

2015 DISPLAY WEEK ISSUE / AUTOMOTIVE DISPLAYS

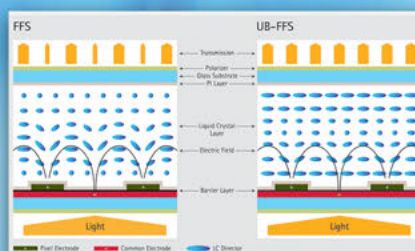
Information DISPLAY

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Display Industry Awards: Innovation at Its Best



**Products on Display at
Display Week 2015**

**Next-Generation
Automotive Displays**

**Novel Transparent Emissive
Head-Up Display**

**Passive-Matrix OLEDs in
Automotive Displays**

**Vehicle Displays
Past and Future**

**Changing the Dynamic of
Display Manufacturing**

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contents

ON THE COVER: The 2015 Display Industry Award winners are, clockwise from top center: LG Display's 1.3-in. Circular Plastic OLED display for the G Watch R, Apple's 27-in. iMac with 5K Retina Display, Samsung's YOUNG Bended Display, Merck KGaA's Liquid-Crystal Materials for Ultra-Brightness FFS-LCDs, Intel's RealSense Technology, and LG Display's 65-in UHD Curved OLED TV Panel.



Cover Design: Jodi Buckeley

In the Next Issue of Information Display

Portable Displays and Interactive Touch

- Unfolding the Foldable Display
- Biosensors and Smartphones for Pregnancy Healthcare
- Flexible Large-Area Hybrid Systems
- Force Sensing in Touch
- Touch-Panel Market Dynamics and Trends

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2 **Editorial:** Welcome to Display Week

■ By Stephen P. Atwood

3 **Industry News:** Apple Watch Hits Market

■ By Jenny Donelan

4 **Guest Editorial:** The Progress of Vehicle Displays

■ By Silviu Pala

6 **Best Products of 2014:** 2015 SID Display Industry Awards

Each year, the Society for Information Display's Display Industry Awards Committee selects six award winners that have advanced the state of the art of display products and technology in the categories of Display of the Year, Display Component of the Year, and Display Application of the Year.

■ By Jenny Donelan

12 **Frontline Technology:** Emissive Projection Technology Enables a Full-Windshield Head-Up Display

The authors have developed a full-windshield head-up display (FW-HUD) for automotive applications. This new display is based on emissive projection display technology and forms photo-quality images on a fully transparent RGB emissive screen, after selective excitation of the screen by images in multiple ultra-violet wavebands from a projector. With this FW-HUD, information can be graphically displayed anywhere on a windshield without limitation on viewing angles.

■ By Ted Sun

18 **Frontline Technology:** Next-Generation Head-Up Displays

HUD 2.0 may function as a primary information-display technology for vehicle drivers rather than a source of merely helpful or ancillary information.

■ By Alan Rankin and Jason Thompson

22 **Frontline Technology:** Technologies and Trends for Vehicular Displays

Displays have become an integral part of the driving experience. The author takes a brief look back at the history of displays and then a look forward at how displays in vehicles will meet the ever-increasing demands put on them.

■ By Silviu Pala

28 **Frontline Technology:** Automotive Applications for Passive-Matrix OLEDs

Passive-matrix OLED technologies offer some excellent advantages for automotive designers. However, consideration also needs to be given to factors that could affect design performance, including luminance decay, burn-in, power consumption, and color availability.

■ By Jeff Hatfield, Yoshiyuki Kobayashi, and Akibiro Nonaka

32 **Display Marketplace:** Can Advanced Assembly Techniques Alter the Dynamic of Display Manufacturing?

The mass production of flat-panel displays has been dominated by the use of TFTs, deposited via vacuum lithography, to drive LCD or OLED panels. This approach has been a strength in terms of standardization and massive scale up to Gen 10 fabs and beyond, but also a weakness in that the cost has made profitability elusive over a quarter century of production and in a limited selection of display shapes and sizes. Emerging manufacturing techniques that combine semiconductor production with relatively simple assembly have the potential to change this dynamic.

■ By Paul Semenza

36 **Trade-Show Preview:** Products on Display at Display Week 2015

Some of the products on display at North America's largest electronic-display exhibition are previewed.

■ By The Editorial Staff

53 **SID News:** iMID 2015 to Take Place in Daegu, Korea

56 **Corporate Members**

56 **Index to Advertisers**

For Industry News, New Products, Current and Forthcoming Articles,
see www.informationdisplay.org



Welcome to Display Week

by Stephen P. Atwood

Welcome to San Jose, CA, for our 52nd annual Display Week event, which includes the SID International Technical Symposium and Exhibition as well as the Market Focus Conferences, Business Conference, Investors Conference, Seminars, Short Courses, and the many other great happenings that are organized each year for your benefit and

enjoyment. This year we are in the San Francisco Bay Area of California, also known as Silicon Valley, birthplace of integrated circuits, computers, Internet technology, and countless display innovations as well. Of course, San Jose is also a great destination city and one that promises lots of options for great food and socializing away from the demands of the office.

It is impossible to see and do all of Display Week by yourself, so invite your colleagues and divide and conquer to suit your interests. Getting the most out of your Display Week experience involves some serious planning. Take time to review the full program and mark off the things that are most important to you. Plan your days to see as many things as you can and coordinate with colleagues to make sure the things you cannot see are covered by others. Usually, there are dozens of presentations and exhibits that I know I want to attend, but I also find many surprises that I can only discover if I explore as much as possible. It's a wonderful mix of the expected and unexpected that awaits you. I've never left Display Week without at least a handful of amazing new discoveries that have since proven invaluable in my day-to-day work.

As we do every year, we have invited a prestigious team of freelance technology enthusiasts to report on all the happenings and they will be hard at work covering everything they can. We will have daily blog updates on the *ID* Web site (www.informationdisplay.org) and a full issue of post-show coverage later in the year. If you have a question about anything on the exhibit floor, just email us at press@sid.org and we will get your question to the right reporter to see what we can find out. The issue of *ID* you are reading now can also be useful for your planning because it features our "Products on Display" coverage, which is assembled each year by our staff to help you get the most out of the exhibition.

Our cover story this month is on the annual Display Industry Awards, which recognize the most innovative display products and technology from all of 2014. The list of choices for these awards was overflowing with worthy recipients and I can honestly tell you as a member of the DIA committee that the final selections were really the best of the best. It's exciting that this year's awards recognize a wide range of different technologies, including OLED, liquid crystals, and the latest in human-computer interactivity. As you read the synopsis of each award winner compiled by Jenny Donelan, I suspect you will also be able to see that there is no shortage of great innovative achievements in this industry.

This is a very full issue and our technical focus topic this month is Vehicular Displays as developed by Guest Editor Silviu Pala. His passion for this topic was abundantly clear not only in the great articles he lined up for us but in the exhaustive array of background information he supplied to us through the editorial process. Be sure to read his industry synopsis in his Guest Editor's note, which includes some interesting bits about his own history in the field.

(continued on page 51)

Information DISPLAY

Executive Editor: Stephen P. Atwood
617/306-9729, satwood@azonix.com

Editor-in-Chief: Jay Morreale
212/460-9700, jmorreale@pcm411.com

Managing Editor: Jenny Donelan
603/924-9628, jdonelan@pcm411.com

Global Advertising Director:
Stephen Jezzard, sjezzard@wiley.com

Senior Account Manager
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Ruiging (Ray) Ma, Universal Display Corp.
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Paul Semenza, *Consultant*
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Apple Watch Hits Market

In late April, the Apple Watch became commercially available in nine countries. As there are already other smartwatches on the market, and not too many people are convinced that they need those, expectations are that Apple's entry will have to offer some powerful capabilities in order to succeed.

The early reviews are in, and they are mixed, with many critics describing the device as "ambitious." Cnet called it "beautiful and promising," but decried its short battery life. "First-gen shortfalls make it feel more like a fashionable toy than a necessary tool," wrote the reviewer.¹ The watch, available in several trims and a variety of colors (Fig. 1) runs from \$349 all the way up to \$10,000 for custom editions. This watch also sports Apple's first-ever OLED display. In terms of features, it synchs with the iPhone 5 and offers health and fitness capabilities as well as a plethora of other apps. It has a haptic engine so that the phone can alert you with vibrations or "taps" on your wrist. And, it tells time.

¹<http://www.cnet.com/products/apple-watch/>



Fig. 1: The Apple Watch interface will appear somewhat familiar to anyone who uses an iPhone.

Lytro Opens Light-Field Imaging Studio

Lytro, Inc., has opened what it claims is the world's first light-field imaging studio. The new studio, in the fashion district of Tokyo (Fig. 2), will be open to professional photographers and members of the general public who would like to gain some hands-on experience with Lytro's light-field cameras and software. The Lytro imaging platform enables

users to render multiple outputs, including 3D pictures, from a single exposure by adjusting aperture, point of focus, tilt, perspective shift, depth of field, and animation in both 2D and 3D.

"With its culture of innovation and active photography, fashion, and creative communities, Tokyo is the perfect city to host this studio," says Jason Rosenthal, CEO of Lytro.



Fig. 2: The new Lytro studio in the Shibuya district of Tokyo will feature light-field works on display and will also offer demos and training to visitors interested in learning how to use the company's imaging platform.

C3nano Acquires Silver-Nanowire Supplier Aiden Co.

C3nano, Inc., a maker of transparent conductive films for the touch sensor and display industry, recently announced that it has acquired the major supplier of silver nanowire in Asia, Aiden Co., Ltd., of Korea. In addition to gaining a vertically integrated silver-nanowire supply for C3nano, the acquisition provides the company with a gateway to the display market in Korea and greater Asia. ■

— Jenny Donelan

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PRODUCT BRIEFS

Covering all the bases for high-end TVs, AUO recently rolled out a family of 55-, 65-, 75- and 85-in. UHD quantum-dot-enhanced curved LCD TV panels at the China Information Technology Expo in Shenzhen.

Japan-based DMC Co., Ltd., and Display Solution AG of Germany have released two projected-capacitive touch-screen panels with COF (Chip-on-Foil) technology. The 7- and 10.1-in. models come with a DMC in-house-developed controller and supporting USB interface. The touch sensor is a single-ITO type with capacitive multi-touch incorporating XY electrodes on the same glass.

Tianma NLT America now has a new 8.4-in. XGA TFT-LCD with the company's "Wet & Glove" projected-capacitive touch sensor bonded to the front. This enables operation even when the screen is wet and/or the operator is wearing gloves (Fig. 3).



Fig. 3: Tianma's new 8.4-in. XGA TFT-LCD provides dry screen tracking, water build-up tracking, and single-glove operation, even in a wet environment. It can also be used with medical-grade defibrillator gel and ultrasound gel.

guest editorial



The Progress of Vehicle Displays

by Silviu Pala

It's hard to believe how far the automotive display industry has come. I first became engaged in automotive display design in the mid-1990s at United Technologies Automotive. The company had an electroluminescent display and was considering expanding its instrument panel group. I started learning about ELD technology with Elliott Schlam, the lead UT consultant on ELD, who was very patient with

my questions at the time. ELD was quite seductive for automotive applications because it had a native military robustness; in those days, it was the only solid-state display technology for vehicles.

The first automotive prototype that we tested in the lab at UTA looked great. It was very bright, with high-resolution pixels – much better than that of vacuum-fluorescent displays (VFDs), the lead automotive technology at the time, and it had much better contrast than LCDs, which had just started to enter the automotive market. In the midst of our euphoria, we took it outside to test its sunlight readability. This was one of the most embarrassing moments of my life. The outdoor contrast was so bad so we could not figure out if the display was powered on or not – it was. Although vehicle-display technology has come a long way since then, sunlight readability continues to be a major challenge, as you will read in the articles in this issue.

After our initial experiments with ELD, we learned that in a high-ambient-light environment, the top reflectivity of the glass is just one part of the contrast calculation. The reflectivity of the underlying structure behind the glass is critical as well. We were successful in our efforts in improving ELD, and, in 1998, it was named one of the top 15 automotive technologies of the year by SAE Automotive Engineering magazine. However, ELD's lack of full-color capability and the progress of LCDs, with their better color and very small package for the same active area, eventually eliminated the ELD as well as the VFD from automotive applications.

The penetration of new reconfigurable displays into automotive applications by the end of the 1990s raised the need to specify optical performance in high-ambient-lighting conditions. How was it possible to measure this without using huge avionics sunlight spheres? While searching for answers, our team was asked by SAE to create a standard! With help from numerous individuals, including Ed Kelly from NIST, Adi Abileah from Planar, Mark Larry from Ford, Tom Creech from GM, Bob Donofrio from Display Consultants, Darrel Hopper and Fred Meyer from U.S. Air Force Laboratory at WPAFB, John Troxell and Drew Harbach from Delphi, Paul Weindorf from Visteon, Chris Slupek from Futaba, Douglas Sadrack from Sharp, Hector Lara and Michael Kline from Photo Research, Tim Moggridge from Instrument Systems, and others, we created the SAE Vehicular Display Group in 1999.

The resulting J1757 was the first standard metrology for high-ambient-luminance performance with requirements defined by the ISO 15008. The most recent SAE J1757 revision was done in January 2015, with ISO 15008 revision pending.

Since 2000, I've been working for DENSO International America, where we struggle to determine where society is headed in the next 10 years with regard to what automotive technologies we will need when we get there. The articles in this issue reflect those concerns. I've written a vehicle-displays overview, "Technologies and Trends for Vehicular Displays," which takes a brief look back at the history and progress of automotive displays, then outlines the key issues and some of the key players for the

(continued on page 55)

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2015 SID Display Industry Awards

Each year, the Society for Information Display's Display Industry Awards Committee selects six award winners that have advanced the state of the art of display products and technology in the categories of Display of the Year, Display Component of the Year, and Display Application of the Year.

Compiled by Jenny Donelan

THIS YEAR'S Display Industry Award winners are a particularly diverse group, which demonstrates just how rich the industry is in terms of technology development. Three out of the six winners are based on OLED technology – a clear signal that recent OLED investment is bringing fruit to the commercial market. The other three winners also show how diversity in investment is continuing. The Display of the Year Gold Award winner, from Samsung, is a flexible AMOLED display for a smartphone. The Display of the Year Silver winner, from LG Display, is a far larger OLED device – a 65-in. UHD television. The third OLED-based winner is the smallest of the three – a 1.3-in. circular watch display that earned LG Display a Silver Award for Display Application of the Year.

Two of the winners are LCD related – Apple, the Display Application of the Year Gold winner, brings its Retina 5K technology to a 27-in. iMac with stunning results. Merck KGaA, a German multinational company that's been innovating successfully for more than three centuries (it's the oldest chemical and pharmaceutical company in the world), has created new liquid-crystal materials that advanced the state of the art for smartphones in 2014 and will do so for tablets and monitors this year.

There always seems to be a product with unique characteristics among the six Display

Industry Award winners, and this year's is Intel's RealSense Technology, winner of the Silver Award for Component of the Year, which combines a camera, infrared sensing components, and software to create a new level of human/computer interaction.

If there is a commonality to this year's far-ranging roster of winners, it's the spirit of innovation behind their development. This spirit has led to displays beyond our wildest dreams. Just a couple of years ago, who could have imagined a smartwatch that looked like a regular/analog watch, a desktop computer with the high resolution of a mobile display, or liquid crystals that perform so well they negate the former weaknesses of that particular material?

We owe a great deal to the companies, and the men and women who work there, who made these innovations possible. Please join us in saluting this year's Display Industry Award winners, the best of the best.

