a lower-cost display. Futaba makes a wide range of these passive-matrix OLED displays and showed a variety of them in its exhibit. For example, the company was showing a 3.5-in. panel with a pixel resolution of 256 × 64 that was only 0.22 mm thick and could be curved to fit a person's wrist. This display even included touch functionality.

Some displays pushed the very boundaries of what it means to be flexible. Among the many papers delivered during the Symposium on the subject of flexible OLED displays, researchers from Semiconductor Energy Laboratory (SEL) in Japan, along with colleagues from Advanced Film Device and Nokia, demonstrated a novel OLED display that could be folded in half and still function — even when still folded. The prototype 7.9-in. display on a plastic substrate had a high-definition 1280 × 720 pixel resolution (249 ppi) and was folded to a radius of 2 mm more than 100,000 times without defects appearing. This could lead to a smartphone with a large display that could easily fold up and fit in your pocket.

Even more impressive was an OLED display created on a plastic substrate by Plastic Logic that was demonstrated in the I-Zone (Fig. 2). This panel used an organic thin-film transistor (TFT) backplane, printed on the plastic film at temperatures below 100°C (boiling water). The device was so flexible that it could be rolled around a standard pencil while operating.

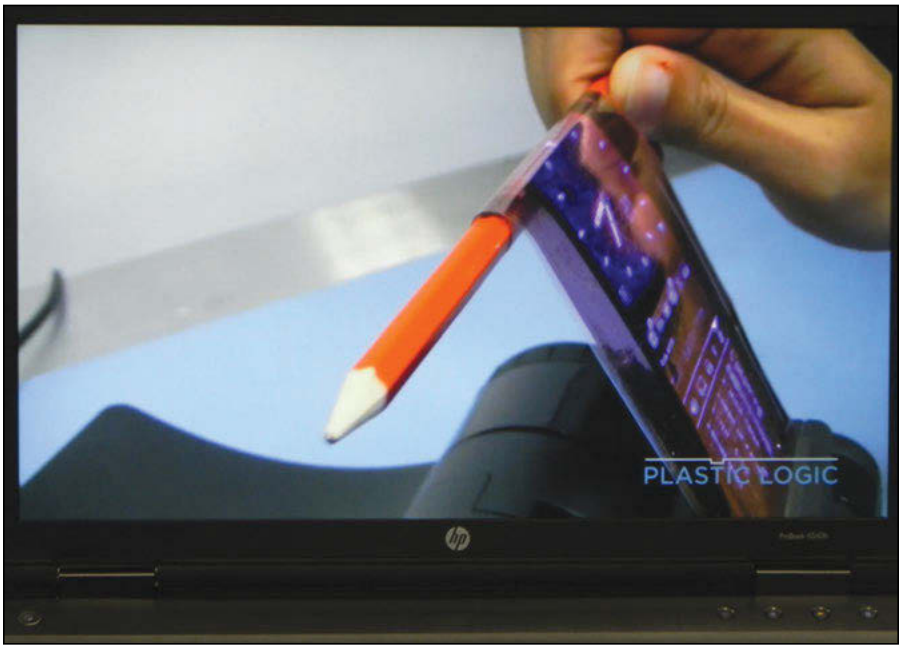

Fig. 2: *Plastic Logic demonstrated a flexible OLED with a printed backplane on a plastic substrate. Photo courtesy Alfred Poor.*

Wearable Displays

These flexible displays point toward one of the fast-growing markets where OLEDs may have a chance to dominate: wearable technology. From Google Glass to the Fitbit, wearable computing has captured people's imaginations for applications ranging from fashion to fitness, from location tracking, to medical diagnosis and treatment. OLED technology's flexibility, light weight, low power consumption, and durability make it an attractive choice for these devices.

Already, we are seeing the second and third generation of smart watches coming to the market. At Display Week, Samsung showed the displays that it uses in its latest watches. The Gear 2 has a 1.63-in. OLED display with a pixel resolution of 320 × 320, delivering 277 ppi and 300 nits of luminance. The Gear Fit (Fig. 3) has a curved 1.84-in. display with a high (or wide) aspect ratio (8:27) and a resolution of 128 × 432 pixels, for 244 ppi at 300 nits. On the whole, smart watches appear to be a market segment with potential that has not yet been realized. The devices tend to be large and thick, but the displays appear to be ready once the manufacturers miniaturize the rest of the components and come up with more compelling usage models.

Not all smart watches rely on OLEDs, however. E Ink's bistable display technology is a good choice for such applications, as it only draws power when the contents of the

Fig. 3: *The Samsung Gear Fit smart watch sports a curved OLED display that would be a lot more attractive if the rest of the watch were thinner. Photo courtesy Alfred Poor.*

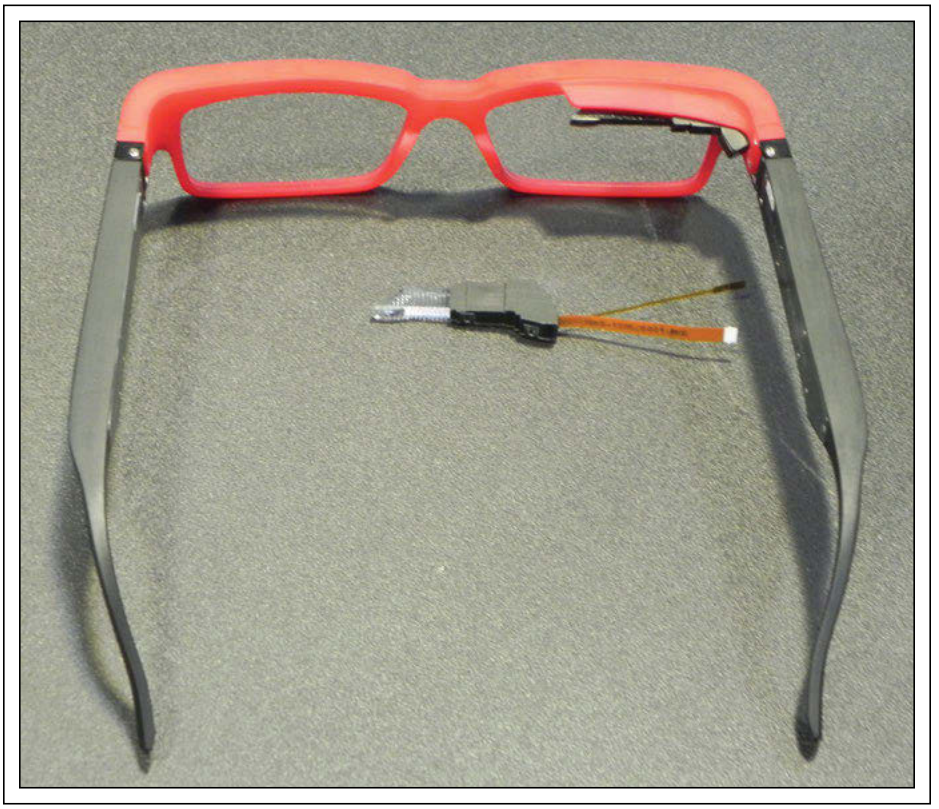

Fig. 4: Not all glasses are made by Google; the Kopin White Pupil demonstrator shows how Kopin's head-mounted display can be hidden in an eyeglass frame. Photo courtesy Alfred Poor.

display change. The company had some smart watches on display in its booth. And there are small, direct-view LCD panels that are also suitable for wearable applications. For example, Sharp showed its octagonal 0.99-in. transflective memory display, which includes memory for each of the 128 × 128 pixels. This design means that the panel only draws 10 µW when displaying a static image and 45 µW when changing the screen's contents.

Of course, some display panels are too small to see unaided with the naked eye. These are suitable for a variety of applications, but Google Glass has many people rethinking the role of head-mounted displays for wearable computing. Sony presented a Symposium paper describing a new 0.23-in. OLED microdisplay with a pixel resolution of 640 × 400. The panel has a pixel pitch of only 7.8 µm and draws just 80 mW when producing 20 nits. The design is based on a white OLED panel with color filters for the subpixels. eMagin also showed OLED microdisplays built directly on silicon backplanes, including a 0.62-in. panel with a pixel resolution of 1280 × 1024.

Other companies also showed microdisplays using additional technologies. Kopin exhibited its White Pupil: a 0.2-in. LCD imager with a pixel resolution of 428 × 240 with optics that could easily be incorporated into the frames of eyeglasses, as shown in Fig. 4. Using Kopin's bright backlight technology, this device can deliver more than 5,000 nits. The result is a sunlight-readable head-mounted display that consumes less than 100 mW. Holoeye showed its LCOS imagers, which were as small as 0.26-in. with a high-pixel resolution of 1280 × 720.

There were some other novel microdisplays that could be suitable for wearable-technology applications shown in the I-Zone. INSiAVA has developed an emissive display fabricated on a CMOS backplane. Its 320 × 240 pixel panel can show graphic images and video. Ostendo Technologies showed its Quantum Photonic Imager, which stacks LEDs on a CMOS backplane. (This technology won the

Fig. 5: Perhaps the most unusual display at the show was the Moon Window from Universal Display Corporation, which demonstrated how transparent white OLED panels can make windows a light source at night. Photo courtesy Alfred Poor.

award for Best Prototype in the I-Zone.) The imager can have a pixel pitch of 5–10 µm and brightness of more than 20,000 nits while consuming less than 300 mW. Lumiode is another I-Zone company that showed an LED matrix display technology it was developing.

Solid-State Lighting

We have been hearing for some time that OLEDs are good for more than just information displays. Their emissive properties and potential for low-cost roll-to-roll manufacturing make them an attractive candidate for solid-state lighting (SSL) applications. The Symposium program included two sessions devoted to the use of OLEDs in lighting.

There were few lighting exhibitors on the show floor at Display Week (in part because Lightfair International was going on at the same time), but UDC showed its "moon window" in its booth (Fig. 5).

This full-size window had a bright-white OLED image of a full moon on the glass, demonstrating how a window could use a transparent OLED device to admit sunshine during the day and then be a source of artificial illumination at night. OLED materials supplier Novaled also showed transparent OLED lighting panels in its booth. During his keynote speech, Dr. Michael Heckmeier from Merck showed examples of how Merck's OLED materials are being used to create lighting for automotive applications, including replacements for location and signal lamps that are incorporated in the body of a car's exterior.

Other SSL technology products were also present. LEDs are already generating significant energy savings worldwide. The same type of diffuser technology used for LCD backlight panels has direct application for LED-based SSL solutions. For example, Luminit, a maker of light-management films and panels, displayed a variety of its light-shaping diffuser products in the Display Week Exhibit Hall.

There were other materials stories at Display Week 2014, especially for OLED technology. One of the most intriguing, perhaps, was Dr. Heckmeier's keynote address about collaboration between Merck and Epson to develop soluble OLED materials for use in inks that could be employed to fabricate OLED displays through ink-jet printing and other processes. Also, Beneq had an exhibit showing its thin-film encapsulation barriers for OLED devices. Based on atomic layer deposition (ALD), this clear and flexible technology could be suitable for roll-to-roll production of OLED displays and lighting devices.

OLEDs on the Rise

While they are not likely to challenge LCDs in all markets, OLEDs have already established dominant positions in several arenas. And, as we saw throughout Display Week 2014, the new markets for wearable computing and solid-state lighting are opening doors where OLED technology may have a strong competitive advantage over other approaches. OLEDs are here to stay and growing stronger. ■

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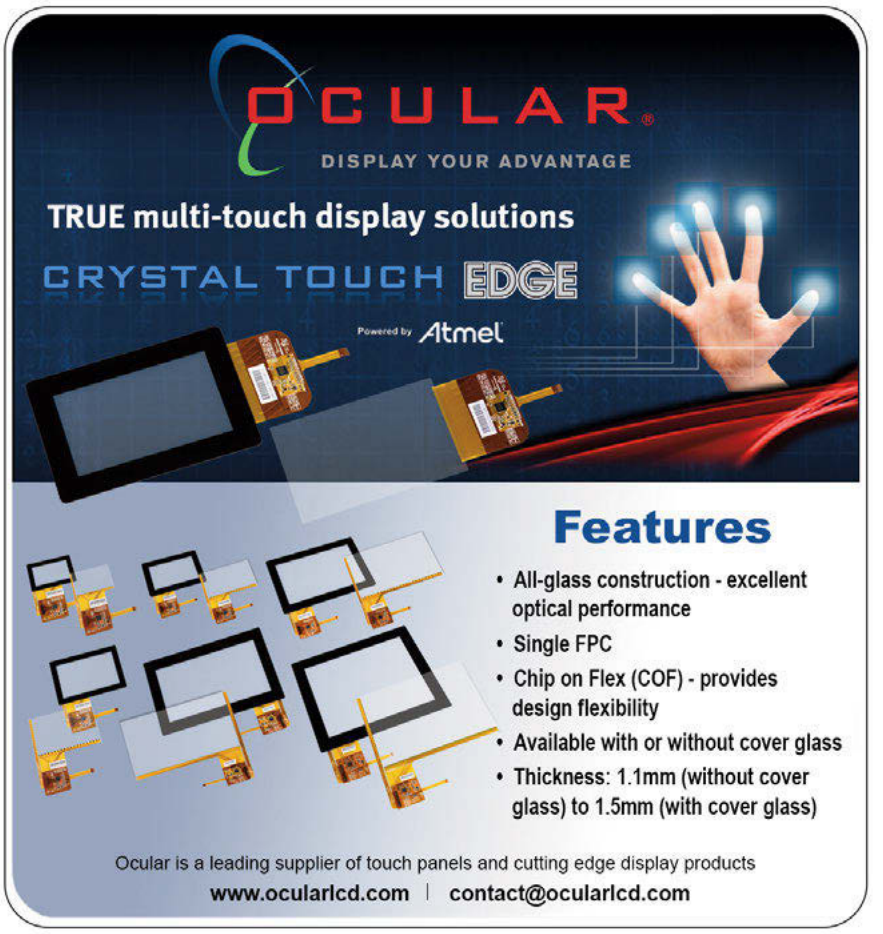

TVs, 3-D, and Holograms at Display Week 2014

Advanced technologies at this year's show included very large curved TVs, light-field displays, and more.

by Steve Sechrist

DISPLAY WEEK 2014 attracted some of the biggest and brightest by way of new TV displays. Flat-screen-TV market leaders Samsung and LG both brought their latest technology to the show as did others, including Sharp and BOE. For its efforts, LG took home SID's Display of the Year Silver Award, which recognized its 55-in. curved FHD OLED TV set, first announced earlier this year as a shipping product.