Display of the Year

This award is granted to a display product with the most significant technological advances or outstanding features.

Gold Award: Samsung's YOUM Bended Display

The YOUM Bended Display (a flexible AMOLED display) represents a major step forward for design innovation in the smartphone market, with the world's smallest radius for screen curvature on a mobile device. Samsung's flexible AMOLED tech-

nology is the vanguard of the second phase in the evolution of curved displays – bended displays. Displays will evolve from curved to bended, to foldable, and then “rollable” designs. The company's state-of-the-art flexible AMOLED display, often referred to as an ‘edge’ display, is now featured on the popular Galaxy Note 4 and a newer version is now being used in the Galaxy S6 Edge, on which it curves over onto both sides, or edges, of the phone.

The 5.59-in. WGXGA (2560 × 1600 resolution) display uses a polyimide plastic substrate material to produce a film less than a millimeter thick. That's thinner than any other display on the market today. Samsung has been able to deposit an electronic circuit onto the substrate and evaporate a luminant RGB organic device to realize the display's industry-leading bendable characteristic.

The display enhances the user experience in a number of ways. Thanks to a 6.9R curvature, it allows a consumer to easily grab onto it with just one hand and also reduces finger fatigue. In addition, it delivers the finest image detail and the smoothest fonts available. The YOUM Bended Display has one of the industry's highest color reproduction rates. It can depict 97% of Adobe RGB, while a typical LCD panel can replicate only about 70%.

Owing to its emissive OLED technology, the device features a contrast ratio of 8,000,000:1 and is capable of switching in as little as 0.01 μ sec.

Jenny Donelan is the Managing Editor of Information Display Magazine. She can be reached at jdonelan@pcm411.com.

DISPLAY OF THE YEAR



Gold Award: Samsung's YOUM Bended Display has been incorporated into the company's Galaxy Note Edge 4. The display wraps around one edge of the phone.

Silver Award: LG Display's 65-in. UHD curved OLED-TV panel uses WRGB OLED technology.

The era of Big Data is accelerating, and the amount of information transfer continues to explode. Under these circumstances, information providers and growing legions of users will want to take advantage of the additional area provided by the smartphone's edges, which previously were considered just dead space. There is seemingly no limit to the growing number of areas of electronics in which Samsung flexible AMOLED displays can be applied. In the future, more consumer products such as wearables and other entry devices to the Internet of Things will embrace the usefulness and attractiveness of flexible-

display curvature and the vibrant, feature-rich world of AMOLED imagery.

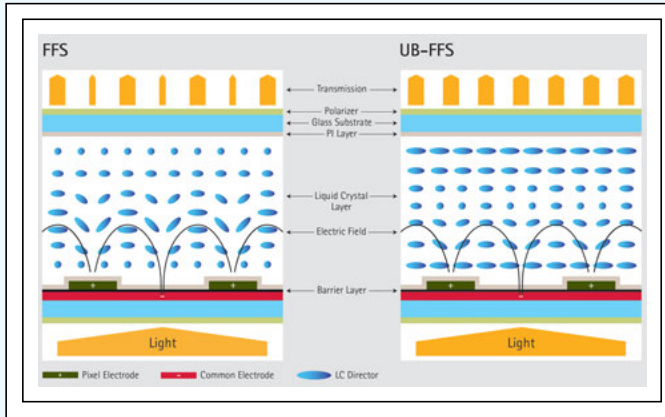
Silver Award: LG Display's 65-in. UHD Curved OLED TV Panel

Following the introduction of one of the world's first OLED TVs, a 55-in. full-HD TV in early 2013, LG Display introduced an even larger TV in 2014, the 65-in. UHD OLED TV. For this display, LG Display utilizes WRGB OLED technology, including an oxide-TFT backplane with WRGB architecture, which the company believes is the optimal technical solution for large-sized OLED-TV panels. In

addition, LG Display's state-of-the-art panels leverage the innate curved design abilities of OLED to provide an aesthetically pleasing TV with an optimal viewing experience.

LG Display's 65-in. UHD OLED-TV panel is sleek and slim: a panel that is only 6 mm thick with a left and right bezel width of 8 mm. It offers superior picture quality, achieving remarkably rich and natural colors with its UHD subpixels. Because OLEDs are composed of self-luminous organic diodes that form each pixel, every pixel emits its own light, and color contrast is optimized. In addition, an OLED can produce perfect blacks and an infinite

DISPLAY COMPONENT OF THE YEAR



Gold Award: Merck KGaA's new liquid crystals enable next-generation FFS technologies to achieve light transmittance that is up to 15% higher than conventional FFS.

Silver Award: Intel's RealSense Technology uses a camera, infrared sensing components, and software to create a touch-free interface that responds to facial expressions as well as head and hand motions.

contrast ratio with deeper and richer colors because there is no light leakage from a back-light. The panel also delivers clear images with a less than 0.001-msec response time.

Users will also enjoy the more theater-like viewing experience offered by the curved screen's wider and brighter field of view. The IMAX-like curvature of the screen minimizes visual distortion and loss of detail. LG Display's curved OLED-TV panel also incorporates the company's acclaimed FPR 3D viewing technology, which minimizes eye and body muscle strain in viewers. The added FPR 3D film on curved OLED TVs offers better depth as well as a clearer 3D effect.

Display Component of the Year

This award is granted for a novel component that has significantly enhanced the performance of a display. A component is sold as a separate part destined to be incorporated into a display. A component may also include display-enhancing materials and/or parts fabricated with new processes.

Gold Award: Merck KGaA's Liquid-Crystal Materials for Ultra-Brightness FFS-LCDs

In recent years, displays for mobile electronic devices have been revolutionized, driven mostly by smartphones and tablets. Among key trends for such devices based on LCDs are improved contrast, a very good viewing

angle, high color performance, and especially ultra-high resolution. This last trend goes hand in hand with a tendency toward more "refined" display technologies, namely, fringe-field switching (FFS).

Merck KGaA of Darmstadt, Germany, has developed liquid crystals for the next generation of displays in cooperation with industry partner LC display manufacturers. As the latest innovative LCD technology, Ultra-Brightness FFS (UB-FFS) offers a future-oriented technology that was brought to the market in 2014 for smartphones and will be introduced in 2015 for most small, medium, and IT applications such as tablets and monitors.

In conjunction with a corresponding panel design, the innovative energy-saving UB-FFS LC mixture permits LC display light transmittance that is up to 15% higher than conventional FFS. UB-FFS uses liquid crystals with negative dielectric anisotropy, whereas "conventional" FFS uses liquid crystals with positive dielectric anisotropy. There were two key challenges to overcome for market introduction: The first was to provide liquid crystals with a sufficiently fast switching speed. The second was to maintain the high reliability level of FFS even though completely different materials with much higher requirements were used.

The higher display transmissions enabled by the new UB-FFS liquid crystals allow

greater design freedom for product developers. Devices now can be made slimmer because of the possibility of using thinner batteries.

Alternatively, designers can opt for a longer battery run-time because fewer LEDs will be required for the backlighting. The higher transmission can also lead to cost reduction for manufacturers and hence for consumers.

Merck KGaA continuously developed new innovative liquid crystals and liquid-crystal mixtures for UB-FFS and finally fulfilled all the requirements for mass production. Based on the recent development of fast-switching LC mixtures, the new generation of Merck KGaA's products enables the application of UB-FFS for nearly all display applications. With a business model of close partnerships in the industry, Merck KGaA is able to offer LC solutions for new technologies such as UB-FFS that can easily be implemented in the existing LCD production setup.

Silver Award: Intel's RealSense Technology

Intel RealSense technology is a new type of human-computer interface and input device based on real-time depth sensing to enable natural user interactions with content on interactive displays and computers. Available on today's most innovative PCs, the Intel RealSense cameras simulate human eyes to add a new dimension to user experience.

DISPLAY APPLICATION OF THE YEAR



Gold Award: Apple's 27-in. iMac with Retina 5K display has a resolution of 5120×2880 .



Silver Award: LG Display's 1.3-in. Circular Plastic OLED for the G Watch R features touch and new power-saving algorithms.

Users can bring toys, games, and books to life using free hand movements to interact with characters and capture faces and objects with 3D scanning technology for sharing, editing, and 3D printing.

The Intel RealSense camera contains a standard video camera as well as infrared sensing components that work together to allow the device to infer depth by detecting infrared light that has bounced back from objects in front of it. It can track up to 22 joints in each hand and even understands the rotation and finger movements of two hands simultaneously. This data, taken in combination with the Intel RealSense software platform, creates a touch-free interface that responds to hand and head motions as well as facial expressions.

Intel RealSense cameras elevate the user interface to futuristic levels by sensing depth and tracking human motion, letting you interact with your device more like you interact with people – with natural movements.

Intel RealSense technology senses distance and movement right from your device so you can scan and save a piece of art, a flower, a toy – even your own face. You are able to save your scan as-is or manipulate it into something new. Then share it digitally or

print a version with the use of a 3D printer. Make your chat space whatever it needs to be. Because the Intel RealSense camera senses depth, you are able to remove your chat background altogether or swap in a replacement and make it look like you are somewhere else. It works like an instant virtual green screen.

Intel RealSense technology is designed to redefine how we are able to interact with our devices, using world-class digital-sensing technology to bring consumers new ways to create, share, and collaborate in a 3D world.

Display Application of the Year

This award is granted for a novel and outstanding application of a display, where the display itself is not necessarily a new device.

Gold Award: Apple's iMac with 5K Retina Display

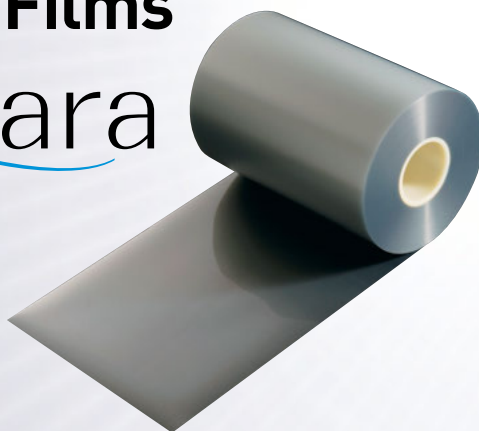
The 27-in. iMac with Retina 5K display features 14.7 million pixels and a resolution of 5120×2880 . With four times more pixels than the standard 27-in. iMac and 67% more pixels than a 4K display, text looks as sharp as it does on a printed page, and users can see more of their high-resolution photos with

pixel-for-pixel detail. The display on the new 27-in. iMac has been engineered for performance, power efficiency, and stunning visual quality. It uses a precisely manufactured oxide-TFT-based panel to deliver vivid display brightness from corner to corner. A single supercharged Apple-designed timing controller (TCON), with four times the bandwidth of conventional-panel TCONs, drives all 14.7 million pixels. The iMac with Retina 5K display also uses highly efficient LEDs and organic passivation to improve image quality and reduce display power consumption by 30%, even while driving four times more pixels at the same brightness. To improve the contrast ratio, the iMac with Retina 5K display uses a new photo-alignment process and compensation film to deliver blacker blacks and more vibrant colors from any viewing angle. In addition, every iMac with Retina 5K display is calibrated using three state-of-the-art spectroradiometers to ensure precise and accurate color.

The iMac with Retina 5K display is also packed with the latest technologies for powerful performance, including a 3.5-GHz quad-core Intel Core i5 processor with Turbo Boost speeds up to 3.9 GHz. It also features AMD Radeon R9 M290X graphics, delivering up to

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3.5 teraflops of computing power, the most powerful graphics ever offered on an iMac; as well as 8 GB of memory, a 1 TB Fusion Drive, and two Thunderbolt 2 ports that deliver up to 20 Gbps each, twice the bandwidth of the previous generation.

Silver Award: LG Display's 1.3-in. Circular Plastic OLED for the G Watch R

LG Display has successfully developed a 1.3-in. full-circle plastic OLED panel for use in its G Watch R. The design incorporates 320 × 320 pixel resolution, a touch sensor, and a barrier film that enables an ultra-thin and lightweight display. The panel also uses new power-saving algorithms that enable an always-on function that provides users with the sensibility of a conventional analog watch along with the convenience of a digital smart-watch.

The truly circular plastic OLED display, the first of its kind, will bring a change to the display paradigm by overcoming the limits of conventional displays. The round shape allows more design flexibility in various products compared to conventional square displays. This innovative design will contribute to display-market development beyond watches to other wearables, including clothing, and also automotive applications. ■

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Emissive Projection Technology Enables a Full-Windshield Head-Up Display

The authors have developed a full-windshield head-up display (FW-HUD) for automotive applications. This new display is based on emissive projection display technology, and forms photo-quality images on a fully transparent RGB emissive screen, after selective excitation of the screen by images in multiple ultra-violet wavebands from a projector. With this FW-HUD, information can be graphically displayed anywhere on a windshield without limitation on viewing angles.

by Ted Sun

AUTOMOTIVE manufacturers have been experimenting with display technologies that allow graphical information to be displayed through or onto the windshield so as to convey critical information to drivers while still allowing them to keep their attention on the road. In this regard, head-up displays (HUDs), invented during WWII for military aviation,¹ which project reflective virtual imagery at a precise angle to the driver, have been the technology of choice. Since their invention, HUDs have undergone a series of evolutionary changes in their design. However, state-of-the-art HUDs still suffer due to limited field of view and viewing angle, which compromise their display capabilities.

Sun Innovations recently developed a novel emissive projection display (EPD) that uses the principles of fluorescent conversion of luminescent materials that can be created in transparent forms. This display allows visible light to be generated on a fully transparent glass surface, displaying superior quality

images. Figure 1 (a) shows a schematic of the system: Highly efficient fluorescent material is applied onto a glass panel with less than 2% in haze level and under 10% reduction in visible-light transmission. An invisible image from a custom-built UV image light engine is projected onto the coated glass. The projected UV image is absorbed and converted by the fluorescent materials on glass to re-emit images in the visible-light spectrum.

We utilized a novel “wavelength selective excitation” (WSE) method² to render the first full-color emissive display without complex screen pixilation [Fig. 1(b)], taking advantage of the transparent nature of the display phosphor films. A full-color screen can be constructed by stacking three layers of transparent RGB emissive films with distinctive absorption and emission characteristics. The projector encodes the original color image into the projected light at three excitation wavebands. Each waveband of the projection light excites its corresponding phosphors in the films and generates a primary color (e.g., R, G, and B) image without interfering with the excitation or emission from the other two layers. Since each fluorescent film is very thin (<50 μm), high-resolution and full-color images are emitted directly toward the intended observer

position rather than being scattered or absorbed. The patented WSE process eliminates the need to register pixels in an emissive projection display; the flat transparent screen can be economically produced roll-to-roll, without pixel structures and the corresponding haze.

The Key Transparent Emissive Screen for Full-Windshield HUDs

In order to achieve FW-HUD, we developed a series of visibly clear emissive materials, with the optic haze level under 2% and a reflectance of ~5% on normal incident visible light.

Figure 2 shows the RGB emissive materials in coatings on (a) glass and (b) polymer films. RGB layers are stacked together and present a full-color image with gray scale using the WSE approach (c).

Our team also laminated the transparent emissive materials directly inside the existing polyvinyl butyral (PVB) resin that is commonly used in windshields to keep the glass layers from shattering. It is a much easier solution to produce HUD-integrated windshields or window glass than the conventional HUD approach, which requires precisely mounted “wedge” reflectors inside the windshield. There is no extra coating step and no

Ted Sun is a material scientist with a Ph.D. from the “University of Berkeley. He founded Sun Innovations and acquired all Superimaging assets in 2010. He can be reached at ted@sun-innovations.com.

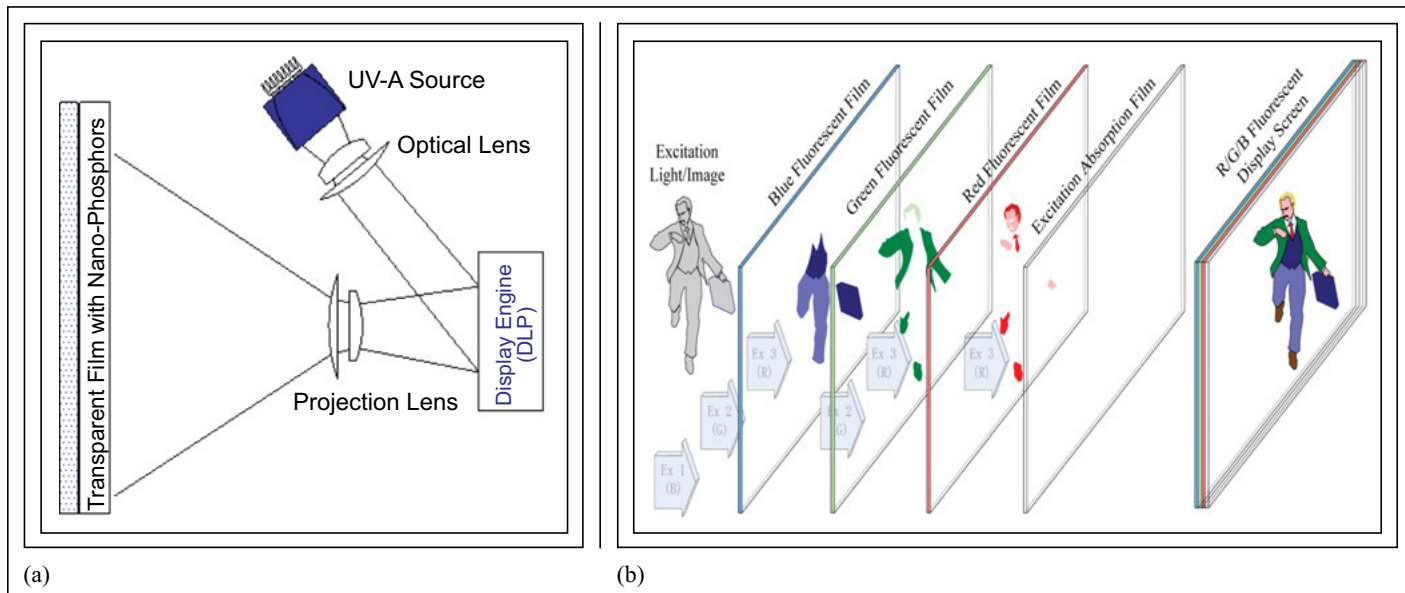


Fig. 1: The schematic (a) shows an emissive projection display while (b) outlines full color rendering by wavelength-selective excitation (WSE) on a transparent emissive screen.

change to the display-windshield manufacturing process; hence, it is also a better route to mass producing display windshields than applying display films to windshield surfaces.

Figure 3(a) shows a display glass with our emissive material inside the PVB, which was sandwiched inside two glass panels. Figure 3(b) shows the optical clarity of a large-panel display glass with a transparent display demo on it.

Figure 3(a) shows a display glass with our emissive material inside the PVB, which was

sandwiched inside two glass panels. Figure 3(b) shows the optical clarity of a large-panel display glass with a transparent display demo on it.

The material lifetime was subjected to several accelerated tests. Figure 4 shows the variation of the fluorescent emission intensity of the transparent display screen after being continuously exposed to harsh conditions for over 2000 hours. Figure 4(a) shows a damp heat test, in which the screen was subjected to a combination of 85°C and 85% RH (relative

humidity). Figure 4(b) shows the temperature cycling of 85-0°C at ~10 minutes per cycle. The result is no noticeable variation of fluorescent intensity under identical UV excitation. The display films used the same polymer base as window film (PET) or glass lamination film (PVB), which can withstand extremely cold conditions; in fact, the phosphor emission efficacy increases at lower temperature. Sunlight has a great deal of UV emission, which affects material reliability and also contributes to emissive back-

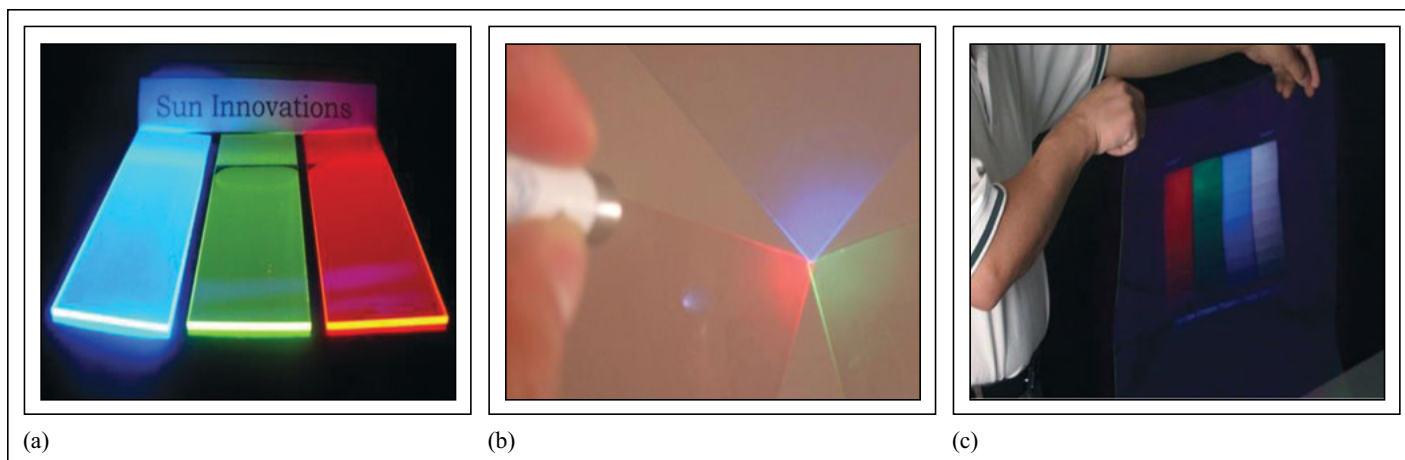


Fig. 2: RGB emissive materials appear in (a) as fully transparent coatings on glass and in (b) as optically clear polymer films. In (c), three transparent RGB layers are stacked together for a single full-color emissive screen without pixilation, using the WSE process.

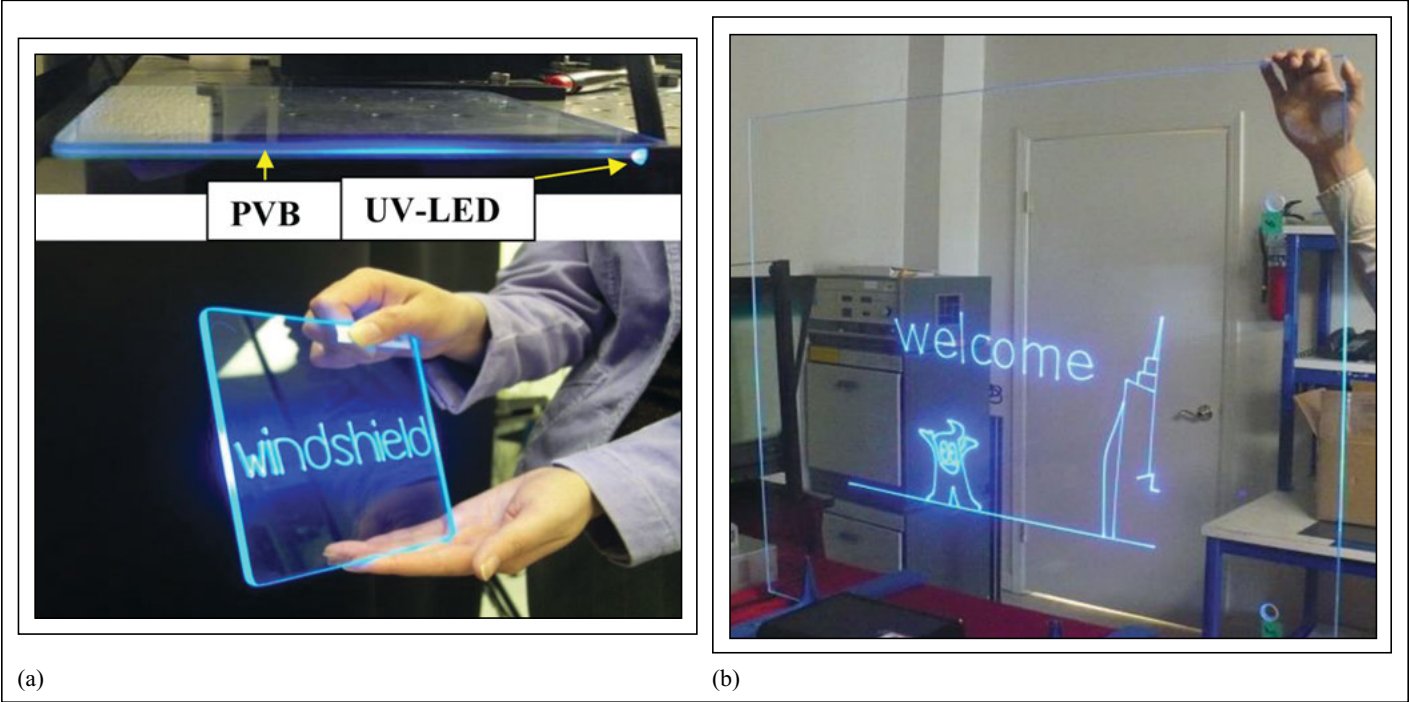


Fig. 3: At the top of (a) a cross section of a display glass with emissive material inside the glass PVB (shown at bottom) is shown. In (b), a demo image on full-sized glass with a phosphor-loaded PVB interlayer is shown. The image is generated by a blue-ray laser projector

ground noise; hence, a clear UV blocking film or layer is typically used before the phosphor films to shield the materials from solar UV.

Miniature Full-Windshield HUD (FW-HUD) Projector and a Complete FW-HUD Kit
For HUD applications, the projector must be

small in order to fit into automobiles with volume restraints. In that regard, we are developing a miniature FW-HUD projector based on blue-ray laser technology and x-y

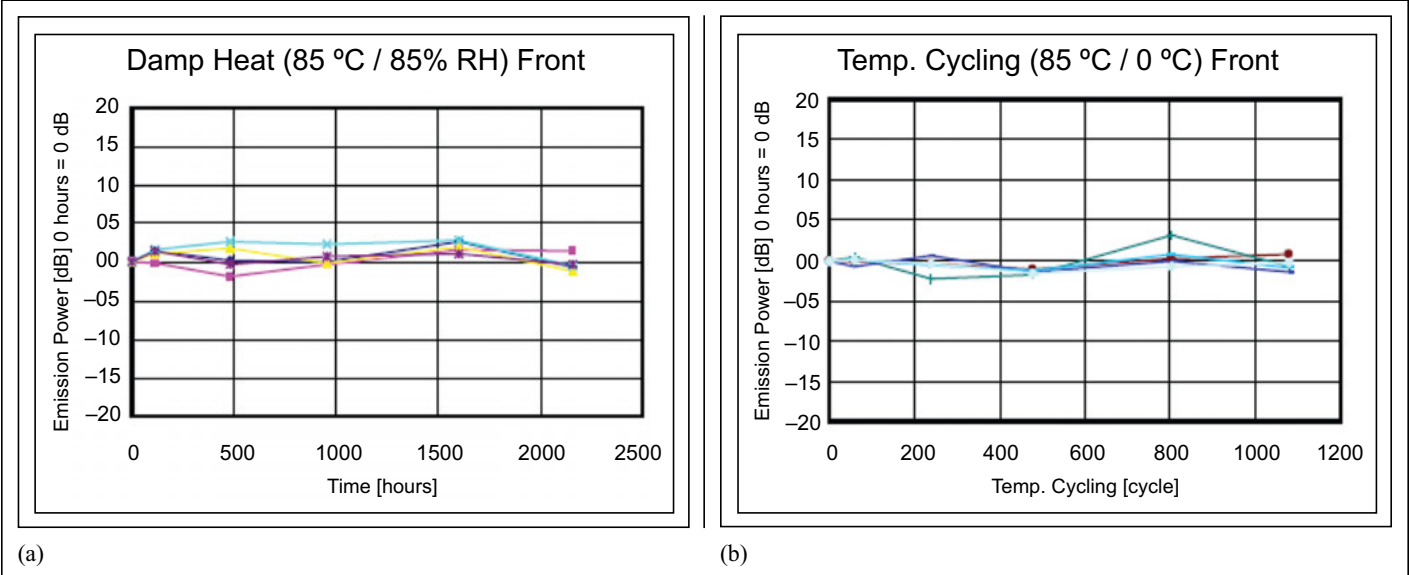


Fig. 4: The reliability of the display-screen materials was tested under various conditions, including (a) high humidity and (b) high and low temperatures. Multiple screen samples were tested simultaneously for statistical studies and are shown in different colors. The screen luminance is ~4400 cd/m² on the tests. The screens remain visually clear after the tests.

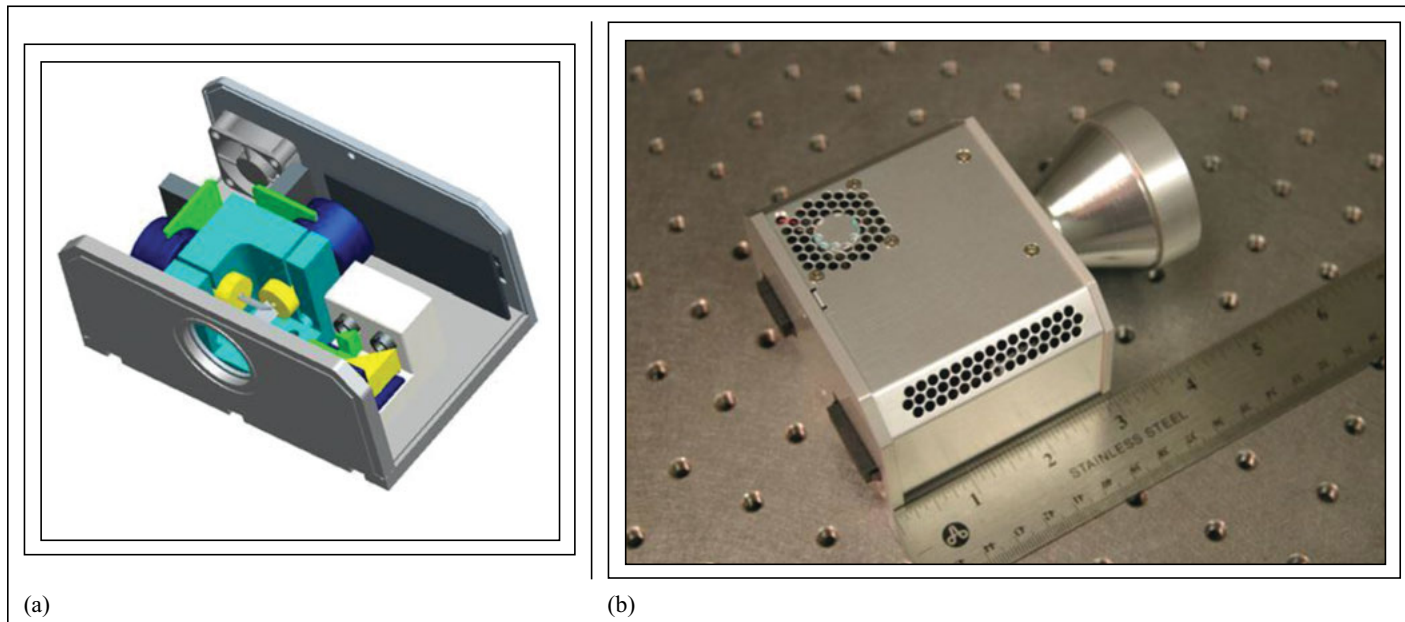


Fig. 5: In (a), a drawing of the overall display engine design is shown. A photo of the miniature laser projector for FW-HUD is shown in (b).

laser image scanners. Figure 5 shows the layout of such a custom-designed miniature HUD projector. It consists of a set of x-y galvanometer scanners, the mechanical base of the scanner, and a light-emitting module. The driver boards, controller boards, and input interfaces are integrated in another housing that is connected to the projector. This separated design allows for flexible and convenient installation. A miniature palm-size FW-HUD projector was built [Fig. 5(b)], which is provided along with an optically clear phosphor-coated display windshield [FW-HUD Standard Development Kit (SDK)] for custom-full-windshield display applications.