LG apparently has made significant progress in moving its big-screen OLED technology to mass production, with independent reports coming from the Korean press earlier this spring that the company has reached yields in the 70% range using its white OLED approach with color filters. When asked at the show about these reports, LG's Chief Research Engineer, Dr. Hong Jae Shin, told *Information Display* that the company could not confirm them but, smiling, added that they would not deny the report.

LG is expanding its OLED TV line-up and showed 65- and 77-in. curved UHD sets and non-curved OLED sets in its large booth at Display Week (Fig. 1). At the show, LG said two larger sets were slated for commercial shipment later in 2014. After the show, LG announced it was planning shipment of its 65- and 77-in. OLED TV sets in Europe, starting in October. This, perhaps more than any yield report, speaks volumes on just how the company is doing vis-à-vis production efficiencies in the OLED-TV category. The company also said it was moving to a more efficient curved AMOLED 55-in. TV with a new FHD model (55EB9600) that incorporates a low-power approach LG calls "Adaptive SVDD." This technology is designed to

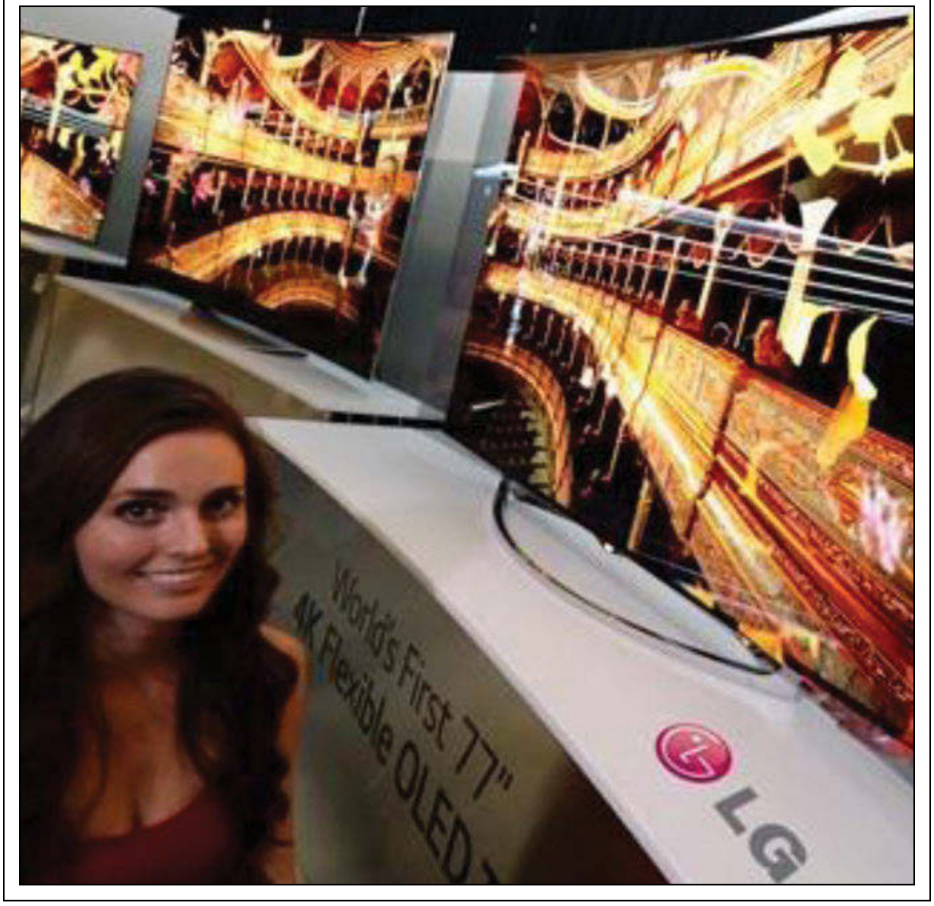

Fig. 1: *In terms of OLED TVs, LG is moving full steam ahead, with plans to sell a high-end AMOLED set in a variety of size ranges, including 55, 65, and 77 in.*

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reduce the number of TFTs and capacitors needed in the set. Power gains include 30% reduction with a voltage drop of 25% and a boost in gray scale by 25.8%, according to LG reports. Tae-Gyung Kim and a team from LG's OLED development group outlined the adaptive SVDD method in a Display Week technical paper entitled "A Novel Power-Saving Technology for OLED TVs with External TFT Compensation."

For its part, Samsung has moved on from its earlier focus on AMOLED TVs and, instead, this year introduced AMLCD curved sets that it plans to use in head-to-head competition with the LG OLED-TV technology. The Samsung booth included an impressive display of large curved TVs, including a 105-in. panoramic curved UHD model with a whopping 5120 × 2160 pixels (yes, a 5K set) that the company showed as a prototype at CES in January (Fig. 2). Samsung also showed a 65-in. curved LCD that recently received honors in the EU from the VDE (Verband der Elektrotechnik) for its ability to create an immersive viewing experience.

Samsung also showed new curved monitors in 27-in. sizes that it stacked side-by-side for an immersive desktop experience. This is the first time we have seen the curved display move from TVs to desktop monitors, and this product may be a strong candidate for a SID award next year if the product ships this year. (If you think this attention to monitors is long overdue, read this issue's opinion piece, "Gazing at the Future of Monitors," by analyst Bob Raikes.)

Clearly, the curved large-screen display is making waves in the consumer-TV space, as evidenced by a move to this technology in LCD format by Samsung. Ray Soneira's research at DisplayMate.com documents the visual benefits (the curvature can cut down on reflection, reduce geometric distortion, *etc.*), making a case for curving the set that goes beyond a mere marketing gimmick. Sony and Samsung are using this innovation to differentiate high-end LCD-based TVs. We expect this to be just the beginning and that more of these curved displays from other TV makers will appear at the Consumer Electronics Show in Las Vegas in 2015. Curved screens combined with UHD resolution (in either LCD or OLED format) make it more likely that consumers will be motivated to upgrade that living-room TV yet again.

Combined, the above innovations make a strong case for the further viability of the long-lived LCD technology. Many big-screen alternatives to LCD TVs have come and gone (remember SED TVs?), but LCDs historically have thus far risen to each challenge, closing the window on their rivals.

Fig. 2: *Samsung showed curved AMLCD TVs rather than OLED TVs this year, including this visually arresting 105-in. panoramic TV.*

3-D

On the 3-D front, we found some compelling developments at Display Week. In its booth at the exhibition, display maker Tianma (now partnered with electronics component maker NLT) announced a 3-D display system with eye tracking that it calls TR3i-2 or "Truly Realistic 3-D imaging." (Tianma NLT America, Inc., was established in November 2013 as a joint venture between Shanghai AVIC Optoelectronics Co., Ltd., and NLT Technologies, Ltd.)

This autostereoscopic eye-tracking system achieves smooth and realistic 3-D images without the use of glasses. It has its roots in NLT's proprietary 3-D image-processing engine that uses H×DP (or horizontally × density pixels) technology, now married to an eye-tracking device that helps localize the 3-D effect by detecting exact eye location. The system is designed to optimize parallax from any view, which will diminish or eliminate problems of motion parallax and 3-D crosstalk (Fig. 3). Takefumi Hasegawa of NLT Technologies provided information on the TR3i-2 system in a Display Week paper entitled "Optimized Parallax Control of Arbitrary Viewpoint Images with Motion Parallax on Autostereoscopic Displays."

NLT's approach is to convert stereo images and place them in the observer's field of view using the eye-position data, and it can even vary the binocular parallax based on the viewing angle of the observer to the display. The company said it is focusing on active-matrix LCD modules for now.

Light-Field Displays

In the abstract for his Display Week technical paper, "Wide-Field-of-View Compressive Light-Field Display Using a Multilayered Architecture and Viewer Tracking," Andrew Miamone of UNC Chapel Hill wrote: "Over the last few years, a new generation of displays has started to emerge: compressive light-field displays. By combining unconventional optical setups, such as multilayer LCDs or directional backlights with compressive computation, these types of displays support unprecedented image resolution and 3-D capabilities using commodity hardware. The key idea behind all of these displays is to directly exploit the compressibility of the presented light-field image content. However,

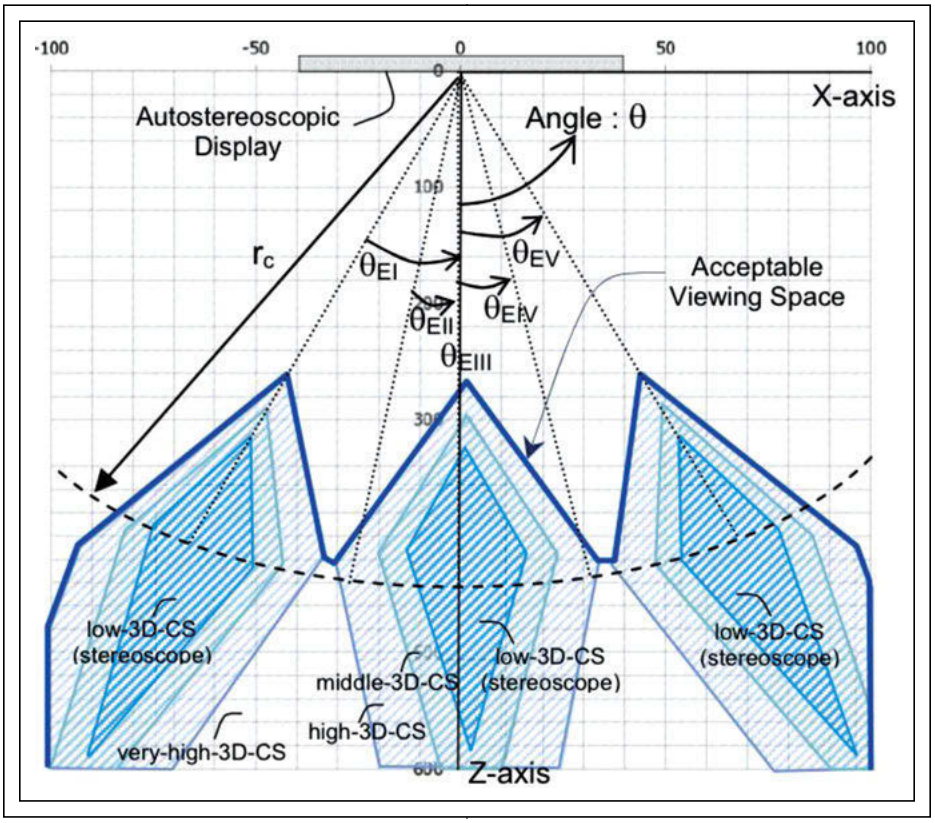

Fig. 3: This diagram shows the 3-D cross-talk space of a proposed autostereoscopic display using TR3i-2 technology from NLT-Tianma. Image source: NLT Technology/T.Hasegawa.

as opposed to conventional 2-D image compression, compressive light-field displays employ a joint optical and computational approach to presenting compressed content that allows the human visual system to act as a decoder."

Work in the area of light fields was discussed in Miamone's presentation, delivered with contributions from his group at UNC and by Ramesh Raskar and Andrew Wetzstein of the MIT Media Lab. This presentation demonstrated a real-time glasses-free 3-D display with a 110 × 45° field of view using efficient optimization and commodity tracking hardware and software. The authors' off-the-shelf prototype included a compressive light-field display created from two stacked LCDs and a Microsoft Kinect sensor that was used to estimate the position of the observer's eyes (Fig. 4). The software is said to be capable of real-time multilayer optimization, allowing the display to be observed over a wide field of view by an eye-tracked user.

The authors included a description of how a wide "apparent" field of view is created by using an extension of these light-field displays, where the narrow-view cones follow the viewer, thus moving autostereoscopic viewing beyond a single viewer experience, creating true parallax for one or multiple observers. This exploratory work using a combination of compressive light-field displays and head tracking to dynamically steer a small instantaneous field of view into the direction of a single tracked observer illustrates one way the perceived field of view of a display could be significantly improved.

In the Innovation Zone at Display Week, a company named PolarScreens was also making use of this compressive approach, but rather than light-field imaging, used two different images and a common mode image. PolarScreens calls it a tri-phase patterned light generator. It operates at 180 Hz and produces an artifact-free autostereoscopic 3-D image.

PolarScreens showed how an autostereoscopic image can be enhanced using a third image. The company says it can deliver full HD (FHD) to each eye and offer "complete freedom of movement" using this approach. The novel 3-D image-processing method includes adding the additional image (what is simply a normal 2-D image) to a left- and right-eye image sequence. According to the company, this central image goes a long way toward reducing flicker that can occur, especially when the viewer is blinking. This technology leverages the similarity between right- and left-eye images in a normal stereoscopic display by creating this third or central view. This common field is displayed during full

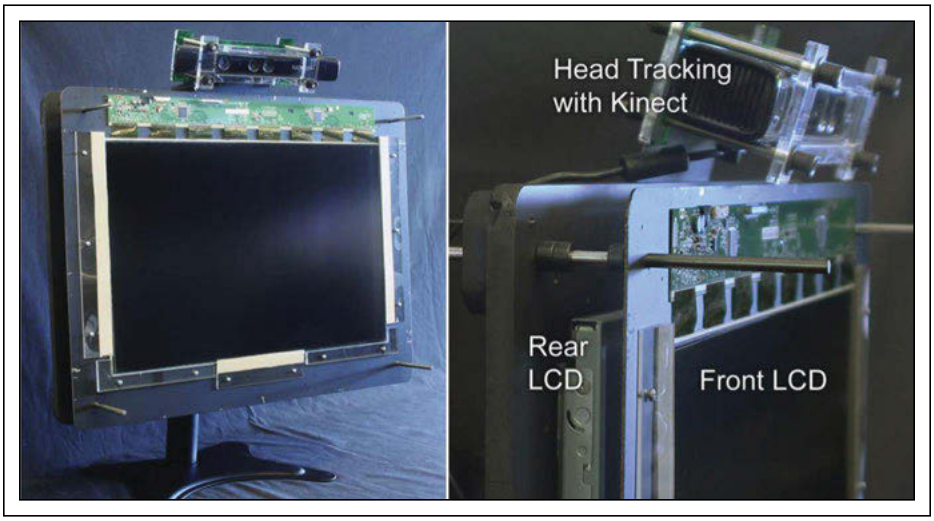

Fig. 4: This off-the-shelf prototype from UNC and MIT Media Lab's presentation on light-field displays shows the components used to extend the apparent field of view with eye tracking.

backlight and during the change (delta fields). It essentially decomposes the video into three fields: (1) common field, (2) left-right delta, (3) right-left delta; this delivers a more fluid transition between images, resulting in a comfortable viewer experience with minimal flickering.

Another example of 3-D in the I-Zone was a novel display device, the Quantum Photonic Imager (QPI), from Ostendo Technologies, which earned SID's Best I-Zone Prototype award. The QPI is a 3-D integrated circuit with what the company calls "micro-pixelated LED layers." The layers are stacked on top of a custom graphics processor and every pixel directly emits multi-color (RGB) light. According to the company, the display offers a density of about 25 million pixels/sq. in. and enables power-efficient and ultra-compact displays and projectors with applications in mobile (wearable) and potentially light-field displays (Fig. 5). Ostendo says it is looking at commercial, defense, air-traffic control, oil and gas, and similar industries with a potential to be operational with a commercial display as early as Q3 2015.

Researchers at Princeton University were also showing 3-D in the I-Zone – a capacitive 3-D gesture-sensing system. The team developed this by extending the sensing range of a capacitive touch screen further into the Z-space. Its sensing system consists of a gesture-sensing sheet that includes a readout IC (up to the 30-cm range) at a resolution of <1 cm or at a distance of 20 cm as developed on a 23-in. display. Princeton researchers said the 23-in.-diagonal display can sense gestures from the 3-D position of the user's hand (or other object) over the entire display area.

Fig. 5: *Ostendo Technologies showed its 3-D integrated circuit, the Quantum Photonic Imager (QPI), in Display Week's I-Zone.*

Holography

Of additional interest at Display Week was a paper covering holographic displays by Xiao Li and others from Shanghai Jiao Tong University entitled "Real-Time Holographic Display Using Quantum-Dot Doped Liquid Crystal." The group reported on creating a real-time holographic display with a refresh rate of 25 Hz from a quantum-dot doped liquid crystal. Other characteristics of the real-time hologram prototype included an

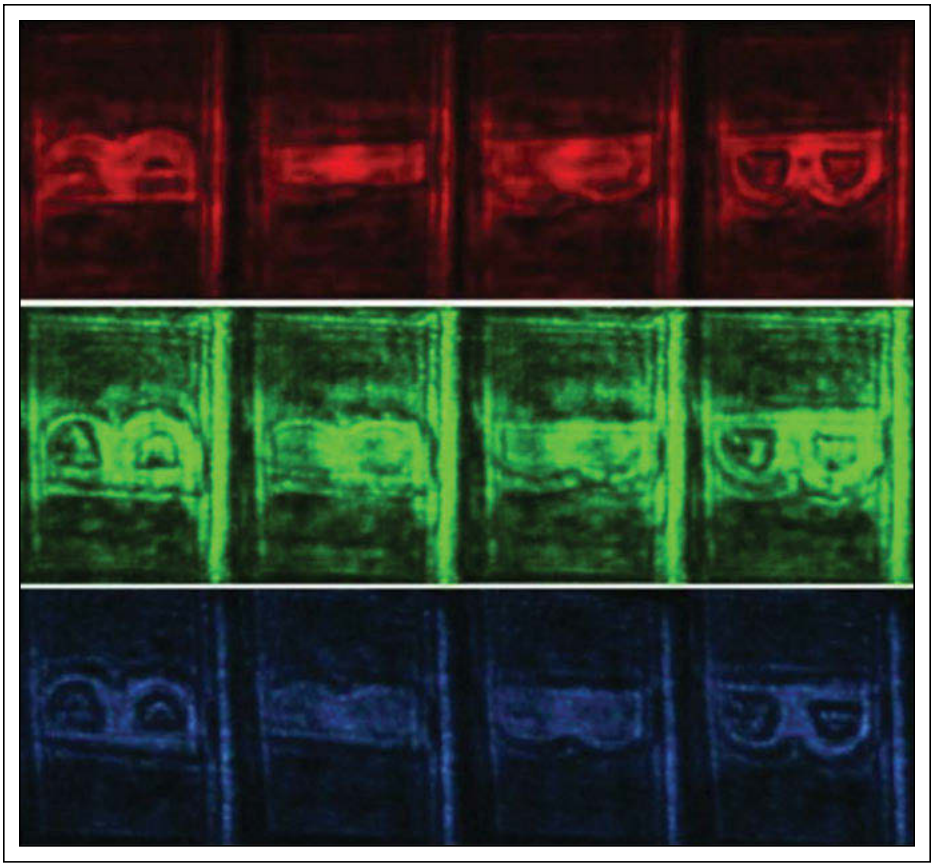

Fig. 6: *Photos from Shanghai Jiao Tong University of an RGB diffracted video image illustrate real-time holographic video from the holographic display.*

Fig. 7: This still image from Holoxica's Interactive Holographic Video Display on Vimeo.com shows how the technology enables a user to draw in "mid air." Source: Holoxica.

applied voltage of around 30 V, a rise time on the order of several to tens of milliseconds, diffraction efficiency up to 20%, and diffraction efficiency controlled by applying the external DC voltage.

The group also said they have successfully shown RGB real-time videos and verified the feasibility as a color holographic display with improvements up to two orders of magnitude (in diffraction efficiency over previous work) (Fig. 6).

Last, but not least, was the second-generation holographic display from Scotland-based Holoxica, Ltd., demonstrated at the I-Zone. The company developed what it calls a holographic optical element (HOA) that uses a laser-based DLP projector subsystem. Its technology is based on the same principles of free-space optics used in creating HUD systems that push the image to display in mid-air beyond the windscreen in a car. To this, the company added an element of interactivity using a Kinect motion sensor and developed a series of applications that engage the user with interactive icons, buttons, and the ability to draw in mid-air. I-Zone demos included a holo-based pong-style game, keypad, and free-form drawing in space and image sequences. This can all be seen in a Vimeo video from the company Web site at www.holoxica.com (Fig. 7).

Pioneering Technologies

Display Week delivered on its annual promise of bringing the best and brightest together in the display industry, from the slick new curved TVs now available in both AMLCD and OLED varieties to the migration of the curved screen to the desktop. (Samsung was first with this here at the show.) Pioneering autostereoscopic and holographic display work was also showcased at Display Week. The recent work in light-field displays, now merging with sensor technology such as eye- and head-tracking devices, is particularly inspiring. These demonstrations, both in the new I-Zone prototype area and in the long-standing SID Symposium with its strict peer-review process, show great promise for the future of the display industry. ■

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Display Week 2015

Networking Events

May 31–June 5, 2015

Looking to meet up with your colleagues in the display industry to discuss technology, business, or just socialize? The events below present just that type of opportunity:

Annual Awards Dinner, Monday:
Each year, SID recognizes individuals that have played a critical role in improving the display industry. This year's winners will be honored at an awards banquet taking place the evening of June 1 at the San Jose Convention Center.

Business Conference Reception, Monday:
Follows the Business Conference, please note conference attendance is required for admission.

Annual Award Luncheon, Wednesday:
The annual Best in Show and Display Industry Awards Luncheon will take place at noon on Wednesday, June 3. Both awards are peer-reviewed, such that the luncheon is well-attended by captains of industry for high-level networking and recognition of the best in the industry over the last year.

Investors Conference:
The IC will feature presentations from leading public and private companies in the display technology supply chain and encourage questions and discussion between presenters and participants. Concludes with Drinks & Displays: Networking Reception with Presenters and Investors

Market Focus Conference Reception, Wednesday:
Follows the Wednesday Market Focus Conference, title and program TBD, please note conference attendance is required for admission.

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Materials Matter

Developments in materials and materials processing are the foundation on which flashier advances in downstream technologies are built. That has certainly been true over the entire history of display development, and it continued at SID's Display Week 2014, held last June in San Diego.

by Ken Werner

THREE OF THE FOUR most important driving categories at Display Week this year (OLEDs, quantum dots, and backplane technologies) have been highly visible for several years, but the devil is in the details and in the progress developers have made. At the show, there were lots of devilish – and angelic – details to capture the imagination. The fourth important driver, technologies for replacing ITO, has been less in evidence but is rapidly gaining momentum, with ITO-replacement technologies finding their initial high-volume application in touch panels.

Quantum Dots

To briefly recap, quantum dots are the elegant realization in an engineered material of the quantum wells that physics majors have learned about for decades. Unlike phosphors, it is the size of quantum dots – not their chemical composition – that is the main determinant of their behavior. And the behavior that is of primary interest in LCD backlight design is that incoming light from blue LEDs can be converted by quantum dots of the appropriate diameters into green and red light with very narrow spectral distributions. The result is an RGB spectrum that looks much like that produced by an OLED display and gives the LCD similar properties of high contrast, saturated colors, and wide color gamut.

It is worth noting that although an RGB spectrum is what is now being used for all commercial quantum-dot applications, it is possible to produce quantum dots that emit at virtually any wavelength that is longer than the blue used to excite the dot. So, Sharp, for example, could add quantum dots to the mix that were sized to produce yellow, thus enabling a quantum-dot-enhanced version of Sharp's Quattron (RGBY) display.

The two major players in quantum-dot materials at the moment are Nanosys, which supplies the materials to 3M for its Quantum Dot Enhancement Film (QDEF), and QD Vision, which supplies the dots for its own glass-encapsulated Color IQ optical element.

At Display Week, 3M and Nanosys showed new ASUS notebook PCs with 15.6-in. 4K × 2K quantum-dot-enhanced screens with a visually striking color gamut (Fig. 1). This is the first high-volume notebook product using 3M QDEF, and 3M sees the product's introduction as a milestone. We are not used to seeing high-resolution wide-gamut images such as those on the ASUS at a short distance, and the effect is so striking that it is hard to look away from the screen. This is a display that could easily sell the product of which it is a part, and it is a fine example of quantum dots' ability to provide dramatic increases in display impact at a very small increase in cost.

3M also showed a 65-in. QDEF-enhanced panel that produced 85% of the new Rec. 2020 gamut. The company's models predict it is possible to get to 92% of the UHD gamut.

Until this year's Display Week, most industry analysts would not have thought of quantum dots as an enabler for high-dynamic-range (HDR) consumer television. Indeed, a year ago, HDR was not on anybody's stated feature list for advanced-generation television. Now, all major TV makers are at least mentioning it. In his Display Week keynote address, Kazumasa Nomoto (Senior GM, Sony Display Device Development Division) specifically mentioned HDR as part of the envelope of future TVs, and at CES this past January, Sharp showed an HDR technology demonstrator using Dolby technology.

And that brings us to the combination of quantum dots and HDR that was demonstrated by Nanosys and Dolby in Nanosys's booth (which won a Best-in-Show award in the Small Exhibit Category). Nanosys showed two TV sets side by side. One was a conventional LCD TV; the second incorporated both QDEF and Dolby's HDR technology, and that image was compelling. But what does QDEF have to do with HDR?