An FW-HUD SDK system has been developed for use in cars and other vehicles. Speed, GPS information, and warnings are projected onto the windshield. The controller has an open software interface; users can build their apps to control the projector display. Figure 6 shows an augmented-reality application from GM using the FW-HUD SDK, outlining the road, and pin-pointing the destination in a poorly lit environment, through integration with various sensors.

Sun Innovations recently demonstrated an FW-HUD in HD color, using a custom-built LED/laser hybrid DLP projector that output three wavebands – 405, 423, and 450 nm – to

excite the emission of red, blue, and green, respectively. Figure 7(a) shows the projector prototype, along with a demo of an HD-image in color on the transparent phosphor-coated windshield (b).

FW-HUD Possibilities

The FW-HUD technology turns any vehicle glass into a real-image transparent display, with great flexibility to display anywhere

desired on that glass with viewability from any angle. Unlike existing HUDs that present a reflective virtual image outside, it does not present an image beyond the glass. While the focal plane is shorter than a “virtual image” HUD, it is longer than any other vehicle display on the dash, and it stays head up. The projected light is completely blocked by a windshield coated with the phosphor film and converted to visible imagery. Energy efficient

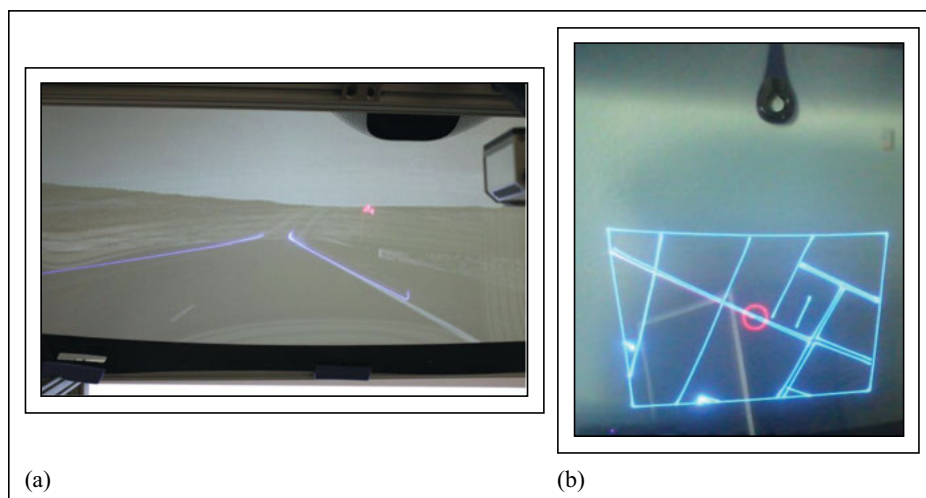
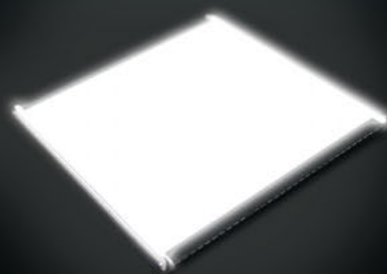


Fig. 6: Examples of the FW-HUD projector (shown in Fig. 5) are shown on a transparent phosphor-coated windshield.

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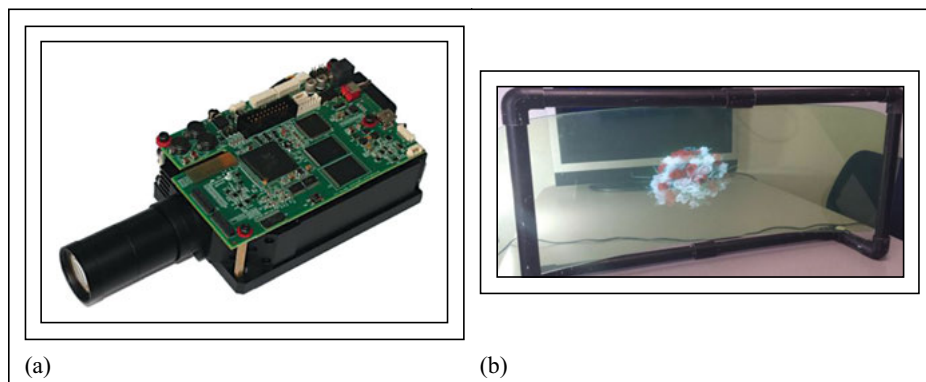


Fig. 7: (a) An HD-HUD projector prototype. (b) An FW-HUD demo shows an HD image in color.

laser or LED projectors can be built to display adequate contrast for daylight applications. This technology will complement other vehicle displays, including HUDs, and enable some unique display solutions, including FW augmented reality.

This novel EPD technology has been applied to the first-ever demonstration of a FW-HUD with unlimited viewing angles. This display technology can be readily applied to any glass windows in any vehicle or building structures.³ It can also be applied to convert any surface to a high-quality emissive display, without hiding or affecting the surface appearance. For example, it can enable the first projection display on a pitch-black screen, with high image contrast in bright ambient light that rivals that of flat-

panel displays. As a new tool for human-machine interfaces in future vehicles, FW-HUDs will enable advanced augmented-reality solutions over the entire windshield after integration with various sensors.

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¹R. L. Newman, "Head-Up Displays: Designing the Way Ahead," ISBN 0-291-39811-1 (1995).

²J-Q. Liu and X. Sun, "System and Method for a Transparent Color Image Display Using Fluorescent Conversion of Nano-Particles and Molecules," U.S. Patent 7090355.

³T. Sun and B. Cheng, "Novel Emissive Projection Display Digitizes Glass Windows," *Information Display* **29**, No. 6, 2-8 (Nov./Dec.) 2013. ■



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Next-Generation Head-Up Displays

HUD 2.0 may function as a primary information-display technology for vehicle drivers rather than a source of merely helpful or ancillary information.

by Alan Rankin and Jason Thompson

CURRENT head-up display (HUD) systems tend to display redundant information – that which is generally available elsewhere in the vehicle. HUD 2.0 – the next generation of this technology – is positioned to become the display of choice for Advanced Driver Assistance Systems (ADAS) information. With the addition of on-board sensors, cameras, and vehicle-to-vehicle/infrastructure communications, the amount of information a vehicle knows about its surroundings has increased exponentially. The challenge lies in how to effectively communicate what critical information is “known” by the vehicle and relay it to the driver. The need will only increase as we move toward semi-autonomous and autonomous driving capabilities. Unlike existing HUDs that tend to be used as secondary displays in user-interface paradigms, HUD 2.0 may be central to the human-machine-interface (HMI) strategy and will function as a primary information display. As such, exceptional image quality and consistent readability in varying sunlight conditions are requirements.

A natural and intuitive way to communicate this information would be to use HUD 2.0 to augment the driver’s world-fixed view with conformal graphics that indicate what the car knows. Features such as navigation indicators, lane-departure warning (LDW), and adaptive cruise control (ACC) indicators could be displayed at a natural image distance

as seen from the driver’s perspective. In Fig. 1, a HUD augments the reality of the driver’s view to provide useful information in real time. Note that the image appears in bright vivid color and is overlaid at the natural distance of the objects so that the driver can easily use the information with minimal distractions.

Challenges

Although a detailed description of HUD design is beyond the scope of this article, we

will review some of the key parameters. As shown in Fig. 2, both the field of view (FOV) and virtual-image distance (VID) play a role in determining perceived virtual-image size. While conventional HUDs cover only a fraction of a single lane, HUD 2.0, with a much larger FOV and longer VID, allows the driver to see images beyond a single lane of traffic. These increases in FOV and VID require higher luminance levels, more saturated colors, higher power efficiency, and increased tolerance to sunlight intensity. Additionally, these



Fig. 1: An augmented-reality HUD shows conformal graphics over the driver’s line of sight.

Alan Rankin is Business Development Manager and *Jason Thompson* is Application Engineering Manager at Texas Instruments DLP Products. Rankin can be reached at rankin@ti.com.

new parameters need to be achieved while also meeting all of the conventional automotive environmental conditions. Table 1 lists some of these parameters for HUD 2.0 as compared to a conventional HUD system.

Luminance and Power Efficiency

A larger FOV and higher luminance levels result in an easy-to-view image for the driver. To help ensure readability in varying sunlight conditions, the HUD should be capable of producing a virtual image between 15,000 and 30,000 cd/m² to provide a proper contrast ratio over a wide range of roads and sunlight illumination conditions. A road covered by snow and directly illuminated by the sun would be the biggest challenge. However, the absolute power needed to create this image should remain low – both to minimize the volume needed for thermal management and also to keep the luminous flux in a workable range of the LED light source. To achieve both a larger FOV and higher luminance while not increasing power, a much more efficient imager is required. (For more about HUD luminance requirements, see the sidebar “HUD Legibility.”)

The Texas Instruments DLP 0.3-in. WVGA Type A100 digital micromirror device (DMD) is one possibility for integration into a HUD 2.0 system. It is >66% efficient and dramatically improves the system’s efficiency to enable the above parameters to be met. A HUD system based on DLP technology and RGB LEDs can achieve the required luminance and larger FOV. For example, a system designed with the 0.3-in. WVGA DMD and OSRAM Q8WP RGB LEDs² uses only 6.0 W of LED power to achieve over 15,000 cd/m² with an FOV of 10°, which is less power than even smaller secondary HUD systems today. The efficacy of this system (lumens per watt) is 10.6 lm/W.

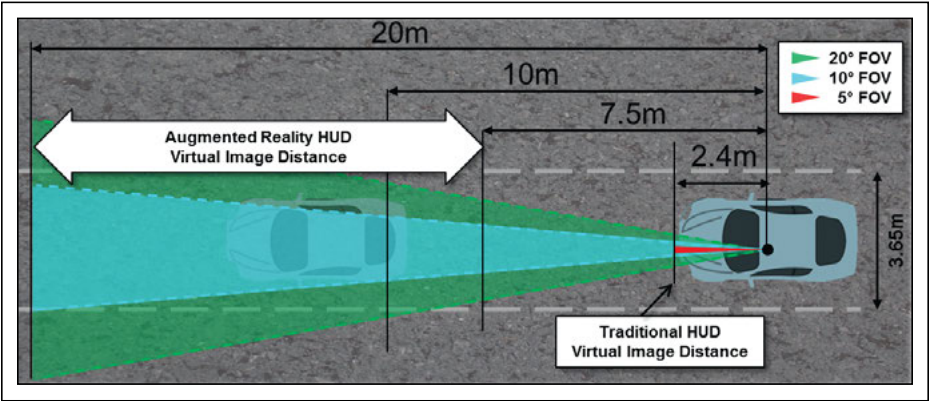


Fig. 2: Both field of view (FOV) and virtual-image distance (VID) impact the perceived size of a HUD image.

Color Saturation

Many conventional TFT-LCD HUD designs use a white LED that is filtered into the component red, green, and blue colors. In contrast, HUD systems based on DLP technology use red, green, and blue LEDs and provide more saturated colors. This allows for increased readability of the image on the HUD display.³ Key performance metrics are used to judge the color performance of a system, including the gamut size measured by comparing its color gamut to the Rec. 709 color space, the hue of each color as defined by its dominant wavelength, and the saturation of the color.

Table 2 compares the TFT-LCD white-LED architecture¹ with HUD architecture based on DLP technology with RGB LEDs. The RGB LED shows significantly higher performance both in the increased color gamut compared to Rec. 709 and the deeper saturated red and blue colors.

Sunlight Thermal Loading

As the FOV of a HUD system increases, so does the amount of sun energy collected by

the HUD optics. Also, as the VID increases to allow the driver to view the image at the proper perspective relative to the real world-fixed view, the energy from the sunlight becomes more focused onto the internal imager of the HUD. The effect of both collecting more sunlight and focusing this energy to a smaller spot on the internal imager can be damaging to the imager due to the amount of heat collected in a small area. The HUD system based on DLP technology uses a diffusing screen material to create the internal image of the HUD system. For a conventional HUD system, the imager (typically a TFT panel) directly emanates the HUD image (Fig. 3).

Table 2: DLP/RGB LED HUD color performance compares favorably to that based on a TFT-LCD with white LED performance.

Table 1: Key parameters for conventional HUD vs. next-generation HUD 2.0 include FOV, luminance, and power efficiency.		
Parameter	Traditional HUD	HUD 2.0*
Field of View (FOV)	<5°	>10°
FOV – From Driver’s Perspective	N/A	>1 lane of traffic @ 20 m
Luminance	Typical ~8000 cd/m ² *	>15,000–30,000 cd/m ²
Power Efficiency	>10 W @ 8000 cd/m ²	<10 W @ 15,000 cd/m ²

*Measured data¹

	Rec. 709 Gamut (%)	Dominant Wave-length (nm) [†]	Saturation (%)
TFT-LCD with White LED ¹	92%	R:621 G:549 B:469	R:72 G:75 B:81
DLP technology with RGB LED*	143%	R:620 G:549 B:456	R:91 G:75 B:95

[†]DW = Dominant Wavelength.
*Measured and modeled data.

HUD Legibility

HUD has specific challenges due to the image overlay on the real ambient-light scene. SAE J1757 (Standard Metrology for Vehicular Displays) and ISO 15008 (Road Vehicles: Ergonomic aspects of transport information and control systems – specifications and compliance procedures for in-vehicle visual presentation) define the display image size and luminance in “high ambient illumination” for legibility.

High ambient illumination is 10–100 klx, with testing recommended at 45 klx. In the case of HUDs, the windshield is the transparent mirror for the HUD optical engine image. The 45-klx background is about $14,000 \text{ cd/m}^2$ (14,324, to be precise). For the image to be legible to a wide range of the population, and in particular to the elderly (see the sidebar “Sunlight and Aging Eyes” in the Vehicle Displays Overview article in this issue), the contrast ratio between information and background should be more than 2. More than $28,000 \text{ cd/m}^2$ is needed for optimal optical-engine luminance – to be legible by all people in all ambient illumination and road conditions (such as sunny snow-covered roads). This still assumes a “perfect reflecting windshield,” with minimum legal transmission and 100% reflection and no attenuation of light from the optical engine through the HUD mirrors, which are needed to create the virtual image 2–7 m in front of the windshield. Unfortunately, this is not possible today, and even more luminance is needed, especially for situations with white backgrounds such as a sunny, snowy winter day.