Nanosys' Jeff Yurek told me that QDEF turns out to be a critical tool in reducing the cost and power consumption of HDR, factors which have until now limited the technology to very expensive professional monitors. Dolby's current technology uses 2300 red, green, and blue LEDs in a full-matrix backlight array. Controlling the LEDs in clusters, known as local-area dimming, is the key to

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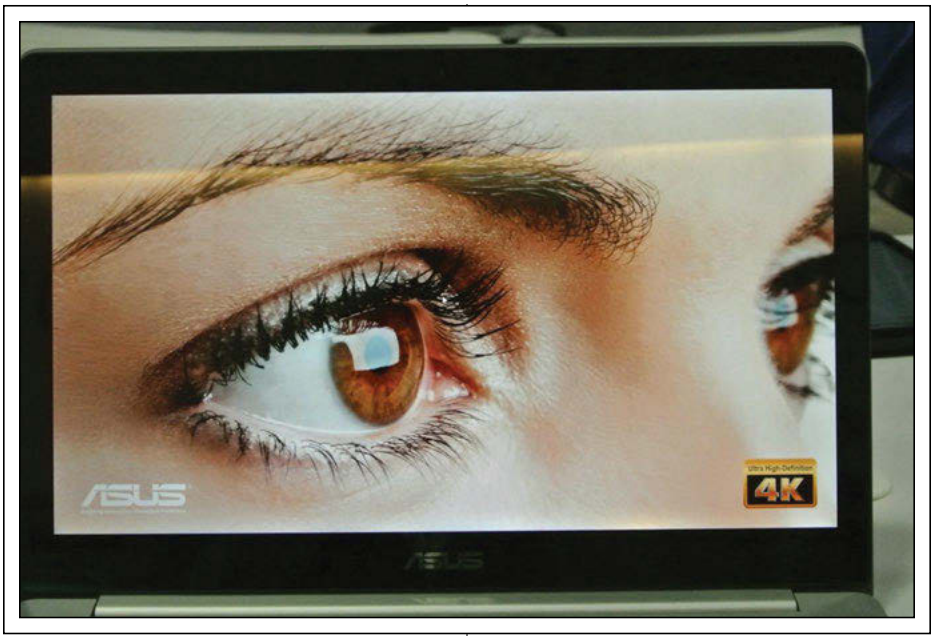

Fig. 1: *This 4K QDEF-enhanced display appears in a new ASUS notebook PC and was shown at the 3M booth at Display Week. The high resolution and wide color gamut of this image cannot be appreciated in the printed version of this image or in a version seen on a conventional display. Photos courtesy Ken Werner.*

HDR, and Dolby is currently controlling the LEDs individually. Some of the LEDs are very inefficient, with lots of heat generated and very high power consumption.

However, if designers employ only efficient blue LEDs and use QDEF to convert the blue light to red and green, the power consumption would be reduced. For consumer television, it is likely that the number of LEDs would be sharply reduced as well.

Two other quantum-dot companies are not yet in commercial production for displays but deserve watching. Nanoco Group gave a presentation at the SID/Cowen and Company Investors Conference at Display Week and discussed the company's cadmium-free technology. (Nanosys and QD Vision's dots have cadmium selenide cores. Some people have objected to the production of quantum dots on the basis of the well-known biological hazards of bulk cadmium, but it is not clear that encapsulated CdSe in a quantum dot poses any biological hazard.)

In early 2013, Nanoco announced that Dow Electronic Materials would have exclusive worldwide rights for the sale, marketing, and manufacturing of Nanoco's dots for electronic-display applications.

At the time of Display Week, Quantum Materials Corp. (QMC) announced that it had received its higher-capacity equipment and would be launching volume production of its tetrapod quantum dots (TQDs) several months ahead of schedule. The announcement read that "production-phase equipment is capable of producing 250 kg of quantum dots per annum." Early in August, the company followed up with an announcement that it had achieved a 95% quantum yield with dots produced in an automated production system.

QMC claims greater efficiency and consistency of application with tetrapodal (as opposed to spherical) dots. Although the dots' tetrapod shape could be exploited to produce different intensity or color of emission in different directions, isotropic emission is the goal for display applications.

To sum up, many new quantum-dot-enhanced products to be introduced this year will have Nanosys and QD Vision quantum dots inside them, but do not forget to keep an eye on Nanoco and QMC.

OLEDs

The 30,000-ft. view of the OLED situation had not changed much for the last couple of years. Smallish OLEDs for smartphones, made mostly by Samsung Display and mostly for Samsung phones, were (and are) a success. Large OLEDs for television were a niche product due to expensive manufacturing, low yields, and consequent high prices. Tablet-sized OLEDs were in an unprofitable no-man's land.

But things are changing. The Samsung technology that produced what Ray Soneira of DisplayMate called the best display he had ever seen in a smartphone has now been introduced in commercially available tablets.

One would think that Samsung's long-held position as king of the small-OLED hill would have invited some serious competition by now, but the modest scale of activity in China and Taiwan has not been enough to make an appreciable dent in Samsung's dominance. Now, however, a significant Chinese player is making a major investment in AMOLED manufacturing.

At Display Week, Tianma was showing several good-looking AMOLED prototypes, including a 4.3-in. display with 480 × 800 pixels, on-cell touch, 250 nits, and a claimed contrast ratio of over 10,000 (Fig. 2) and a 5.5-in. display with 720 × 1280 pixels, 4-lane

Fig. 2: *Tianma's cell-phone-sized AMOLED prototype was on display at Display Week in San Diego. Photo courtesy Ken Werner.*

MIPI interface, 200 nits, and that same claimed a contrast ratio of over 10,000.

Tianma's Stephen Liu told me that the company is now building a Gen 5.5 AMOLED fab in China and expects to be ramping up commercial production of smartphone and tablet sizes in mid-2015.

It's worth saying that Tianma's exhibit area at Display Week was decidedly major league and fully competitive in design and presentation with those of its first-tier competitors. Tianma combined its China-based Tianma and U.S.-based Tianma-NLT teams to design the booth and select the products and technologies to be presented. Tianma and NLT personnel said they worked hard and long on the exhibit and were very pleased with the result.

On the larger side, LG Display has announced substantially improved manufacturing yields for TV panels, and Tier 1 OLED-TV makers have announced prices that are so sharply reduced that a larger percentage of consumers in a (slowly) improving economy are likely to be tempted.

LG Display's View of OLEDs and Backplanes

At Display Week, Changho Oh (SVP for LG Display's OLED TV Development Division 1) told me that the company's Fab 1 was producing panels for LG's 55-in. OLED TV at a 70–80% yield. This is a remarkable improvement from what was widely estimated to be a 10% yield in the middle of last year and 50% early this year.

LG will be offering new 55-, 65-, and 77-in. curved OLED TV models this year. All new models for 2014 will be curved, although some holdover models will be flat. The panel yield will be different for each size, Oh said.

On the question of IGZO stability, Oh said very frankly that the oxide-TFT process has very narrow process margins and was difficult in the development stage. It is necessary, he said, to understand all of the characteristics and to be able to control them precisely. The situation with the OLED frontplane, he said, "…is not so difficult because we use WOLED," referring to the white OLED process LG uses for its TV panels. He confirmed that most of the yield issues were related to the oxide-TFT process and the "very complicated backplane," which uses three or four transistors per pixel (LG uses four). As a result, an extra power line must be designed into the backplane. Farther down the line, LG might consider using a different oxide. For now, the company has made its investment and is enjoying the fruits of its labors.

Oh agreed that the blue OLED lifetime remains on the short side. LG's spec is a D6500 white point that does not vary by more than 500°C over 20,000 hours, which represents about 7 years of viewing for the typical consumer. Oh said this is a tough spec, but it is being met. He also said that an oxygen/moisture barrier for TV-sized panels is not the problem that I had thought it was. LG uses a 0.1-mm metal sheet and tests the seal by bending the panel 20,000 times without any problems.

I asked about solution processing, which is widely regarded as the way to make OLED manufacturing costs competitive with that of LCDs. Oh confirmed that LG has a large research program in this area, and also that equipment and development are expensive. LG's goal is to have solution-based panels available in 2018.

To date, LG has had the most experience and the most success with IGZO backplanes for OLED displays, but Sharp has taken the lead with IGZO for LCDs. Sharp is not stopping with LCDs, though. For some time, the company has been working with the Qualcomm subsidiary Pixtronix on using IGZO TFTs to drive Pixtronix's in-plane MEMS shutter display. At Display Week, Sharp showed a very-late-state prototype of a 7-in. Pixtronix display with IGZO backplane (Fig. 3). The display will initially be marketed for industrial applications, said Sharp Senior Product Marketing Manager Dave Hagan, and it is likely we will see commercially available displays before the end of the year.

ITO Replacements

New transparent conductors to replace the industry standard but unloved ITO were intended to be a featured topic at Display Week. But the only regular session devoted to touch sensor materials contained a mere three papers, two devoted to metal mesh and one to Canatu Oy's Carbon NanoBud material.

The Exhibitors Forum session entitled "Transparent Conducting Films" contained six presentations: Carestream's FLEXX silver nanowire, NanoWeb's submicron metal mesh, Cima NanoTech's self-assembling nanoparticle technology, Canatu's Carbon NanoBud (again), Daido's sputtering targets for barrier layers and copper interconnects, and Oxford Advanced Conductors' silicon zinc oxide as an ecologically sensitive substrate for ITO. Not mentioned, as far as I could determine, were graphene or organic semiconductors, which are getting lots of attention elsewhere.

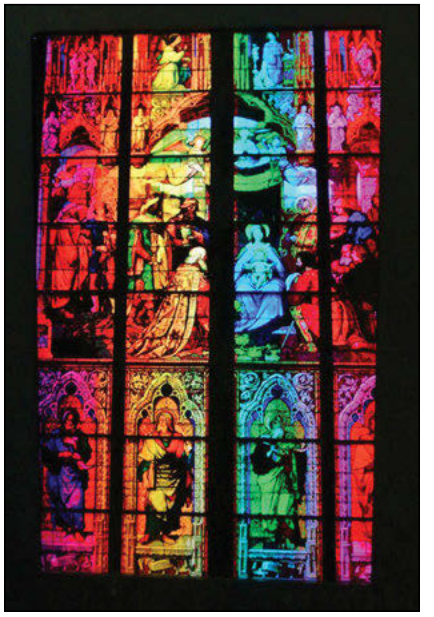

Fig. 3: *Sharp used its IGZO backplane to drive this 7-in. Pixtronix in-plane MEMS display, which was exhibited in Sharp's booth at Display Week. The entire display will be manufactured by Sharp, initially for industrial applications, and should be available this year. Photo courtesy Ken Werner.*

For the moment, self-assembling silver nanowires and silver metal mesh are the ITO replacement technologies that have made an impact in commercial products.

Materials Make the Difference

It is clear that developments in display materials and materials processing are being energetically pursued, and we have not even discussed developments in OLED and LCD materials themselves. As long as those developments continue, we can look forward to significant improvements in display panels and display-centric products. ■

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Flex for Real

The increasing reality of flexible technology was clear at Display Week 2014, where it appeared on the show floor, in the technical sessions, and as the subject of its own Market Focus Conference. e-Paper also appeared in its largest format yet.

by Jenny Donelan

SOMEDAY, we are told, we will have electronic newspapers, maps, and other devices that fold up to fit into our pocket or purse. As with most technological advances, we will not get there overnight. We will not wake up tomorrow morning to read our pocket newspaper. Yet, there really are displays – at least prototypes – that roll up and keep working when rolled and unrolled. And there are a host of products and enabling materials such as films and substrates that are enabling the reality of flexibility. We did not have all that just a few years ago. Progress toward flexible displays is being made, and you could hear about it and see it at Display Week 2014.

Flexibility on the Floor

There were plenty of flexible displays on hand at the Display Week exhibition, and, this year, the majority were OLED-based. Flexibility is one area in which OLEDs shine, as contributing editor Alfred Poor points out in his OLED Display Week review in this issue. Poor was especially impressed by a 5-in. panel from AUO on the show floor. This display had high-definition resolution (1280 × 720 pixels) and was built on a plastic substrate with a thin-film barrier for encapsulation. This active-matrix panel was just 0.2 mm thick – equivalent to about two sheets of paper – and could be bent to a radius as small as 1 cm.

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Curved OLEDs on the show floor included phones such as LG's G Flex and Samsung Display's Galaxy Round, and the very large, curved TVs from LG. These products are not meant to be rolled or flexed (although the G Flex does actually bend somewhat, which should help in terms of durability), but the fact that they were flexible enough to be manufactured in a curved format speaks to recent advances in flexible formats. Both phones won Display Industry Awards this year, and LG won both a DIA and a Best in Show for its OLED TV products. Samsung was showing not curved OLED TVs like it did last year, but curved LCD-based sets.

In the Zone

Display Week's Innovation Zone, a special area of the show floor where start-ups and researchers can show forward-looking technology, had a couple of interesting flexible exhibits. One was DaeFlex, a family of products from Korean company Daetec, that is designed to meet flexible-display manufacturing challenges. Technologies shown in this year's I-Zone included cast flexible transparent substrates, strippers, and washable coatings.

We took note of an OLED display created on a plastic substrate by Plastic Logic that was demonstrated in the I-Zone. This panel used an organic thin-film-transistor (TFT) backplane that had been printed on plastic film at temperatures below 100°C. This device was so flexible that it could be rolled around a pencil while continuing to operate. For a picture, check out Alfred Poor's OLED review in this issue.

Flexible Displays Market Focus Conference

This year's Display Week event featured a Market Focus Conference dedicated to flexible displays. The conference was co-sponsored by SID and the market research firm IHS and coordinated by Mark Fihn, publisher of the *Veritas et Visus* family of display-industry newsletters. Among the many presenters at this all-day event were Kent Displays, Industrial Technology Research Institute, the Holst Centre, FlexTech Alliance, Argus Insights, Corning Glass Technologies, E Ink, Bardsley Consulting, Plastic Logic, Canatu Oy, and IHS.

John Feland from Argus Insights in Los Gatos, CA, talked about emerging consumer trends in wearables and what that means for display makers. What users want, said Feland, is lower power to minimize "care and feeding," great readability in full sunlight, a very flexible form factor, and rich color imagery – all for somewhat less than the cost of a Rolex. Manufacturers are not there yet in meeting those desires, but efforts toward the above winning combination will drive broader adoption as performance is perfected and the elusive "killer app" for wearables is developed.

Gerwin Gelinck from the Holst Centre in the Netherlands spoke about the many layers required for flexible OLED displays and the need for moisture barriers, heat resistance, and other features in many of these layers. Noting that flexible prototypes have been demonstrated for more than a decade, Gelinck pointed out that new materials and processes are still needed in order to make these flexible

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e-Paper

E ink has become almost synonymous with e-Paper and, as usual, had a booth chock-full of cool e-Paper products, including watches, signs, e-Readers, and other items. This year was no different, and E Ink was also showing off a new 32-in. display (Fig. 1); its largest yet, created in partnership with Global Display Solutions (GDS), a developer of outdoor and indoor digital-signage applications.

The new display is targeted primarily at applications in the digital-signage and information-kiosk markets and is available in black and white and color (E Ink's Triton) modules. This is obviously a great application for the E Ink technology, as it enables signs that are lightweight, low power, and readable in ambient light conditions.

Fig.1: *E Ink's new 32-in. electrophoretic display comes in gray scale (shown here) and color and is designed for indoor and outdoor signage.*

displays cost-effective for a wider variety of applications on a mass-production basis.

Technical Flex Topics

The Display Week technical symposium also covered flexible technology in depth, with sessions including Flexible OLEDs I and II, Flexible AMOLEDs I and II, one on Flexible TFTs, and other sessions on wearables and various flex-related topics. Among the many flexible-OLED-display papers, we took note of one in particular from researchers at Semiconductor Energy Laboratory (SEL) in Japan, along with colleagues from Advanced Film Device and Nokia, who demonstrated a novel OLED display that could be folded in half and still function – even when folded. The prototype 7.9-in. display on a plastic substrate had a high-definition 1280 × 720 pixel resolution (249 ppi) and was folded to a radius of 2 mm for more than 100,000 times without defects appearing.

Roving Reporter Steve Sechrist (whose TV and 3-D review from Display Week also appears in this issue) noted the work in printed organic TFTs (OTFTs) reported by the Research Center for Organic Electronics at Yamagata University in Japan. Here, Shizuo Tokito and team showed a 30 × 30 pixel OTFT array using silver nanowire inks. In the paper, they discussed work using printed TFT arrays and ICs employing a "pseudo" CMOS inverter printed on plastic film. They claimed electron mobility of 2 cm^2/V-sec and a delay time of 3.5 msec.

In addition to the above papers, Display Week this year offered a seminar entitled Flexible OLED Displays and Lighting Devices by Universal Display Corporation's Ruiqing Ma. In all, if you had any interest in flexible technology – and if you are in the business of displays, you should – Display Week was the ideal place to catch a glimpse of what the future has to offer. ■

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Gazing at the Future of Monitors

A strange contradiction exists in the display business. While there have been major improvements in many of the displays in our lives, including mobile devices and TVs, few of these improvements have reached the displays many of us spend the most time with – desktop monitors.

by Bob Raikes

In recent years, there have been dramatic upgrades in the visual performance of displays, many of them driven by Apple's marketing of the concept of the "Retina display." Apple took advantage of the great technology available from display makers to create products that simply looked better. Consumers, it seemed, were happy to pay more for the compelling visual and intuitive interactive experience. TVs have also undergone sweeping improvements in terms of form factor (thin and/or curved), resolution, and price.

Yet, the revolution in mobile displays, for example, that is adding more than 500 ppi, wide color gamut, wide viewing angles, and high brightness to our devices is barely impacting the world of desktop monitors, the display we spend the most time with. As somebody said to me this week: "I spend more time with my monitor than with my wife!"

Admittedly, there has been an increase in the share of the market taken by monitors with in-plane-switching (IPS) panels for wider viewing angles, and there is a move by some vendors to boost vertical-alignment (VA) LCD panels in monitors, but the vast majority of shipping monitors use twisted-nematic (TN) technology – long abandoned in tablets and smartphones. There is a huge installed base (probably close to a billion) of monitors with only 70–100 ppi, poor viewing angles, and low color performance.

Although mobile devices are garnering an ever-increasing market share, monitors will continue to be important for most PC users. We saw, after the advent of netbooks, that good-sized displays are essential for heavy usage, and, of course, in the European Union, employers are obliged by health and safety law to provide users, even those with notebooks, with monitors that can tilt and swivel. Many netbook buyers later went back and bought monitors to use with them. The peak of netbook sales in 2010 is the only period in which monitor sales have not dropped in recent years.

The Unchanging Desktop

Another strange thing about the desktop experience is that it has not really changed for a very long time. I remember seeing a Perq workstation at a technology event around 1980 or 1981 that had a graphic screen, a keyboard, and a mouse. The interaction model with desktop PCs has not changed significantly since, although it was Apple that made it accessible and Microsoft and Intel that made it pervasive.

At Display Week 2014, Samsung did show some monitors in a new, curved form factor designed to create a more immersive desktop experience. But it seems to me that there is a great opportunity for someone to do for the desktop what Apple did for the mobile phone, by transforming the interaction experience. Over the last 2 or 3 years, I have been repeatedly asked by clients, "What about touch on the desktop?" For a couple of years, I made it pretty clear that touch on the desktop was not going to be important. If you hold a device in your hand, touch is clearly a good idea. If you have the display attached to the keyboard, as you have in a notebook, it could work, but doesn't make as much sense.

However, desktop monitors are used at a further distance from the operator than notebooks or tablets (it is a function of the human visual system that it is more comfortable if displays are at a distance closer to the "resting point of vergence" – typically 90 cm when the user is looking slightly down). That means that to touch them, the arm has to be fully extended and that is not a practical maneuver throughout the working day. I can see the headlines about repetitive stress injury in shoulders!

Alternatives to Touch

I am nevertheless convinced that a transformation of the user experience is possible. Some people have suggested to me that sound input might be a good match for computer input, but most office workers do not want to say out loud what they are writing (the people in the airline seats around me as I write this article would not be very happy if I were

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dictating it). Furthermore, intensive use of the voice is tiring and uncomfortable, as anyone who has run a full-day training course will know.

Could it be gestures? I can imagine some kind of swipe or zoom gesture, close to the keyboard, being useful, but it's hard to see what advantage there is to swiping a screen over swiping a touchpad, for example, so I cannot back that idea for general input.

I think there is a technology that can transform the user experience and that is gaze recognition. With this technology, a system consisting of a couple of cameras and an infrared light source can track where on the screen the user is looking. It's not as accurate as using a mouse or trackpad, but it's broadly as accurate as touch. You do need an operating system that is designed to work well with touch. That's not the problem it used to be, now that Windows 8 is here – although the touch interface has not proved popular with desktop users. (Could that be because it is not used with gaze?)

Personally, I like to have my mouse set up so that it is not particularly sensitive, which makes fine work easier. However, it also makes it painful to move the cursor a long way, and I frequently lose my tracking of the cursor when I'm back at base with my notebook and a large desktop display. How much better it would be if the cursor moved to where I was looking!

Gaze Needs Multi-Modal Input

Although I have seen demonstrations of gaze being used alone for input (as it might be by users who have accessibility issues with keyboards and mice), it seems to me that the real key to unlocking the power of gaze is to combine all the different forms of input for the PC. For example, it would be great just to look at a Google Map and press the zoom button on my ergonomic keyboard or turn the wheel on my mouse and zoom to the point I'm looking at. I would love to be able to look at a word on the screen I am using and hit a function key to check the spelling.

It occurs to me that we really do not make the most of our limbs. Combining gaze with a foot pedal would be much better for me, as a heavy-duty writer, as it would mean that I would not need to take my hands away from the keyboard. I want to drive my PC like I drive my car!

Of course, the gaze recognition does not have to be built into a monitor, but it makes sense to do that, especially as monitors often have integrated USB connections that could send gaze data back to the host system. Some monitor makers are already looking at this – Tobii had a BenQ prototype monitor with an integrated tracker at CES (Fig. 1) and a notebook with an integrated sensor at CeBIT in March in Germany.

The company is also working with gaming peripheral manufacturer SteelSeries to modify PC games to exploit what gaze recognition can do. The first games should be in the market by the time you read this.

In summary, it seems to me that the market is ready for someone to significantly transform the user experience of desktop computing, just as Apple did to the experience of using a phone. It seems the least that could be done for the display we spend more time with than any other. ■

Fig. 1: *Tobii showed a BenQ monitor with eye control at CES last January.*

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Practical Computer Vision Enables Digital Signage with Audience Perception

Signs that see and understand the actions and characteristics of individuals in front of them can deliver numerous benefits to advertisers and viewers alike. Such capabilities were once only practical in research labs and niche applications. But semiconductor price, performance, and power-consumption trends are now making audience analytics, gesture interfaces, augmented reality, and other features feasible for high-volume mainstream deployments.

by Brian Dipert, Rabindra Guha, Tom Wilson, and Robert Green

THE digital-signage market is one of the brightest stars in today's technology sector, both in replacing legacy static signage in retail and other environments and in expanding the overall market for advertising, information, augmented reality, and other applications. While digital signage has been around for decades in the form of LED-based signs, it has taken off and evolved in recent years due to a variety of factors, including computing technology that is both better and lower cost, and a growing understanding of ROI and content management on the part of deployers. Analyst firm IHS has forecasted that the digital-signage market will reach $17.1 billion by 2017, from $13.2 billion in 2012.[1]

The integration of vision-processing capabilities within digital signs is a critical element in the market-growth momentum that IHS and other analyst firms forecast. These types of image perception, understanding, and decision-making processes have historically been achievable only using large, heavy, expensive, and power-draining computers and cameras. Thus, computer vision has long been restricted to academic research and relatively low-volume production designs by virtue of the high cost and high power consumption of the required hardware. However, with the emergence of increasingly capable processors, image sensors, and memories, along with robust algorithms, it has become practical and cost-effective to incorporate computer-vision capabilities into a wide range of systems, including digital signs.

Audience Analytics

The ultimate aim of digital signage is to make money for advertisers. In comparison to traditional static posters, even basic digital-signage implementations, which distribute advertisements to network-connected screens, have proven to be effective in attracting audiences to products and services. However, despite compelling content such as frequently updated still images and even high-quality video, conventional digital signage is becoming commonplace, thereby muting its initial wow factor. And such elementary approaches only support "blanket" delivery of a generic set of content, regardless of who is looking at the screen at any particular point in time.

A more compelling approach involves using a camera, either embedded within or located near the display, to determine the age range, gender, ethnicity, and other attributes of the viewer(s), thereby enabling the delivery of audience-tailored content. Emerging technologies such as face detection and audience analytics are making a critical difference in such applications. Targeted advertising holds the viewer's attention longer, resulting in longer memory retention of the advertisement and translating into higher sales. Other benefits include the ability to track shoppers as

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they move through the store via multiple signage locations, thereby determining general traffic flow, analyzing interests and bottlenecks, and resulting in optimized store layouts.

Person Discernment

Detecting people in order to count them and subsequently determine more about them is a challenging computing task for a number of reasons. The object of interest can be difficult to discern in poor lighting conditions and in environments containing cluttered backgrounds, for example, and people have a wide range of appearances (including clothing options), body sizes, and poses. But automotive applications have shown that with in-car cameras and analytics algorithms, it is now possible to detect pedestrians with such accuracy that driver-assistance systems are even employed to help control the car and avoid collisions.[2] Such algorithms are conceptually also applicable to digital-signage analytics setups.[3]

Xylon's logiPDET Pedestrian Detector is an example of an intellectual property (IP) core developed for vision-based applications.[4] The techniques employed by logiPDET follow the common principles of all such systems; detect an object, then classify it. In this particular case, the Histogram of Oriented Gradients (HOG) is a feature descriptor that describes the structure of a pedestrian, while the Support Vector Machine (SVM) is a machine-learning algorithm that is trainable to recognize HOG descriptors of people. By means of a movable detection window, logiPDET computes a HOG descriptor at each window position, which then transfers to the SVM in order to determine whether the object should be classified as a person.

Xylon's logiBAYER Color Camera Sensor Bayer Decoder IP core captures, pre-processes, and stores the input video image in external memory (Fig. 1).

LogiPDET then works in combination with the logiCVC-ML Compact Multilayer Video Controller and logiWIN Versatile Video Input IP cores to detect and categorize pedestrians at various sizes, in order to enable detection at various distances. A second logiCVC-ML core then outputs the video of the detected pedestrians to the screen (Fig. 2).