The diffusing screen is a passive element with two primary advantages: (1) it does not absorb the sun energy – it diffuses the light – and (2) it is not a source of heat itself. These attributes allow HUD systems based on DLP technology to more readily scale to the large FOV and longer VID needed for augmented-reality HUD systems. In addition to being bright enough to be seen in various ambient light conditions, a HUD virtual image should also be readable when the driver is wearing polarized sunglasses. Since DLP technology projects unpolarized light, this gives OEMs the ability to optimize the HUD for use with polarized sunglasses.

Environmental Conditions

Imaging technology used in automotive HUD systems must also be able to reliably operate in rigorous environmental conditions such as high humidity, extreme temperatures (including dramatic temperature changes), shock, and vibration. The DMD is a microelectromechanical system (MEMS), and some may wonder about its ability to meet the temperature cycle, shock, and vibration experienced in an automobile. The DLP 0.3-in. WVGA Type A100 DMD meets these conditions. Its mechanical structure is robust under shock and vibration in the <5-kHz range because the

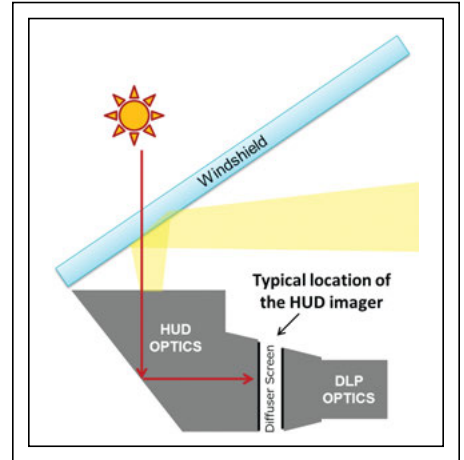


Fig. 3: This block diagram shows the architecture for a conventional non-diffuser screen HUD design.

mirror resonant frequency is well above 100 kHz. Table 3 lists some of the critical tests that have been successfully completed on the 0.3-in. WVGA Type A100 DMD without issue.

DLP Chip Inventor Receives an Oscar®

Earlier this year, the Academy of Motion Picture Arts and Sciences honored the inventor of the Texas Instruments DLP chip, Dr. Larry Hornbeck, with an Oscar® at the Academy’s 87th Scientific and Technical Awards Ceremony in Hollywood (Fig. A). The DLP chip contains a rectangular array of up to 8.8 million hinge-



Fig. A: Dr. Larry Hornbeck received the 2014 Scientific and Technical Academy Award® of Merit (Oscar® statuette) for the invention of the digital micromirror device (DMD) technology as used in DLP Cinema® projection.

mounted microscopic mirrors; each of these mirrors measures less than one-fifth the width of a human hair. The DLP chip micromirrors tilt either toward the light source in a DLP projection system to be “on” or away from it to be “off.” The result is either a light or a dark pixel on the projection surface.

The technology can be employed for high-speed, efficient, and reliable spatial light modulation and has found use in industrial, medical, telecom, security, and many other applications. In particular, “The digital micromirror device (DMD) is the core technology that has enabled Texas Instruments DLP Cinema projection to become the standard of the motion picture industry,” the Acad-

emy said in announcing the award. According to TI, DLP technology can now be found in more than 8 out of 10 movie theaters around the world.

TI notes that DLP technology is also now positioned to become a vital part of the automotive industry, through new display and headlight applications.

Table 3: Automotive tests completed include temperature cycle and mechanical shock.

Tests Performed on DMD	Condition
Temperature Cycle	-55°C / 125°C, 500 cycles
Mechanical Shock	1500G
Vibration	20G, 20-2000 Hz Constant Acceleration 10 kg

Enabling the Next Generation

Automotive HUDs are becoming a more critical part of vehicle HMI strategies, especially as more and more ADAS technology is deployed in the vehicle. With HUDs transitioning from small secondary displays to large primary displays, the expectations for image quality, readability, and reliability increase. As mentioned earlier, HUD designers are particularly challenged by the need to achieve the above requirements while also meeting all of the conventional automotive environmental conditions.

Acknowledgment

Data throughout this article provided by TI unless otherwise noted.

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1. "ITO replacement—Non ITO transparent conductor technologies, supply chain and market forecast" 2015 report.
2. "Quantum dot display and lighting technologies and market forecast" 2015 report
3. "Active pen technologies, supply chain and market forecast report"
4. "Touch Panel for vertical Market report"
5. "Flexible, curved, foldable 2015 report"
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Technologies and Trends for Vehicular Displays

Displays have become an integral part of the driving experience. The author takes a brief look back at the history of displays and then a look forward at how displays in vehicles will meet the ever-increasing demands put on them.

by Silviu Pala

VEHICLES have practically become our homes and offices on wheels. According to the National Highway Traffic Safety Association (NHTSA), vehicles will ultimately enable all productivity and infotainment features used in homes and offices, and drivers will have almost no responsibilities regarding actual driving. (The NHTSA refers to these operative capabilities as Level 4. See the sidebar “NHTSA Levels and Definitions” for the other levels.) Many experts are estimating that we will be at Level 4 by 2020, but that may be too optimistic. Due to sensor reliability and the need for safer redundancy, we may be looking much farther down the road – at least two automotive cycles or more than 10 years from now.

In the meantime, we are starting to see Advanced Driver Assistance Systems (ADAS) features such as autonomous cruise control with “collision imminent” braking, lane-departure warnings, autonomous parking, and so forth, combined with more information and safety features related to Level 2 autonomous drive and anticipating Level 3. In addition, consumer desire for better connectivity is prompting designers of vehicle interiors to create vehicular extensions of our smartphones, smartwatches, etc., through displays that are larger, more strategically located, and sunlight readable.

Silviu Pala is with DENSO International America in Southfield, Michigan. He can be reached at silviu_pala@denso-diam.com.

This article offers a short history and overview of vehicle-display technology and a longer look at current automotive-display requirements and the technologies required to realize them.

Vehicle-Display Background

Up until the late 1970s, all displays and controls inside a car were mechanical gauges that were illuminated by bulbs. Futaba’s vacuum-fluorescent display (VFD) helped start the digital display revolution in cars by introducing the first digital clock for autos in 1976 (Fig. 1).

Futaba also began replacing analog indicators with digital segmented or dot-matrix



Fig. 1: The first digital clock in an American automobile was a vacuum-fluorescent display from Futaba, in the 1976 Dodge Aspen. Image courtesy Ben DiCicco/Chrysler.

displays. This technology dominated the automotive market until the early 2000s. The key advantages of VFD technology, as achieved by companies such as Futaba and Noritake, were its modern (for the time) appearance and high reliability. The main drawbacks were the bulkiness of the package, limited color, and low resolution due to the high voltage needed to operate each dot.

A new technology contender appeared in 1984 with the passive-matrix LCD from Delco and Hitachi, which was introduced in a digital speedometer and tachometer (Fig. 2).

This was a multicolor high-resolution instrument-cluster design, revolutionary at the time but very expensive. The manufacturing cost was about \$250 for the speedometer and about \$275 for the tachometer, according to Bob Bordo, the GM manager involved in their



Fig. 2: The first digital speed and tachometer LCDs, by Hitachi and Delco, appeared in the 1984 Corvette. Image courtesy Bob Bordo, GM.

design. The backlight illumination was achieved with bulbs. Large heat dissipation and operation at low temperatures were just some of the many display-integration challenges. Despite LCD technology drawbacks such as long response times at low temperature and low viewing angles, the high resolution and multicolor capability combined with a smaller package and improved reliability put this display ahead of VFDs by the late 1990s.

The CRT was another technology used in automotive displays. GM introduced an IR touch screen over a CRT display in its 1989 Oldsmobile and Buick (Fig. 3).

This display was the grandfather of the “tablet in the center stack” that we know today, but it arrived on the market too early. Turn-by-turn navigation and smartphone capability, which would have made the display more desirable, did not exist, and the display was too bulky for the space it occupied in the instrument panel. (The instrument cluster and center stack area of the panel are some of the most valuable real estate in a vehicle due to HVAC air ducts, cables, *etc.*, competing for space there.)

LCD-based vehicle panels, despite being high resolution for the time – 100 dpi – lacked the crisp-looking output of analog meters. So, automotive engineers developed a custom solution to achieve interior designer requests: electroluminescent (EL) technology for a transparent digital information center over analog meters, as introduced in 1998 by Toyota in a display featuring a Denso cluster meter with a Planar transparent EL display. EL has very high reliability and optical performance – the space shuttle was using it at the time. However, lack of full color and improvements in TFT-LCDs prevented EL gains in the market.

OLEDs started to be used in 2005 by GM and Chrysler in small information center displays.

This technology has excellent optical performance (contrast ratio, view angle, resolution). The key challenge for OLED displays is differential aging, especially for full-color displays. Futaba, one of the lead automotive VFD makers, is now manufacturing monochrome PMOLEDs for automotive applications. (See the article “Automotive Applications for Passive-Matrix OLEDs” in this issue.) Futaba’s technology is just one among many that are being deployed to meet the challenges faced by today’s vehicular

NHTSA Levels and Definitions

NHTSA defines vehicle automation as having five levels:

1. **No Automation (Level 0):** The driver is in complete and sole control of the primary vehicle controls – brake, steering, throttle, and motive power – at all times.
2. **Function-Specific Automation (Level 1):** Automation at this level involves one or more specific control functions. Examples include electronic stability control or pre-charged brakes, where the vehicle automatically assists with braking to enable the driver to regain control of the vehicle or stop faster than possible by acting alone.
3. **Combined Function Automation (Level 2):** This level involves automation of at least two primary control functions designed to work in unison to relieve the driver of control of those functions. An example of combined functions enabling a Level 2 system is adaptive cruise control in combination with lane centering.
4. **Limited Self-Driving Automation (Level 3):** Vehicles at this level of automation enable the driver to cede full control of all safety-critical functions under certain traffic or environmental conditions and in those conditions to rely heavily on the vehicle to monitor for changes in those conditions requiring transition back to driver control. The driver is expected to be available for occasional control, but with sufficiently comfortable transition time.
5. **Full Self-Driving Automation (Level 4):** The vehicle is designed to perform all safety-critical driving functions and monitor roadway conditions for an entire trip. Such a design anticipates that the driver will provide destination or navigation input but is not expected to be available for control at any time during the trip. This includes both occupied and unoccupied vehicles (<http://www.nhtsa.gov/>).



Fig. 3: The first automotive digital information center with a touch screen was introduced in the Oldsmobile Toronado in 1989. It featured a color CRT display with infrared touch by Denso. Monocolor for the Buick Riviera by Delphi.

Sunlight and Aging Eyes

Beginning in the 1930s, transportation legibility began to be studied with respect to character sizes and proportions for road signage and military applications. In the 1950s and 1960s, legibility within the automotive industry focused on buttons, switches, and gauges, typically with white-painted graphics and black backgrounds. In more recent years, the introduction of flat-panel displays within the vehicle posed unique challenges to legibility, especially under daytime conditions when sunlight can flood the displays and reduce contrast.

In addition to these factors, the human eye and its capabilities change as we age. For instance, contrast sensitivity declines and sensitivity to glare increases as we grow older. The typical retina at 65 years of age sees about 40% of the light that a typical 20-year-old retina sees. The author conducted a study in which licensed drivers were asked to read a line of letters and numbers presented in a display, using occlusion goggles to simulate a driving environment. Text height, width, and stroke width were varied

Text height, width, and stroke width were varied

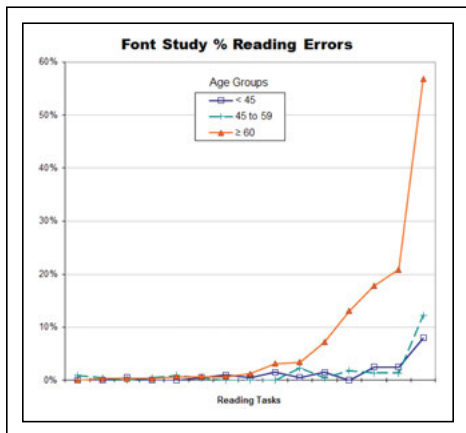


Fig. A: Reading errors by age group increased drastically for the more difficult tasks at right in subjects over 60 years of age.

with a range that included easy and difficult text to read. The subjects ranged in age from 25 to 91 years, binned into three groups. Figure A shows the percent reading errors for the three age groups, resulting from each of the 15 reading tasks ordered from easy to difficult. The older age group had significant difficulty reading fonts that the two younger age groups could read relatively easily.

When bright daylight conditions are added to the mix, legibility becomes an even greater challenge, especially for aging eyes. The author conducted another study in which subjects were asked to read a line of text in overcast and direct-sunlight conditions. The overcast condition used only diffused light shining on the display measured at 5 klx, whereas the direct-sunlight condition added directional lighting at 45 klux, both in accordance with SAE standard practice J1757. Reading tasks were varied by luminance

contrast and color contrast in 32 combinations. Figure B shows the effect of age on the percentage of text read correctly across all reading tasks. Here, it is clearly evident that aging eyes struggle to perform under typical daytime lighting conditions unless strong luminance and color contrast is provided. Color contrast is reduced to a minor contributor under bright sunlight conditions; however, luminance contrast is key. Figure C shows the results of the reading tasks for only the older age group (60 and up) relative to the recommended ISO 15008 contrast levels.

Legibility will always be a concern as long as displays are placed in vehicles and as long as human eyes age. Font characteristics such as height, width, and stroke width, as well as text to background contrast under the challenges posed by daytime conditions, can have a huge effect on the ability of older eyes to read the important information that displays present.

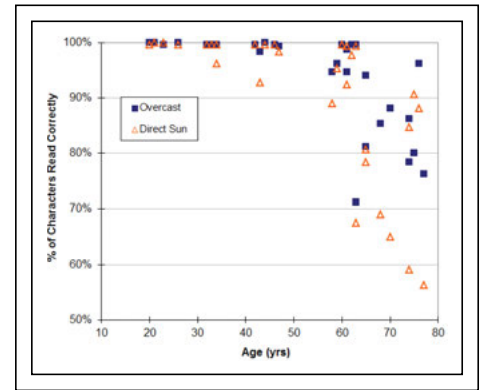


Fig. B: The chart shows percent of text read correctly across all reading tasks by age of the participant in overcast and direct-sunlight conditions. Direct sunlight caused errors in all age groups, but particularly in the older participants.

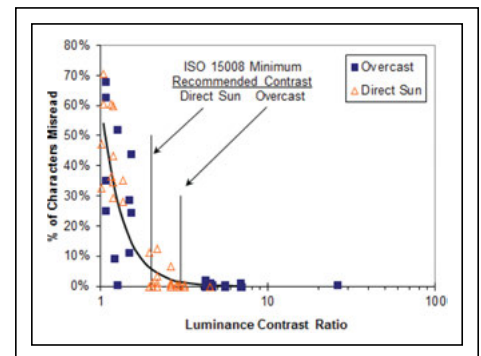


Fig. C: The chart shows the percent of reading errors for the 60 and older age group for all 32 reading tasks as measured by luminance contrast. The ISO 15008 recommended contrast correlates to an error rate of 10% or less.

— Shannon O'Day

Ford Motor Co., Core Ergonomics Research Engineer

displays, from which ever more functionality is expected. The rest of this article looks at those challenges and requirements, including some of the products that have been developed to meet them.

Tough Requirements

It is important to measure automotive-display performance in terms of specific stress tests, including mechanical vibrations and shock, as well as operation at different voltage variations, such as low battery, nominal, and high alternator voltage. (In the early 1990s, the author measured a 512-V spike on a 12-V

battery line due to a door-lock event.)