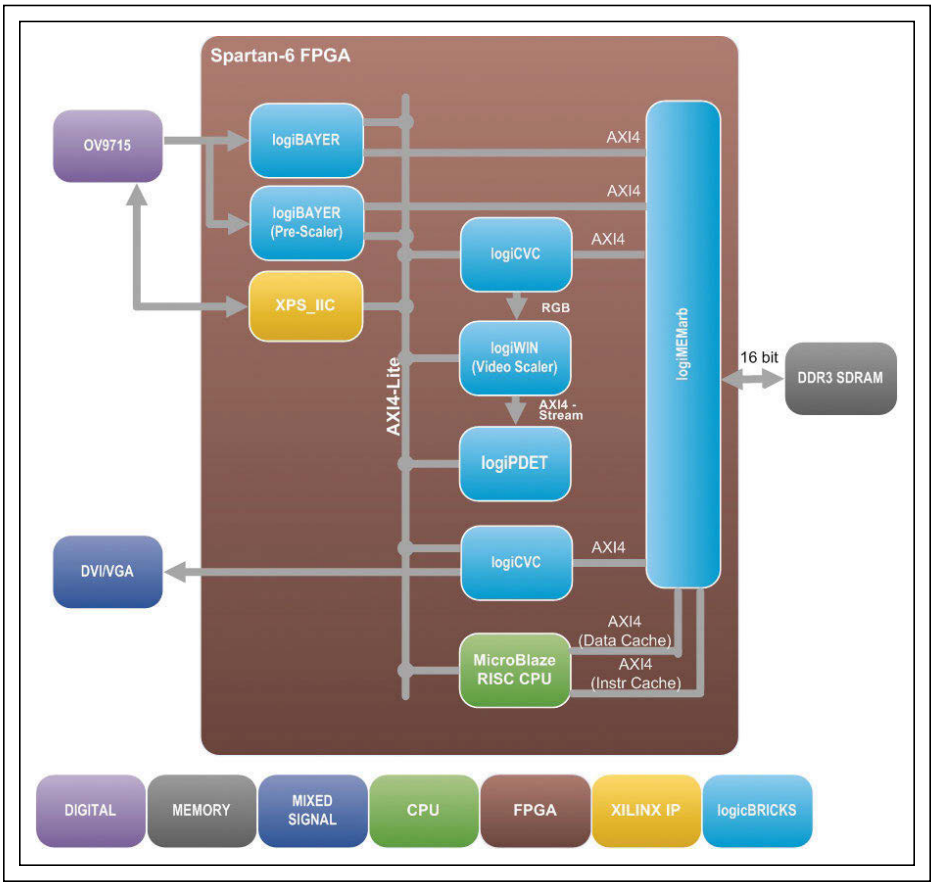

Fig. 1: *Xylon's pedestrian detection reference design is based on Xilinx FPGAs, which combine ASIC-like performance, logic density, and low power consumption with implementation flexibility analogous to that of software running on a CPU – all attractive attributes in vision processing.*

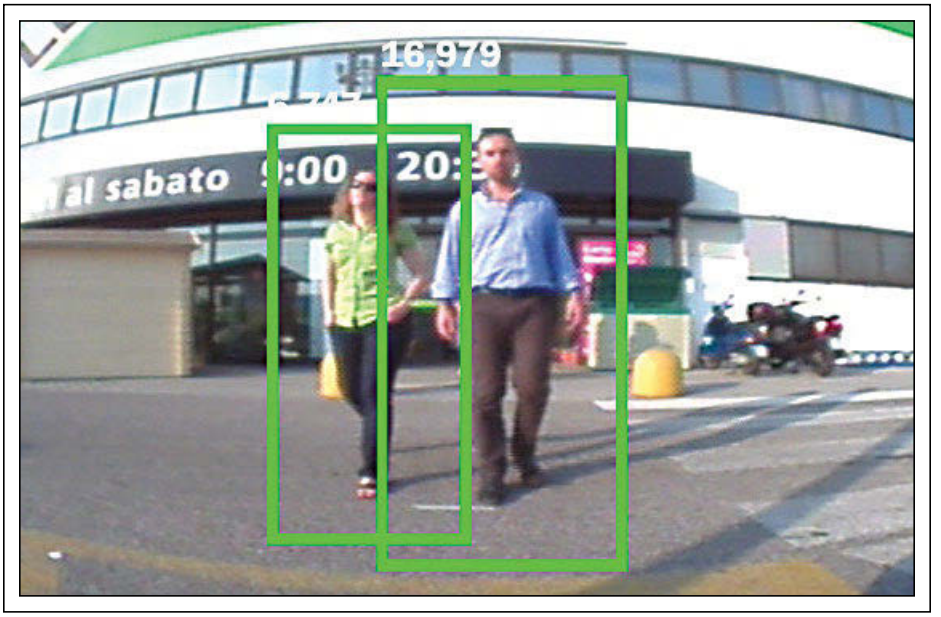

Fig. 2: *The logiPDET Pedestrian Detector leverages other Xylon-developed cores to capture and pre-process incoming images, then output results to the display.*

Detecting pedestrians in real time is perhaps obviously necessary in automotive driver-assistance systems and is desirable in many digital-signage applications as well. High-speed processing is a key means of ensuring sufficient detection and classification performance. Such performance can also be harnessed in digital-signage designs to enable the simultaneous detection of multiple passersby, with the processor remaining cost-effective and small in footprint, as well as consuming little system power. Low power consumption translates into low heat generation, thereby enabling digital-sign designs that are thinner, lighter, more reliable (no fans), and more economical to manufacture than would otherwise be possible.

Facial Analysis

Face-analysis software is currently able, with impressively high accuracy, to determine signage viewer characteristics such as age range (child, teenager, adult, senior citizen), gender, ethnicity, and even emotional state. In combination with data on the location and time of each viewing, it enables advertisers to discern demographics of the people looking at the digital signs. And the analytics algorithms are then also able to serve up an optimum advertisement or other piece of information to each viewer.[5]

Detecting the face is a reasonably straightforward exercise since most humans have the same basic eyes, nose, and mouth. Scanning the image frame for areas of dark and light corresponding to similar areas in stored reference images is well within the capabilities of even today's basic consumer digital still cameras and camera phones. Complications can arise when the viewer wears headgear (scarves, hats, glasses, *etc.*), but with more reference data and increased algorithm sophistication, a face detector can be taught to identify such a viewer.

As with the HOG/SVM technique, a facial analysis system typically stores and classifies hundreds of low-level visual features, such as dark and light zones and the distances between various reference points on the face. Many combination sets of these zones and distances need to be evaluated by the detection algorithm in order to accurately ascertain gender, ethnicity, and other attributes. Length of hair alone is insufficient to determine whether someone is male or female, for instance. Categorization accuracy depends on how well the algorithm has been "trained" (*i.e.*, the quality of reference images for comparison, for example). It also depends on environmental factors such as lighting conditions, on image sensor quality, and on other factors. For example, it is difficult to accurately discern faces and their expressions when the viewer is not looking directly at the camera; profiles are particularly challenging to analyze.

A face detector is provided for embedded vision applications in the OpenCV (Open Source Computer Vision) library, available for multiple operating systems and processor options.[6] The algorithm uses the popular Viola-Jones method of computing an integral image and then performing calculations on areas defined by various black and white detection rectangles to analyze the differences between the dark and light regions of a face, as shown in Fig. 3.[7]

A sub-window then scans across the image at various scales to establish if there is a potential face within the window. In the post-processing stage, all the potential faces are checked for overlaps, with multiple potential matches needed to confirm the presence of a face.

After detecting a face, it is then possible to use the same dark- and light-zone measurements to ascertain the viewer's age, gender, and ethnicity. Technology developer Amscreen, for example, is implementing automated advertising analytics in thousands of gasoline stations and convenience stores across Europe.[8] The company claims that its system is capable of monitoring and reporting on consumers' advertising viewing habits, providing a breakdown of the gender, age, date, time, and volume of viewers of various advertisements. Intel and Kraft also recently developed a vending machine that dispenses samples of a pudding product aimed at adults called "Temptations by JELL-O"... but only if the automated facial analysis algorithm running inside the system decides that the user is old enough to fit the target audience demographic.[9]

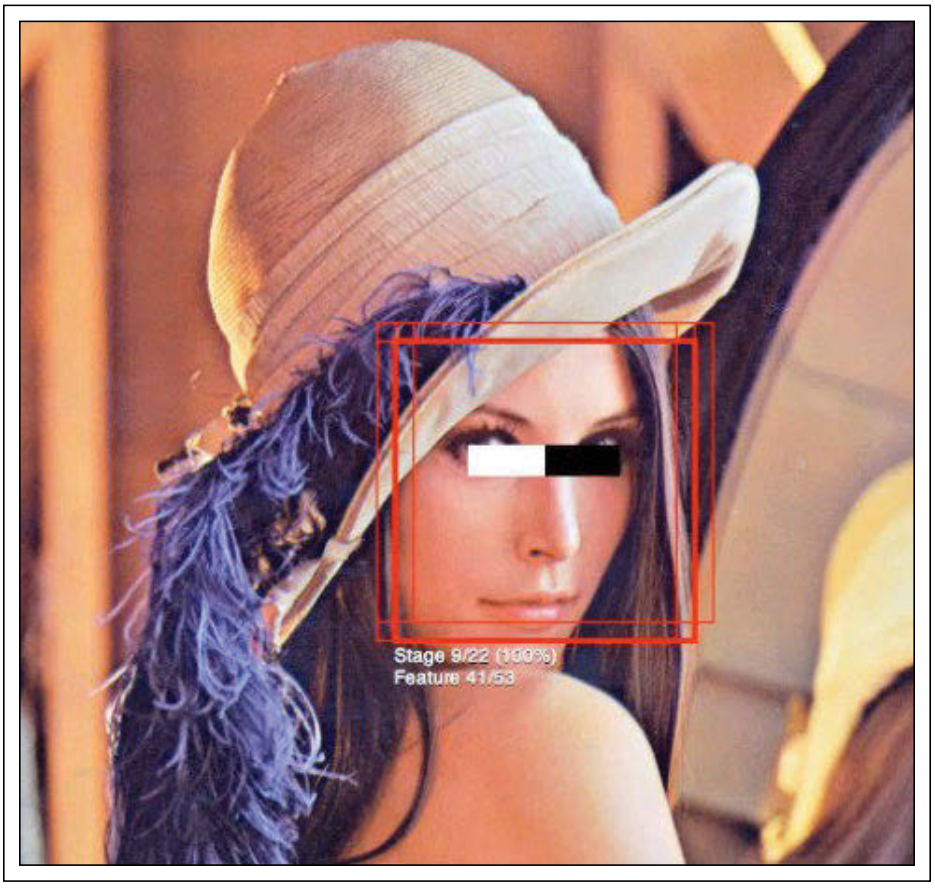

Fig. 3: *This OpenCV face detection example uses the Viola-Jones technique.*

Another recent example involves bus-stop-installed billboards from Plan UK, a charity organization that raises funds for educating girls in third-world countries. The billboard will only display a complete promotional clip if it decides (with claimed 90% accuracy) that a female is looking at it. Why? Quoting from the organization, "men and boys are denied the choice to view the full content in order to highlight the fact that women and girls across the world are denied choices and opportunities on a daily basis due to poverty and discrimination."[10]

It is even possible to establish viewers' emotional states.[11] This information can be extremely useful when deciding what content should be shown on-screen and in measuring the effectiveness of the content. Primary emotions (6–8 in number, depending on which researcher's theory you follow) are easiest to measure, with secondary emotions more difficult to determine (Fig. 4).

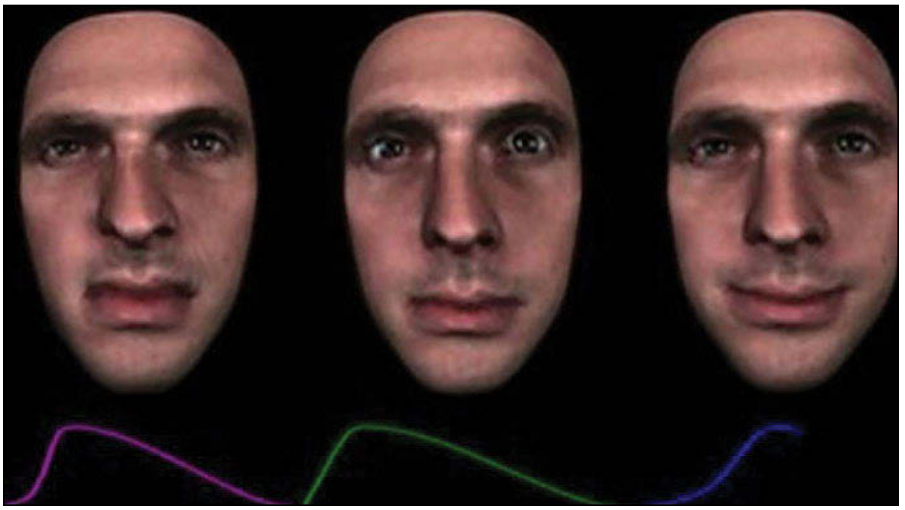

Fig. 4: *Facial expressions are capable of communicating a wide range of emotions; these are some of the primary ones that analysis algorithms strive to discern.*

Gesture Interfaces

The previously described applications for digital signage constitute a largely one-way information flow to the advertiser, with the consumer primarily a passive participant in the process. However, digital signage is rapidly also becoming interactive, adopting Natural User Interfaces (NUIs). The focus here is on the gesture aspects of NUIs, although the term also encompasses touch, gaze tracking, and other concepts. Gesture recognition offers the audience the opportunity to directly interact with signage and retail kiosks and, ultimately, the advertiser and retailer (Fig. 5).

This interaction can control the interface and select among a variety of options or it can provide dynamic feedback.[12]

There are numerous examples of gesture interfaces gaining ground in the world of digital signage. These instances span a range of use cases and installation scenarios. For example, in late 2013, Quebecor Media and the Société de transport de Montréal installed gesture-controlled digital signage in Montreal bus shelters. Commuters use gestures to navigate through menu items in order to access weather and news information, as well as bus and Metro schedules.

Multiple vision technologies are also coming together to create a more complete user experience. The Grab & Go kiosk, for example, combines gesture recognition and QR codes (*i.e.*, marker detection) in an interactive system. After activating the gesture interface by means of the QR code, consumers can select items promoted on interactive screens and "drag" them into their mobile phones with hand gestures. Once such products or information are gathered, a consumer can then share this information with others over social media, save it on the phone, and even purchase the items directly from the phone.

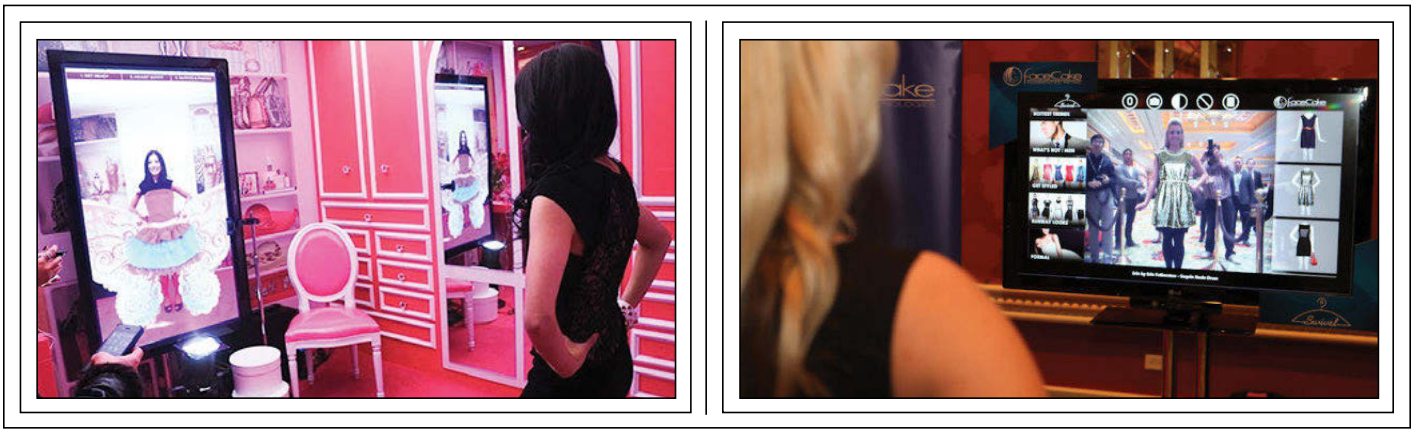

Fig. 5: *Augmented reality enables you to "try on" new outfits in a virtual dressing room environment, whether for fun (left) or more serious shopping purposes (right).*

Fig. 6: Gesture interfaces offer the opportunity to directly interact with signage and retail kiosks, in order to control the interface and select among a variety of options and to provide dynamic feedback.

Augmented Reality

The Grab & Go kiosk's ability to allow consumers to swipe items from the virtual world of the digital sign directly into their mobile electronics devices is a creative example of yet another vision-processing application, augmented reality (AR).[13] The integration of AR experiences with digital signage is accelerating rapidly. One interesting example is a recent campaign by Pepsi in London. Commuters within a bus shelter were treated to an augmented view of the street scene, containing attacking alien ships or rampaging tigers. Promotional campaigns like this one are capturing the imagination of the public and, in the process, demonstrating the promotional value of AR technology. Much of the near-future revenue associated with AR, in fact, is expected to come from advertising.

However, AR has a role to play beyond the standard advertising paradigm.[14] Digital signage can combine with AR to enhance the fitting-room experience, allowing shoppers to virtually "try on" clothing, accessories, and makeup.[15] Zugara, for example, recently introduced an updated version of a virtual dressing-room experience, where a shopper is able to dynamically alter the color of their clothing via an AR display (Fig. 6).

Another example is the FaceCake Swivel system, wherein the consumer interacts with a digital display using gesture recognition to select clothing and accessories. The AR view provided by Swivel lets the shopper instantly visualize how the items would appear in a real setting.

Industry Assistance

Swivel uses a Microsoft Kinect 3D sensor to implement gesture control, but the types of sensors (2-D versus 3-D, and 3-D variant) vary across the systems discussed here.[16] Sensor selection, in fact, has a significant impact on the function of the digital-signage application. The Web site of the Embedded Vision Alliance contains an abundance of technical resources on processors, sensors, software, and other aspects of vision-enabled system designs.[17]

The rapidly expanding use of vision technology in digital signage is part of a much larger trend. From consumer electronics to automotive safety systems, vision technology is enabling a wide range of products that are more intelligent and responsive than before, and thus more valuable to users. The Embedded Vision Alliance uses the term "embedded vision" to refer to this growing use of practical computer-vision technology in embedded systems, mobile devices, special-purpose PCs, and the cloud, with digital signage being one showcase application.

Vision processing can add valuable capabilities to existing products, such as the vision-enhanced digital-signage systems discussed in this article. And it can provide significant new markets for hardware, software, and semiconductor manufacturers. Implementation challenges remain in some cases, but they are largely no longer defined by a dearth of hardware capability potential. Instead,

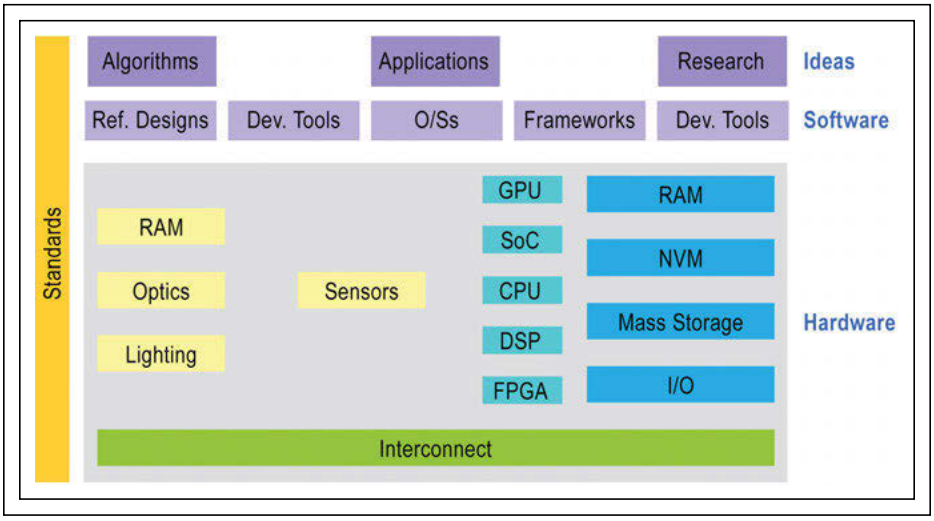

Fig. 7: The embedded-vision ecosystem spans hardware, semiconductor, and software component suppliers, subsystem developers, systems integrators, and end users, along with the fundamental research that makes ongoing breakthroughs possible.

they usually center on selecting an optimum hardware implementation among contending candidates, along with the development and optimization of software that exploits this hardware potential and resolves often-unique design requirements. The members of the Embedded Vision Alliance, along with other key industry organizations and players, are working hard to address these remaining challenges as quickly and robustly as possible. As such, the future is bright for practical computer vision, both in digital signage and a plethora of other high-volume applications.

About the Embedded Vision Alliance

The Embedded Vision Alliance, a worldwide organization of technology developers and providers, is working to empower product creators to transform the potential of vision-enhanced digital-signage systems into reality (Fig. 7). CogniVue and Xilinx, the co-authors of this article, are members of the Embedded Vision Alliance.

The Alliance's mission is to provide product creators with practical education, information, and insights to help them incorporate vision capabilities into new and existing products. To execute this mission, the Alliance maintains a Web site (www.embedded-vision.com) providing tutorial articles, videos, code downloads, and a discussion forum staffed by technology experts. Registered Web site users can also receive the Alliance's twice-monthly email newsletter (www.embeddedvisioninsights.com), among other benefits.

The Embedded Vision Alliance also offers a free online training facility for vision-based product creators: the Embedded Vision Academy (www.embeddedvisionacademy.com). Course material in the Embedded Vision Academy spans a wide range of vision-related subjects, from basic vision algorithms to image pre-processing, image sensor interfaces, and software development techniques and tools such as OpenCV. Access is free upon registration.

The Alliance also holds Embedded Vision Summit conferences in Silicon Valley. These are technical educational forums for product creators interested in incorporating visual intelligence into electronic systems and software. They provide how-to presentations, inspiring keynote talks, demonstrations, and opportunities to interact with technical experts from Alliance member companies. These events are intended to:

- Inspire attendees' imaginations about the potential applications for practical computer-vision technology through exciting presentations and demonstrations.
- Offer practical know-how for attendees to help them incorporate vision capabilities into their hardware and software products, and
- Provide opportunities for attendees to meet and talk with leading vision-technology companies and learn about their offerings.

Vision-Based Security and Surveillance Capabilities

Vision processing in digital signage enables dynamic new customer insights, shopping experiences, and user interfaces. Additional opportunities exist to leverage those same cameras and processors in security and surveillance applications.[a] Such digital signage can be placed where security cameras are not typically located. For example, some digital displays are co-located with Point of Sale (POS) terminals. These terminals typically have two display screens, one facing the cashier and the other facing the shopper. The cashier-facing display allows the operator to monitor his or her transaction actions, while the customer-facing display combines digital signage with a read-out of those same transactions.

Adding a camera to each display screen allows for a new level of security, both for fraud detection (operator side) and theft detection (customer side). Fraud detection can involve recording and time-stamping all cash transactions. In addition, the vision application can monitor the operator's productivity and activity via analytics. For example, a POS terminal with a facial recognition function can ensure that the operator logged into the system matches the person who is currently in control of the cash drawer.

Such checking prevents thefts that might otherwise occur if the operator has been compromised. The POS terminal will lock down if an unknown operator is accessing the cash drawer. This concept goes beyond theft; it is also pertinent in protecting against malware. In a document titled "DBIR 2014: Point-of-Sale Attack Trends – The State of Security," Tripwire, a maker of IT and security products, stated that a two-factor authentication of users accessing a POS terminal was listed as a recommended strategy to protect the POS network against malicious software infection.[b]

Alternately, applications that detect facial emotional cues in the cashier, such as fear or anxiety, can find use in detecting potential criminal situations. Similarly, facial analysis software can be used to detect masks or threatening behavior on the customer-facing camera side. The integration of these small and innocuous cameras within the POS system's digital signage enables a new range of security and surveillance solutions

[a] http://www.embedded.com/design/real-world-applications/4430389/Vision-based-artificial-intelligence-brings-awareness-to-surveillance

[b] http://www.tripwire.com/state-of-security/security-data-protection/dbir-2014-point-of-sale-attack-trends/

The most recent Embedded Vision Summit was held in May, 2014, and a comprehensive archive of keynote, technical tutorial, and product demonstration videos, along with presentation slide sets, is available on the Alliance Web site. The next Embedded Vision Summit will take place on May 12, 2015, in Santa Clara, California.

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continued from page 2

e-Paper coverage written by Jenny Donelan. In virtually all of these reviews, you will see some key OLED technology playing an enabling role. I hope you will also see that innovation and diversity are alive and well in our industry with the wide range of new products and concepts being shown. And, in case you think we forgot, our extensive coverage of touch and interactivity will run in the next issue of *ID*, ably presented by Geoff Walker. My thanks go out to everyone who worked so hard on all this coverage and helped us organize it for your enjoyment.

With countless new products and technologies being exhibited, the SID awards committee had many great choices, and after lots of consideration came through with their selections of the very "Best in Show" in small, medium, and large exhibit categories. Those, along with the I-Zone "Best Prototype" winner, are showcased on our cover and described in more detail by Jenny Donelan in her awards coverage article. While these few were singled out, a great many more exhibits deserved mention and I wish we had the space to highlight them all. You can see everything for yourself next year. Mark your calendar for May 31 to June 5, 2015, at the San Jose Convention Center.

Along with our show review coverage we are pleased to also bring you a Frontline Technology article titled "Practical Computer Vision Enables Digital Signage with Audience Perception," written by Brian Dipert and colleagues who are working to extend the experience and effectiveness of interactive digital-signage applications augmented with computer-vision technology. I'm excited to see so many great ideas becoming practical and I'm grateful to all the authors of this article for their efforts.

Last but not least, we have a thoughtful contribution from Bob Raikes of Meko on the topic of "Gazing at the Future of Monitors." Bob correctly points out that while there have been countless advantages in the performance of many display formats, computer and workstation monitors seem to have missed the party and are way overdue for some fun innovations in performance and interactivity features. I'm with Bob, and while my monitor is working OK for writing this editorial, I also would enjoy an upgrade and a chance to try out some of the concepts discussed. So, enjoy this opinion column and I'm sure Bob would welcome your comments as well.