Displays are also measured under conditions of temperature variations from -40°C to 85°C and at thermal and humidity cycles combined with thermal shock. These last events might include opening the door of the car when the interior is hot and the outside is freezing or when the car is air conditioned but it very hot outside, such is in summer in Arizona.

Another factor to consider is electromagnetic compatibility (EMC), which prevents the display from introducing electromagnetic noise to the electronic modules or the radio (especially in the AM band).

Look, Feel, and Legibility

Display appearance or “look and feel” has traditionally been implemented by designers and engineers, then followed by validation from a focus group. There are many anecdotes about the wife of the boss changing the design look and feel after the first prototype vehicle was built! Vehicle displays for radio and HVAC used to be judged primarily on comfort and convenience. Legibility requirements were secondary to brand image and shape (see the sidebar, “Sunlight and Aging Eyes”). Of course, the speedometer, odometer, PRNDL, and warning-icon displays were all subject to regulatory standards.

QPI Benefits for HUD Designs

The quantum photonic imager (QPI) is a three-dimensional integrated-circuit (3D-IC) semiconductor device comprising a high-density array of digitally addressable micro-sized pixels. Each pixel (see Fig. D) consists of a vertical stack of multiple light-emitting-diode (LED) layers, each of which generates light of a different primary (red-green-blue) color.

3D-IC techniques are used to meld the patterned photonic material to an equivalently patterned CMOS digital logic comprising an array of the pixel’s control circuits. The result is an array of digitally addressable “smart” pixels, each containing its own light-generating material as well as all of the needed logic to control it. The QPI architecture alleviates many drawbacks of existing microdisplay devices – in particular, those related to power efficiency, compactness, and cost. The small footprint of the QPI combined with its high luminance and low power consumption makes QPI an ideal candidate for head-up displays (HUDs).

In terms of high brightness, for mobile applications the QPI device can create a luminance of more than 20,000 cd/m² for a power consumption of less than 300 mW. The power consumption includes the driving electronics and the light creation. For a HUD application in which the power consumption can be increased further, the QPI luminance can theoretically be dialed up to more than 100,000 cd/m², based on Ostendo’s lab experiments.

The QPI does not require any external light source or driving electronics; both the light source and the driving logic are part of the display chip, and therefore inefficiencies in having separate devices are eliminated. The compact size of the QPI enables multiple QPIs to be used in advanced HUD concepts such as using the full windshield as a HUD, while taking up a much smaller space compared to existing HUD solutions.

The multiple colors generated by the RGB QPI share the same pixel aperture. This feature is completely novel and

sidesteps the artifacts associated with conventional field-sequential and spatial color display architectures. In terms of better contrast and power efficiency, QPI beam divergence can be

adjusted to match the étendue of the system optics. This means that the light generated by the QPI is used completely by the system and is not wasted, resulting in no stray light and improved image contrast while consuming less power. The QPI pixel structure does not allow light to leak from a pixel to its adjacent pixels, and when the QPI pixels are off they are truly off, resulting in high image contrast and reduced power consumption.

Last, the QPI does not require temperature tuning and because the modest amount of heat generated is uniformly distributed over the entire device surface, thermal management is not a problem. As a result, a thermoelectric cooler is not required. Currently, Ostendo is designing advanced prototypes that can achieve state-of-the-art results in HUD performance while significantly reducing volume.

— Zahir Y. Alpaslan
Director of Display Systems
Ostendo Technologies, Inc.

and

— Erhan Ercan
VP of Marketing
Ostendo Technologies, Inc.

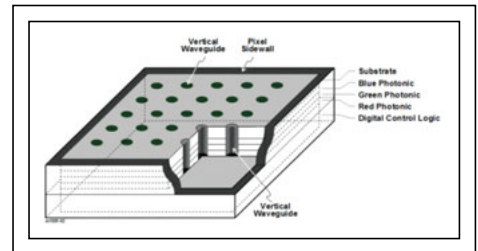


Fig. D: Each pixel of the quantum-photonic-imager device consists of a vertical stack of multiple LED layers.

More recently, the proliferation of mapping, turn-by-turn navigation, and more complex driver information and ADAS features have brought about the need for the International Organization for Standardization (ISO) and Society of Automotive Engineers (SAE) to adopt more quantifiable metrology for display legibility. The latest SAE revision of J1757 was approved in January 2015 and it is included in the next revision of ISO 15008 (in progress).

The look and feel of a display are also very much determined by its shape. Curved shapes with round corners and a high ratio between the display's active area and the total display surface to minimize packaging volume are essential requirements, enabling vehicle interior designers more freedom in "non-flat" instrument-panel designs. Improvements in contrast ratio combined with free-form displays such as those now being developed by Sharp are providing instrument-panel designers with freedom to design more advanced looking interiors with better ergonomics.

According to a recent brief from Sharp, "Conventional LCDs are rectangular because of the circuitry required to drive the pixels that are conventionally located around the perimeter of the display. Sharp moves the drive circuitry away from the perimeter and disperses it throughout the pixels on the display." There are tradeoffs, however. Sharp continues: "As with any new technologies, there are challenges in bringing [these free-form displays] to large-scale manufacturing." Such challenges include meeting automotive requirements and implementing high-volume

production of the glass cutting and fabrication of the in-pixel driver circuit process. Last, notes Sharp, the final shape of the display, the complexity of the design, and how efficiently it is used from the motherglass can impact cost.

The size of the display module also relates to look and feel. In general, the smaller the package the better because it can be more easily and optimally incorporated into the vehicle. A slimmer profile is helped by advances such as Kyocera's On-Cell Touch (OCT) technology, which uses a projected-capacitive (PCAP) touch-sensor layer built into the LCD structure. By adding a fractional amount of thickness to the LCD module, Kyocera eliminates a full touch-screen panel over the display surface, resulting in a thin and light-weight structure. Additionally, according to the company, by eliminating a touch substrate layer, it eliminates the interior optical reflections and improves visibility, without making the display significantly more fragile.

Beyond the Dashboard

One of the most promising display technologies for vehicles are head-up displays (HUDs) that remove the display from the dashboard, where it forces drivers to look down, to the windshield, where it allows them to keep their eyes on the road. Two articles in this issue take an in-depth look at HUD technology, "Emissive Projection Technology Enables a Full-Windshield Head-Up Display" and "Next-Generation Head-Up Displays." The sidebar "QPI Benefits for HUD Designs," from the 2014 SID Best Prototype award

winner Ostendo Technologies, offers a glimpse of a new technology that may increase the viability of HUDs as a market-ready technology.

Figure 4 offers a look at the sort of free-form all-encompassing display panel that is becoming more common in today's vehicles. The major challenges involved in achieving optimal display aesthetics and functionality in vehicles today include better (lower) power consumption and better (higher) contrast ratio at low and high ambient illumination. Of course, safety and usability remain chief concerns. As previously mentioned, one technology that offers a great deal of promise is head-up displays (HUDs), which augment the windshield view to provide valuable information while allowing drivers to keep their eyes on the road.

Down the Road

Key trends for the automobile of tomorrow relate to autonomous drive and technologies enabling similar life styles whether in vehicle or home/office. There are many multi-modal human-machine interface systems under development that relate to Levels 2 and 3 and eventually Level 4. However, based on the Yerkes-Dodson law of performance vs. workload/stress, more information will generate more distraction and lower performance, and increased automation may also reduce performance. Finding the optimal range requires a good quantifiable measurement tool. DENSO with MIT AgeLab, Touchstone, Honda, Jaguar, and Subaru have founded the AHEAD (Human Factors Evaluator for Automotive Distraction) consortium to develop this multi-modal tool kit. Within the next 10 years, HUDs and AR will become very important to the "robot" – "driver" tandem paradigm.

Vehicles at this level of automation will enable the driver to cede full control of all safety-critical functions under certain traffic or environmental conditions, and in those conditions to rely heavily on the vehicle to monitor for changes that would require a transition back to driver control. The driver would be expected to be available for occasional control (this is one of the greatest challenges), but with a sufficiently comfortable transition time. An important aspect to this evolution in levels, of course, is consumer acceptance of the new capabilities. Not so long ago, people were wary of cruise control, and a bit farther back, automatic transmissions, but we have since learned to accept these "augmented" capabilities in our vehicles. ■



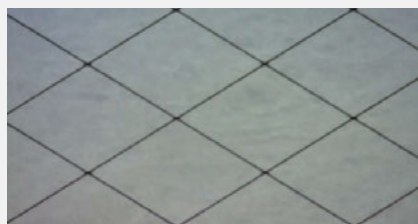
Fig. 4: The large curved display (with capacitive touch) demonstrated in a concept car from Chrysler in 2009 demonstrates the direction that vehicle manufacturers are headed in terms of vehicle displays. Image courtesy Ross Maunders Chrysler Interior Design.

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Automotive Applications for Passive-Matrix OLEDs

Passive-matrix OLED technologies offer some excellent advantages for automotive designers. However, consideration also needs to be given to factors that could affect design performance, including luminance decay, burn-in, power consumption, and color availability.

by Jeff Hatfield, Yoshiyuki Kobayashi, and Akihiro Nonaka

DUE TO improvements in passive-matrix OLED (PMOLED) technology, Futaba Corp. has successfully launched PMOLED displays into the automotive OEM market. One example is a display appearing in the 2015 Hyundai Sonata (Fig. 1). The digital information in the center area of this instrument cluster is seamlessly integrated with the analog displays and automotive icons in the rest of the cluster, due to the real black level of the emissive PMOLED display, which has a dark-room contrast ratio between image and background of more than 100,000:1. PMOLED technology represents a giant step forward for vehicle technology in terms of design flexibility and viewing angle. It is not a one-size-fits-all technology, however, as we will describe throughout the rest of this article.

As Fig. 1 indicates, PMOLED displays are currently in production today for an automotive cluster application, but other applications are a good fit for PMOLEDs as well, including climate-control displays, rear/front-seat status indicators, etc. These smaller applications are an ideal use for PMOLED displays based on the thin-packaging and custom-design possibilities it offers. (Futaba has

other PMOLED displays in automotive development but cannot share details at this time.)

PMOLED, as the name implies, is a passively driven array of self-emissive pixels creating a graphical-type display. Although fixed-segmented OLEDs that are statically driven, and currently being used for automotive applications, this article will focus mainly on PMOLED graphical displays. PMOLED technology offers some distinct advantages, such as fast response times (temperature independent), self-emissive (thin packaging

with no backlight), high contrast, and wide viewing angle. On the other hand, other aspects that can affect design performance include luminance decay, burn-in, power consumption, and color availability. As with any display technology, the end user should consider both the positive and negative aspects of the chosen technology.

Luminance Output

PMOLED displays are limited in luminance output based on the scan rate and energy available to illuminate the organic pixel. In



Fig. 1: This instrument-cluster meter with a 3.5-in. PMOLED display (center section of display) manufactured by DENSO for the Hyundai Sonata shows seamless integration of the display, with no display outline and no different background since the contrast ratio is more than 100,000 to 1.

Jeff Hatfield is with Futaba Corporation of America. Akihiro Nonaka and Yoshiyuki Kobayashi are with Futaba Corporation of Japan. They can be reached at jhatfield@futaba.com, Nonaka@fmd.futaba.co.jp, and KobayashiY@fmd.futaba.co.jp, respectively.

general, the higher the scan (frame) rate, the lower the luminance. This scan scheme currently limits the practical automotive usage of PMOLED displays to an approximate array size of 168×256 pixels, putting the industry common QVGA (quarter video graphics array), or larger-type display applications, out of reach for PMOLED displays. This same scan scheme limit, in turn, makes only monochrome applications practical, as the color filtering needed for a color PMOLED display, using white-emitter material reduces the luminance further than that of a monochrome PMOLED display, making the luminance too low for automotive usage.

For reference, a typical automotive white monochrome PMOLED display can provide 300 cd/m^2 (500 cd/m^2 for fixed-segmented-type OLEDs), with white being the most common monochrome color, but blue and red also being possibilities. The aforementioned luminance is after the inherent automotive-grade circular polarizer (CPL) deemed necessary to enhance contrast for automotive applications has been incorporated. Luminance can also vary at the pixel level to allow gray-scale appearances by using available IC and software configurations.

Dead-Front Appearance

Due to the nature of PMOLED display’s self-emissive technology, there is no backlighting required because, as the name implies, the PMOLED display is self-emissive; *i.e.*, it creates its own light without the need for backlighting. Consequently, an all-off pixel condition will create a dead-front appearance from the PMOLED display. (A “dead-front” appearance allows the display to be flush with the rest of the panel, so that the light is only visible when the display is illuminated.) The other consideration for a dead front is to apply enough front-lens darkening filtering to ensure the inherent OLED mechanical structure remains hidden in the final application.

Contrast Ratio

Figure 2 shows the typical PMOLED display contrast ratio across a variety of ambient conditions.

Color Availability

As mentioned above, the color palette available for PMOLED displays is not infinite. Due to the special color ratio of organic

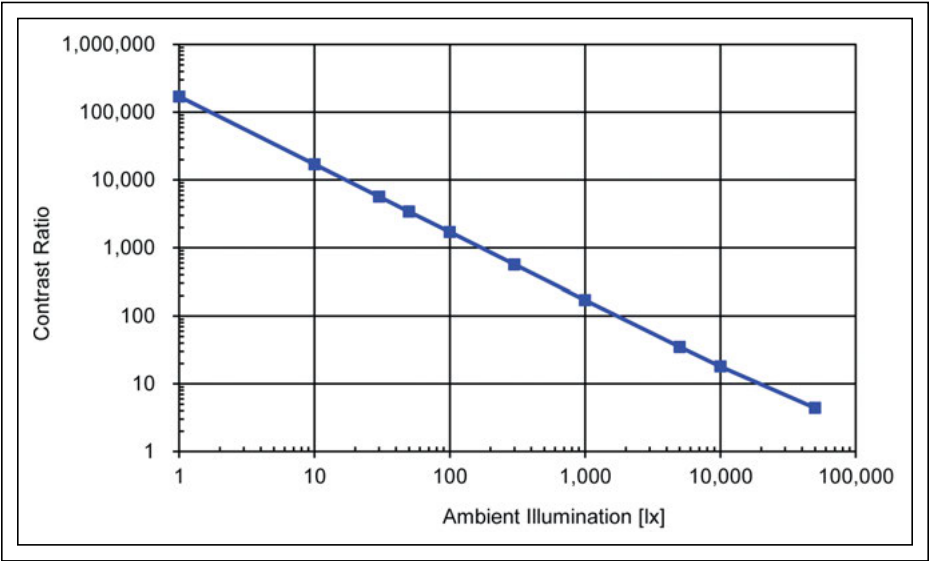


Fig. 2: A typical PMOLED display contrast ratio (CR) is compared to ambient illumination. For reference, the typical CR for a similar appearing LCD in low ambient is about 1000:1.

material making up the pixel, available color ranges are limited and consideration must be taken to match the PMOLED display capabilities to end-user color coordinates.

The CPL filter can provide some additional filtering, but it too will have finite color characteristics.