And now with Display Week 2014 in the rear-view mirror, we bring this issue to a close and look forward to the next one, which will have a great lineup of TV and light-field display articles. ■

TOUCH DISPLAY RESEARCH

Dr. Jennifer Colegrove, CEO and analyst, Touch Display Research Inc.

Touch Display Research--empower your business strategic planning and investment on touch screen, touchless, active pen, ITO-replacement, OLED display, OLED lighting, flexible/curved display, quantum dot, near-eye display, and new materials.

1. New report "Touchless HMI 2014 report"
2. "Active pen technologies, supply chain and market forecast 2014 report"
3. "Quantum dot display and lighting technologies and market forecast report"
4. "Touch Panel for vertical Market 2014 report"
5. "ITO replacement—Non ITO transparent conductor technologies, supply chain and market forecast". Semi-annual report

6. Monthly report: "Touch and Emerging Display"
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Display Week 2015
May 31–June 5, 2015
San Jose, CA, USA

International Display Workshops Take Place in Niigata, Japan

The 21st International Display Workshops (IDW) will take place December 3–5, 2014, in Niigata, Japan. These workshops, sponsored by the Society for Information Display and the Institute of Image Information and Television Engineers, consist of oral presentations by invited and contributing speakers as well as poster presentations, discussions, and special R&D updates. According to SID President Amal Ghosh, "The IDW conference has grown into one of the premier display workshops in Japan. It features all the important topics in the display industry and is very well attended. In addition, IDW and SID's Display Week conference complement each other very well time-wise since the former is held in December and the latter is held in a May/June timeframe."

The IDW '14 workshops are organized into specific fields that are currently vital to information-display technology. These are:

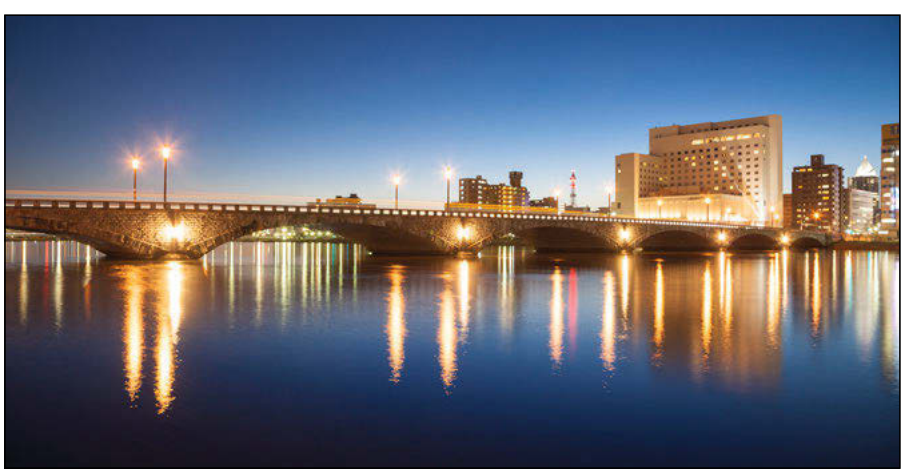
- Active-Matrix Displays
- Display Electronic Systems
- Emissive Technologies
- e-Paper
- Flexible Electronics
- Image-Quality Evaluation and Human Factors
- Liquid-Crystal Technologies
- Manufacturing, Process, and Equipment
- Materials and Components
- MEMS and Nanotechnologies for Displays
- Organic Light-Emitting Displays and Organic Devices
- Projection and Large-Area Displays
- 3D/Hyper-Realistic Displays
- Touch and Interactive Technologies
- Plus special topics of interest: Oxide-Semiconductor TFTs, Augmented Reality and Virtual Reality, Lighting Technologies, and Printed Electronics

Last year's conference in Sapporo, Japan, drew more than 1100 participants from 22 countries. This year's conference takes place at Toki Messe Niigata Convention Center in Niigata City, the capital of Niigata prefecture in the center of Honshu, Japan's largest island. Niigata is the largest city on the Sea of Japan coast, in an area famous for its rice, sake, and fresh seafood.

The awards committee will select the most outstanding papers from those presented at IDW '14, and some papers will be recommended as extended works for the Special Section of the *Journal of the ITE*, the *Journal of the SID*, and the *IEICE Transactions on Electronics*.

This year's conference is organized by Kazufumi Azuma, General Chair, from Shimadzu; Shinichi Komura, Executive Chair, from Japan Display; and Akiyoshi Mikami, Program Chair, from the Kanazawa Institute of Technology. For more information, contact the IDW '14 Secretariat at idw@idw.or.jp or visit www.idw.or.jp.

– Jenny Donelan



The Bandai Bridge over the Shinano River is a well-known sight in Niigata City. Photo courtesy Niigata Visitors & Convention Bureau.

Display Week 2015

Networking Events

May 31–June 5, 2015

Looking to meet up with your colleagues in the display industry to discuss technology, business, or just socialize? The events below present just that type of opportunity:

Annual Awards Dinner, Monday:

Each year, SID recognizes individuals that have played a critical role in improving the display industry. This year's winners will be honored at an awards banquet taking place the evening of June 1 at the San Jose Convention Center.

Business Conference Reception, Monday:

Follows the Business Conference, please note conference attendance is required for admission.

Annual Award Luncheon, Wednesday:

The annual Best in Show and Display Industry Awards Luncheon will take place at noon on Wednesday, June 3. Both awards are peer-reviewed, such that the luncheon is well-attended by captains of industry for high-level networking and recognition of the best in the industry over the last year.

Investors Conference:

The IC will feature presentations from leading public and private companies in the display technology supply chain and encourage questions and discussion between presenters and participants. Concludes with Drinks & Displays: Networking Reception with Presenters and Investors

Market Focus Conference Reception, Wednesday:

Follows the Wednesday Market Focus Conference, title and program TBD, please note conference attendance is required for admission.

continued from page 4

We are expecting to increase attendance for all SID conferences by at least 10% over the next 2 years. Since the display industry has a large presence in Asia, a major goal is to reach out and expand our activities in that region. Our primary focus will be in China, where the display industry has seen very rapid growth over a short period of time. SID would like to participate and contribute toward this growth in China. More SID-sponsored conferences and the introduction of educational programs are some of our initial strategies.

In any society such as ours, publications play a crucial role. Our *Journal of SID* and *Information Display* magazine are the two key periodic publications, while our *Symposium Digest* and technical books play significant roles as well. John Wiley and Sons is our primary publisher, and this partnership is vital to the progress of our publications. Our goal for the next few years will be to improve and expand the quality and quantity of these publications which, in turn, should vastly improve the society's impact factor.

Lastly, the society's governance structure is more than 50 years old and needs an overhaul. The executive committee is in the process of strategizing a new structure that will not only be more efficient but will also allow for a more streamlined administration.

I would like to take this opportunity to thank our outgoing President, Brian Berkeley, and the entire SID leadership team for doing an outstanding job of turning around the financial health of the society. Just a few years ago, due to various unforeseen worldwide issues, including the SARS virus and economic downturns, the society's very existence was in question. Under Brian's leadership, the society has made a comeback and is once again doing well financially.

By the time you read this, SID and the Korea Information Display Society will have held the IMID 2014 conference in Daegu, Korea, in the last week of August. (This took place in conjunction with the SID board meeting.) The other major event of this year will be IDW (the International Display Workshops) in Niigata, Japan, to be held in December. I hope many of you will be able to attend this conference.

Finally, I hope you had an enjoyable summer vacationing with family and friends. We look forward to an exciting and productive fall season. ■

Display Week 2015

SID International Symposium, Seminar & Exhibition

May 31–June 5, 2015

San Jose Convention Center
San Jose, California, USA

Rolling Out the Red Carpet

I-Zone

Competition of live demonstrations regarding emerging information-display technologies, such as not-yet-commercialized prototypes and proof of concepts.

Individual Honors and Awards

The SID Board of Directors, based on recommendations made by the Honors & Awards Committee, grants several annual awards based upon outstanding achievements and significant contributions.

Display Industry Awards

Each year, the SID awards Gold and Silver Display of the Year Awards in three categories: Display of the Year, Display Application of the Year, and Display Component of the Year.

Best in Show Awards

The Society for Information Display highlights the most significant new products and technologies shown on the exhibit floor during Display Week.

***Journal of the Society for Information Display* (*JSID*) Outstanding Student Paper of the Year Award**

Each year a sub-committee of the Editorial Board of *JSID* selects one paper for this award which consists of a plaque and a $2000 prize.

Information DISPLAY

Official Monthly Publication of the Society for Information Display

2014 EDITORIAL CALENDAR

■ January/February

Flexible Technology, e-Paper, and Novel Materials

Special Features: Color e-Paper Update, Materials Market Study

Related Technologies and Markets: e-Paper, OLEDs, glass, films, coatings, manufacturing, MEMs, nanoparticles

Jan 3: Ad closing

■ March/April

Display Week Preview, OLEDs, Backplanes

Special Features: Symposium Preview, SID Honors and Awards, Display Week at a Glance

Related Technologies and Markets: OLED TVs, Flexible OLEDs, backplanes, mobile displays, oxide TFT

Mar 13: Ad closing

■ May/June

Display Week Show Issue, Wearable Displays

Special Features: Display of the Year Awards, Products on Display

Related Technologies and Markets: Head-up Displays, OLEDs, LCDs, Military

May 5: Ad closing

■ July/August

Interactivity/Touch/Tracking, Tablets

Special Features: Tablet Market Study, Interactivity Update

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■ September/October

Display Week Wrap-up, Manufacturing

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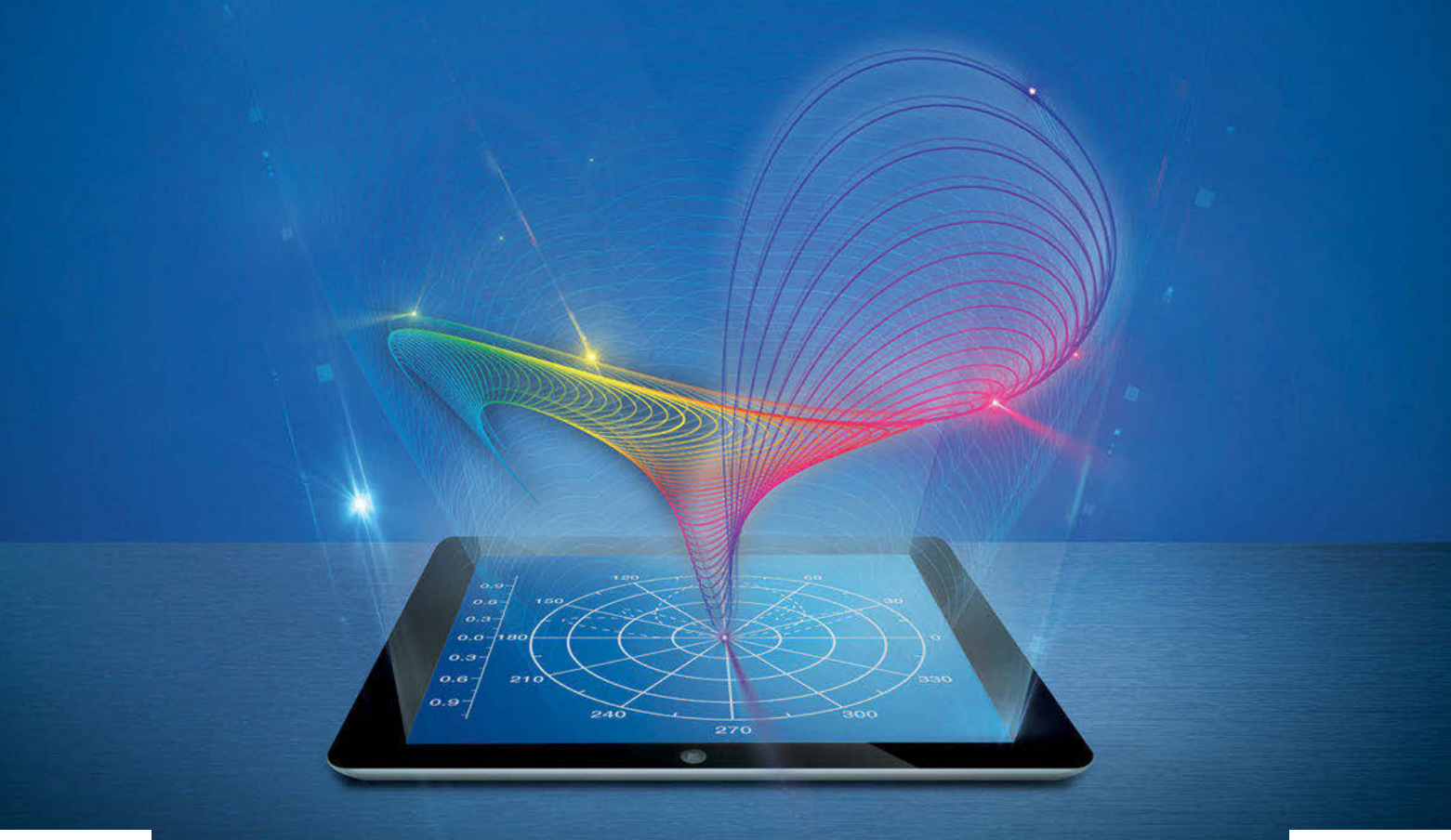

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