Viewing Angle

Although a PMOLED display is considered to have a wide viewing angle, as evident in Fig. 3, it is important to consider the effects of color shift at extreme angles. This phenomenon for PMOLED displays is due to variations of light refractions inside the PMOLED

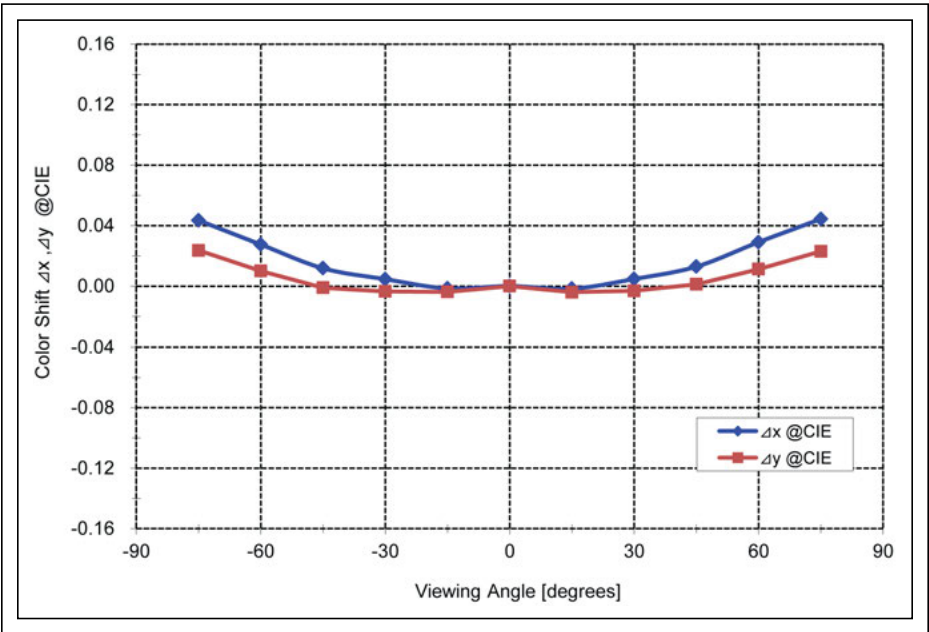
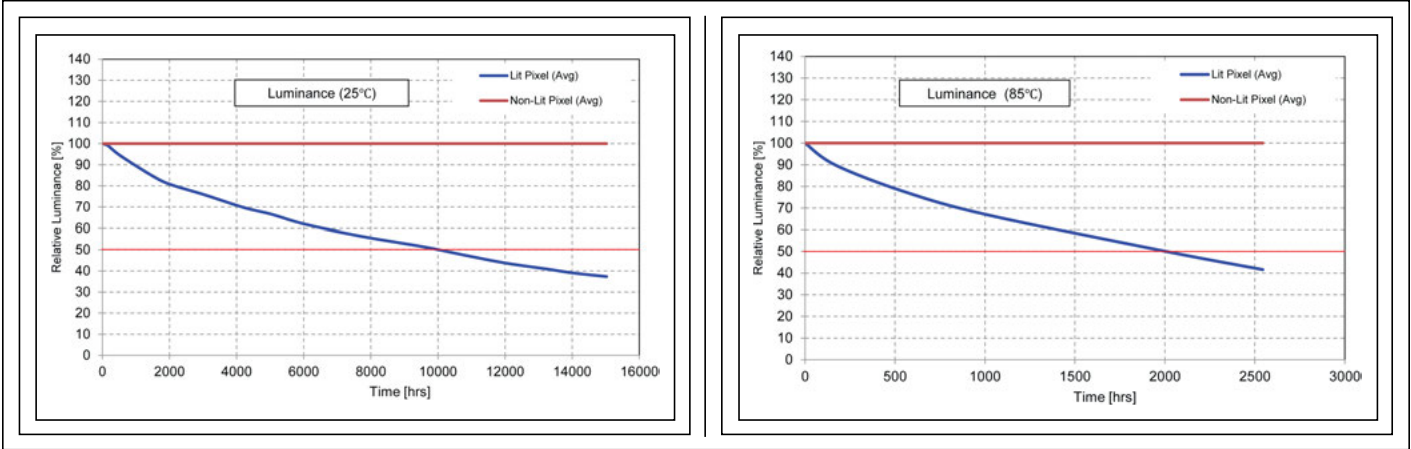


Fig. 3: Color shift is compared to viewing angle.



Figs. 4 and 5: Relative luminance is compared against time (25 and 85°C).

display; as the viewing angle increases, it causes a shift in the light wavelengths that are visible to the eye. It should be noted that although the display viewing angle in a dashboard is fixed, there is a wide range of possible locations for a display’s dashboard or center stack application placement. An OLED display’s wide viewing angle, with limited color and luminance change, offers flexibility to designers in terms of center-stack location — close to the hand rest, close to the windshield, or in the instrument-cluster meter.

Power Consumption

Depending on the application, power consumption could be a positive or negative aspect of PMOLED displays. In general, the power usage is directly proportional to the amount of pixels lit. For example, a typical PMOLED display

might consume 2 W with 100% “on” pixels, whereas 50% “on” pixels would consume 1 W.

Reliability

PMOLED displays have been certified and tested to meet various automotive OEM conditions. Special or extreme conditions are evaluated on a case-by-case basis to determine any detrimental results from special test conditions. For example, a typical severe automotive grade test is 85°C/85% RH @ 1k hours and PMOLED displays will not pass this condition/time.

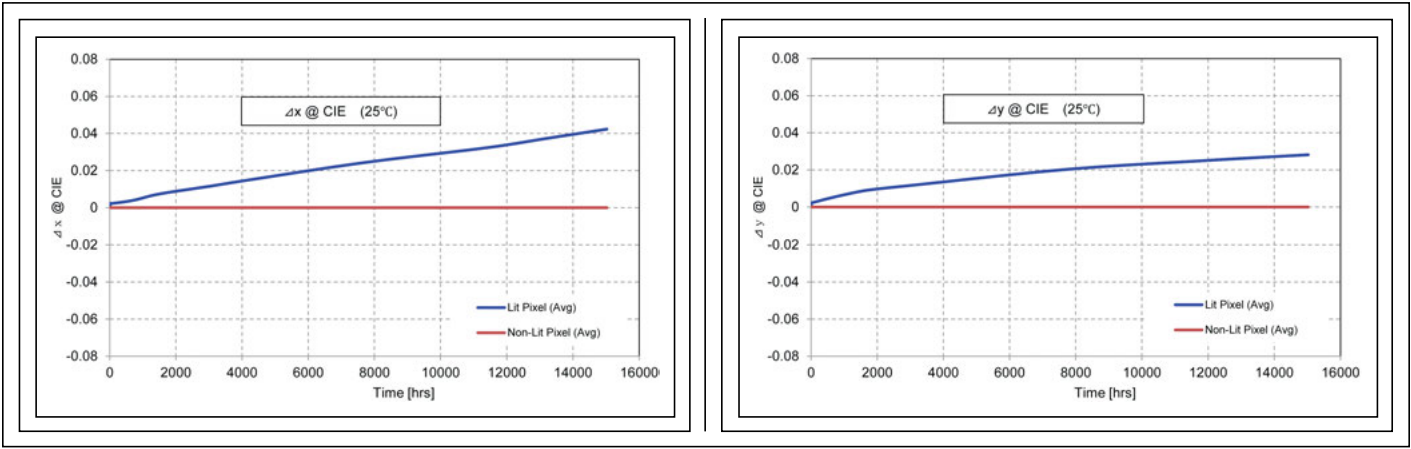
System Interface and Unique Design Applications

PMOLED displays uses a chip-on-glass (COG) graphic-controller driver arrangement with two voltages required in the 8–16 V

range plus logic 3.3V. Based on the custom-size-package options and small package footprint, PMOLED displays can be designed into various non-conventional display applications such as control knobs, switches, and other such niche configurations. The ability to add a “corner-cut” in the glass package provides additional packaging options. At this time, a true circular-type display is not available.

Luminance Decay

Luminance decay over the lifetime of the display is a factor for all self-emissive displays. Ambient temperature is a contributing factor in the slope of this luminance decay, and real-world considerations should be considered in evaluating the relevance of various temperature and lifetime conditions. Some



Figs. 6 and 7: Color shift vs. time (25°C) are compared.

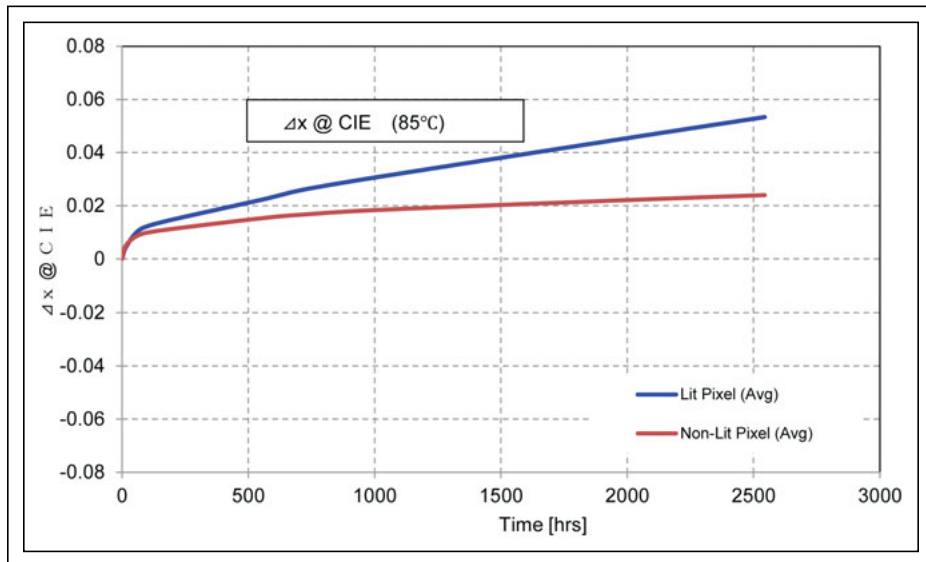


Fig. 8: Color shift vs. time (85°C) are compared.

other contributing factors to luminance decay are luminance output and pixel-on time. If luminance requirements can be lowered, life-time will increase (see Figs. 4 and 5 for 25°C and 85°C luminance decay data).

Differential Aging (Burn-In)

Another aspect of self-emissive-type displays is the tendency to create a “burned-in” image based on different pixel usage rates in the displays. The classic example: a single character

displayed for a period of time can still appear as a “ghost” image when the character is no longer displayed and replaced with another character or background (see Figs. 4 and 5 while comparing lit and non-lit pixel areas). One of the negative points of PMOLED displays is this differential aging issue.

Color Shift

Under normal operating time, PMOLED displays can be expected to demonstrate some

color shift. This phenomenon can be accelerated under high-temperature conditions (see Figs. 6, 7, 8, and 9 for 25°C and 85°C color-shift data).

As with any display technologies, PMOLED displays have their own set of unique pros and cons based on their physical design and structure. PMOLED displays offer the advantages of high contrast ratio, dead-front appearance, wide viewing angle, and slim packaging when compared to some other display technologies. On the other hand, care must be taken to consider the effects of differential aging and color shift/luminance degradation, especially with higher-temperature environments. Consultation with the manufacturer will provide assistance in providing the overall best solution. ■

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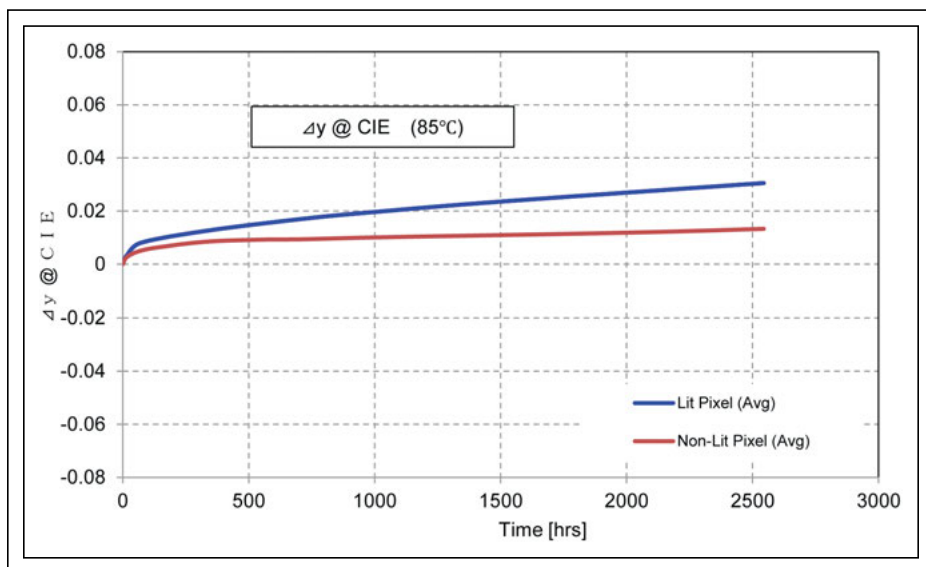


Fig. 9: Color shift vs. time (85°C) are compared..

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Can Advanced Assembly Techniques Alter the Dynamic of Display Manufacturing?

The mass production of flat-panel displays has been dominated by the use of TFTs, deposited via vacuum lithography, to drive LCD or OLED panels. This approach has been a strength in terms of standardization and massive scale up to Gen 10 fabs and beyond, but also a weakness in that the cost has made profitability elusive over a quarter century of production and in a limited selection of display shapes and sizes. Emerging manufacturing techniques that combine semiconductor production with relatively simple assembly have the potential to change this dynamic.

by Paul Semenza

SINCE the first TFT-LCDs went into mass production in the late 1980s, vacuum-based photolithography has been the most important part of the manufacturing process for FPDs. It is critical to the process of fabricating TFTs on increasingly larger substrates to create the backplanes for active-matrix LCDs, OLEDs, and EPDs. The ability to deposit the multiple layers (requiring as many as 10 mask steps) needed to create advanced TFTs across square meters of area has enabled larger and higher-resolution displays every year for decades. The process has also been flexible enough to enable different TFT types, including amorphous-silicon, low-temperature polysilicon, and metal oxides, which in turn have allowed faster switching and smaller devices.

However, this progress has come at great cost, with advanced TFT fabs requiring billions of dollars in capital expenditure.

Paul Semenza, an independent consultant, has managed market research in flat-panel displays and photovoltaics, including The NPD Group's DisplaySearch and Solarbuzz businesses, and iSuppli's display business. He can be reached at psemenza@gmail.com.

Once a company has invested such sums of money, the financial imperative is to keep the fab fully utilized by making high volumes of ever-larger panels, regardless of demand. This has meant that FPD manufacturing continues to be a very risky business financially. The shift in investment from TFT-LCDs to AMOLED displays has only accentuated the risk since the TFT backplanes for OLED displays are more challenging to produce (and the organic material deposition process is not nearly as mature as that for LCDs). The need to keep fabs running at full capacity has also led to a high degree of commoditization because the similar-sized fabs produce similar panel sizes because sizes are chosen to maximize the usable area of the substrate. The lack of interest in or lack of capability on the part of leading manufacturers with regard to producing non-standard panels has enabled some more specialized firms to use older fully amortized fabs to produce custom panels, but this accounts for a modest share of industry revenues.

Some believe that a shift to flexible displays – in particular, the long-held dream of roll-to-roll manufacturing of displays – will enable the production of various sizes, shapes, and

types, not driven by the need to fit into a specific substrate size and not driven by the high costs of vacuum lithography. Current techniques – such as EPLAR developed by Philips and SUFTLA developed by Seiko-Epson – involve producing the TFT array on rigid carriers in a batch process, then using a laser release process to separate the array, which is then bonded to a flexible substrate. This process is currently limited to small array sizes. It is likely to be some time before flexible OLEDs (or any other equivalent in terms of performance) will be mass-produced outside of a modified batch process using vacuum deposition. (EPLAR and SUFTLA are described in the article “Lasers Enable Diverse Display Production Techniques” by Rainer Paetzel of Coherent, GmbH, in the April 2009 issue.)

Breaking Out of the TFT Trap

However, this does not necessarily mean that the FPD industry will always be shackled to the high-cost standardized-product manufacturing model, as methods under development outside the industry could have implications for FPD manufacturing. An ongoing series of efforts has been aimed at utilizing mature

wafer-based semiconductor processes – such as CMOS transistors or processing epitaxial wafers for LEDs – then dicing the wafers into individual chips and using various techniques to assemble the devices onto a large-area substrate used for displays or lighting products.

The common element of these approaches is that they seek to de-couple the production of backplane and display, by taking advantage of the scale and low cost of semiconductor manufacturing¹ and then using relatively simple assembly techniques to distribute the circuits across the large area of a display substrate. Since the assembly techniques are largely done outside a vacuum and at room temperatures, they can be used for plastic substrates and also in roll-to-roll processing. Also, since CMOS transistors have much higher electron mobility than TFTs, they are especially attractive as backplanes for OLED displays, given the high-current requirements, as well as for very-high-pixel-count displays, such as 8K × 4K, given the requirement for very fast switching speeds. Some of the same advantages are seen for the use of these techniques to assemble arrays of inorganic LEDs, whether for solid-state lighting, display backlighting, or direct-view LED displays.

Pick, Place, and Assemble

In one such technique, called fluidic self-assembly, circuits are fabricated on wafers and are then shaped and removed through etching into “nanoblocks,” which can range in size from 10 to several hundred microns. The nanoblocks are then suspended in a liquid and flowed onto a substrate into which cavities of appropriate size and shape have been etched, stamped, molded, or laser drilled. Fluidic self-assembly was developed at the University of California at Berkeley in the 1990s and proposed for assembly of LED arrays as well as TFT backplanes. Alien Technology was formed to pursue applications in flat-panel displays, but the technology was never successfully demonstrated for display production, and Alien moved to focus on RFIDs. (*Information Display* ran an article on this flat-panel research, “Bringing Alien Technology Down to Earth,” in the November 2000 issue.)

Another technique, pick and place, has been used for years in circuit-board assembly and chip packaging, although mainly for large devices and at rates too slow for assembling thousands of pixels on a display or LED array.

A startup called Luxvue developed a high-throughput version of pick-and-place assembly for creation of micro-LED (devices 100 μm or smaller) arrays. The transfer device uses an arrangement of protruding mesas, each of which contains electrodes with a thin coating of dielectric. By providing a charge between the electrodes, an electrical field is created that electrostatically attracts the miniature chips. The approach enables selectively choosing to remove specific micro-devices from a source substrate by applying voltage only to the projecting mesas corresponding to the positions of the device to be transferred. This could enable the manufacture of micro-LED backlights or displays. Other than filing patents, Luxvue released very little information, and in 2014 was acquired by Apple, which has not commented on its plans for the technology.

A Different Type of Printing

In a wide-ranging effort, first at Bell Laboratories and, since 2003, at the University of Illinois at Urbana-Champaign (UIUC), John Rogers has led groups developing micro-transfer printing, a process in which a structured elastomer print-head or stamp is used to transfer microscale semiconductor devices from their native substrates onto other substrates. Rogers and colleagues have demonstrated the use of transfer printing with micro-LEDs, TFTs, carbon nanotubes, graphene, and other materials. This approach has multiple benefits, including the ability to work with different types of semiconductors and substrates; the ability to transfer large numbers of devices in parallel, and to do so in a way that translates from dense wafer arrays to sparser arrays on substrates in a precisely controllable fashion; and, finally, simplicity in that the lift-off and attach processes are conducted at room temperature and pressure, without the need for adhesives or other chemical processes.

In 2006, Semprius was spun out of UIUC to commercialize the technology. Working with Kodak before it sold its OLED business to LG Display, Semprius demonstrated the ability to create AMOLED displays using $167 \times 50 \times 8$ mm CMOS chips that were etched and removed with an elastomer print-head and transferred onto a glass substrate.² The company also reported producing backplanes suitable for 5-in. QVGA full-color AMOLED displays in which each IC was designed to drive two pixels (six subpixels); the array of

192×240 chips was transfer-printed with a process yield in excess of 99.9% and sub-micron placement accuracy.³ The printer used at the time was capable of handling up to 200-mm-diameter source wafers and target substrates up to 500 mm × 400 mm. In 2013, X-Celeprint was founded by acquiring the rights to the technology outside of photovoltaic applications.

Printing Arrays of LEDs

In 2009, Rogers and colleagues published results of work applying transfer printing to the creation of arrays of LEDs, combined with printed metal mesh for connection of the arrays, thus enabling arrays of LEDs to be constructed on metal or even plastic substrates.⁴ The demonstrations involved the creation of GaAs LEDs as small as 25×25 mm, in arrays as large as 40×40 , deposited on glass and plastic sheets, enabling transparent displays (with less than 1% of the display area accounted for by the printed LEDs) as well as flexible and also stretchable configurations. The authors suggested that the process could be competitive with LCD and OLED panels and direct-view LED displays, as well as enabling transparent and head-up displays.

In some cases, materials that are difficult to deposit directly with the required resolution and performance may be deposited through transfer printing. For example, Samsung demonstrated quantum-dot (QD) light emission in a display through spin-coating, but was not able to pattern individual RGB QDs due to cross-contamination and found that other techniques resulted in poor quantum efficiency. However, following work at MIT,⁵ Samsung was able to demonstrate 4-in. full-color QD displays (driven by oxide TFTs) on glass and plastic substrates using a nano-transfer process.⁶

Solid-State Lighting First

The more direct path to market for this technology appears to be in solid-state lighting. In 2009, Cooledge Lighting was spun out of the UIUC work (Fig. 1).

In 2011, Rogers' group published further work outlining materials and techniques for interconnection, thermal management, wavelength conversion, and light distribution in thin, flexible, solid-state lighting systems created through transfer printing.⁷ They demonstrated white-light performance by using laminated films of YAG phosphors precisely deposited onto sparse arrays of

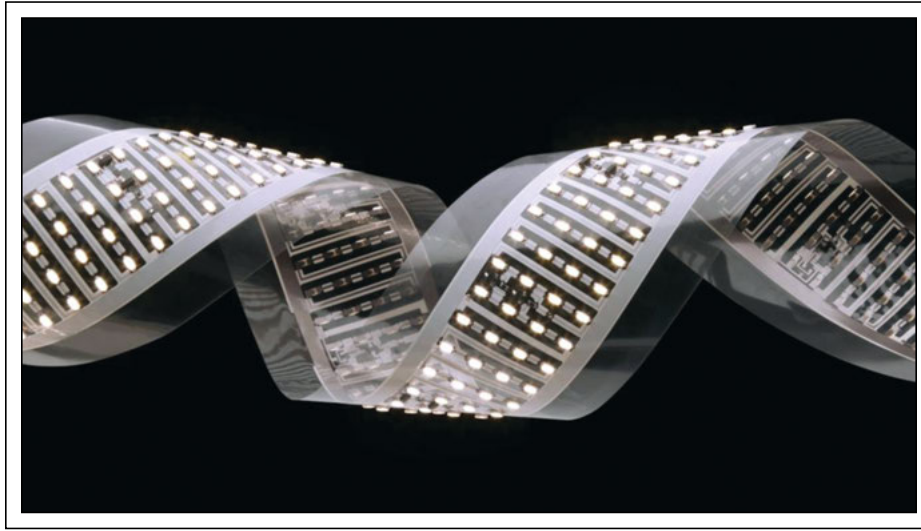


Fig. 1: This flexible LED light sheet was developed by Cooledge Lighting.

micro-LEDs. The authors showed that the use of sparse arrays of micro-LEDs enables the use of an equivalent amount of LED dice to illuminate a large area without the need for heat sinks and special light management. In 2012, a group at the Korea Advanced Institute of Science and Technology reported transfer printing of individual GaN devices onto a polyimide substrate and also made white-light LEDs. The group suggested the possibility of flexible backlight units.⁸

Can Printing Change Display Dynamics?

Could future display backplanes – or direct-emission displays – be produced through transfer printing or electrostatic pick and place of CMOS or epitaxial semiconductors? As has been the case with many other promising technologies, the question will largely be answered through attempts to scale up the technology to mass production. A fab that starts 60,000 sheets a month, producing 8-up full-HD panels at a 95% yield rate might create as many as 3 billion pixels an hour, which is orders of magnitude more than the capability of the systems disclosed to date. In any event, flat-panel makers are not likely to change such a crucial aspect of their production process, even if that process results in significant swings in profitability.

While it is not likely that these assembly technologies would replace TFTs in LCDs, there could be entry points in new forms of direct-view LED displays, lighting, backlight-

ing, transparent displays, and other non-standard display types. With very little investment, researchers have demonstrated the potential that both transfer printing and electrostatic pick and place have for accurate high-yield placement of high-performance semiconductor devices. Such displays can break out of the commodity flat-panel market – Sony caused a stir at the 2012 Consumer Electronics Show with its “Crystal LED Display,” a 55-in. full-HD direct LED display, but it was apparently so difficult to produce that the company dropped the technology. It will be interesting to see what transfer printing could do with even a fraction of the tens of billions of dollars that have been invested in TFT process equipment to date.

References

- ¹As noted by Dan Hutcheson in *IEEE Spectrum*, in 2014, the semiconductor industry produced 250 billion billion (250×10^{18}) transistors, at roughly a billionth of a dollar each; <http://spectrum.ieee.org/computing/hardware/transistor-production-has-reached-astronomical-scales>.
- ²C. A. Bower, E. Menard, S. Bonafede, J. W. Hamer, and R. S. Cok, “Active-Matrix OLED Backplanes using Transfer-Printed Microscale Integrated Circuits,” *Proc. Elec. Comp. Tech. Conf.* (60th ECTC) (2010).
- ³C. A. Bower, D. Gomez, K. Lucht, B. Cox, D. Kneeburg, “Transfer-Printed Integrated Circuits for Display Backplanes,” *Proc. IDW* '10, 1203–1206 (2010).

⁴S.-I. Park *et al.*, “Printed Assemblies of Inorganic Light-Emitting Diodes for Deformable and Semitransparent Displays,” *Science* **325**, 977–981 (2009).

⁵L. Kim *et al.*, Contact printing of quantum-dot light-emitting devices, *Nano Lett.* **8**, 4513–4517 (2008).

⁶T.-H. Kim *et al.*, “Full-colour quantum-dot displays fabricated by transfer printing,” *Nature Photonics* **5**, 176–182 (2011).

⁷H. Kim *et al.*, “Unusual Strategies for Using Indium Gallium Nitride Grown on Silicon (111) for Solid-State Lighting,” *Proc. Nat. Acad. Sci.* **108** (25), 10072–10077 (2011).

⁸H. G. Yoo *et al.*, “Flexible GaN LED on a Polyimide Substrate for Display Applications,” *Proc. SPIE* **8268** (2012). ■

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Products on Display at Display Week 2015

Some of the products on display at North America's largest electronic-display exhibition are previewed.

by The Editorial Staff

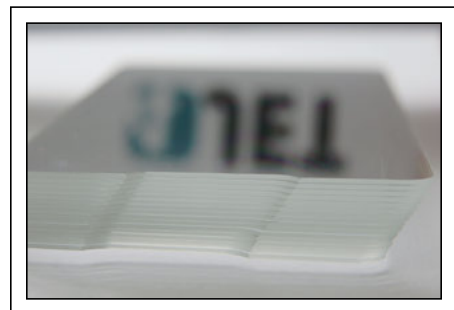
THE SID 2015 International Symposium, Seminar, and Exhibition (Display Week 2015) will be held at the San Jose Convention Center in San Jose, CA, the week of May 31. For 3 days, June 2–4, leading manufacturers will present the latest displays, display components, and display systems. To present a preview of the show, we invited the exhibitors to highlight their offerings. The following is based on their responses.

4JET TECHNOLOGIES GmbH

Alsdorf, Germany +49-2404-552300
www.4jet.de
Booth 1523

Touchless Precision Cutting Process for Glass Materials

German laser system integrator 4JET Technologies GmbH will feature PearlCut™, a new process solution for precision cutting of glass. The process uses ultrafast laser pulses and a unique beam-shaping solution for a controlled crack propagation in brittle materials. Applications include free-shape cutting of thin glass parts for mobile electronics and display substrates and cover glasses, yet the process is also suitable to separate thicker glasses for other applications. Processable glass types include soda-lime and chemically strengthened glass with any ion-exchange depth. Additional brittle transparent materials such as sapphire can also be processed.

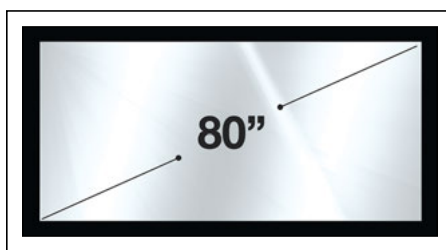


ABRISA TECHNOLOGIES

Santa Paula, CA, USA 1-877-622-7472
www.abrisatechnologies.com
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Large-Format Screen-Printed Glass

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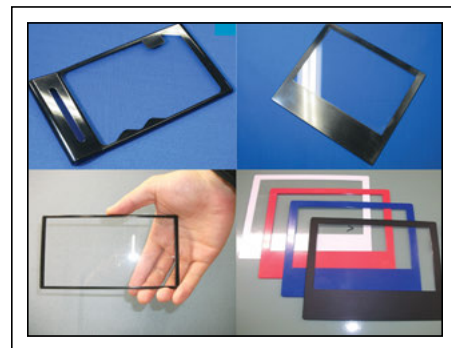
ASAHI GLASS CO., LTD. (AGC)

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www.agc.com
Booth 333

Glass-Resin Integrated Component Technology

AGC's Glass-Resin Integrated Component technology "SURFIC" provides new value in display cover glass that has never been realized in conventional post-joined products and edge-coated products. It offers a gapless and waterproof surface, design selection (corner R and open part), accurate posi-

tioning (resin absorbs glass tolerance), maximized space for glazing due to a strong adhesion between the glass and the resin, and a minimized assembly process (cost reduction). SURFIC will make design dreams possible – wide touching area in the display edge, variable design frames, waterproof narrow design frames, and many other possibilities.

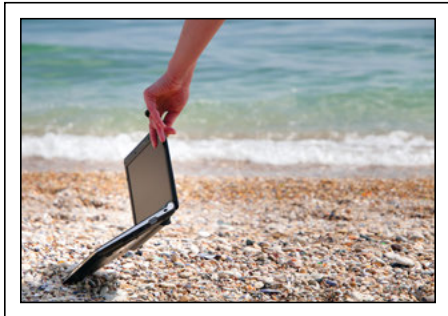


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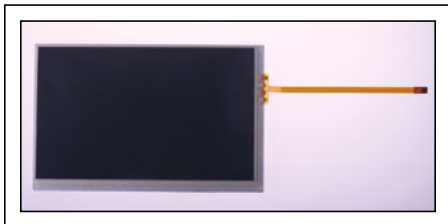


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LCD Modules for Industrial Applications

Ampire will be featuring small- and medium-sized LCD modules for industrial applications. These modules have a resolution of 800×480 with a 262K white LED brightness from 500 to 1000 nits, low-voltage differential signaling (LVDS), and an RGB interface. A touch panel is available with different value-added options including a cover lens with optical bonding, sunlight readability, wide viewing angle, and automotive-grade features.



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Laser-Engineering Technology

Applied Laser Engineering's Maestro Green is available as a short-pulsed system option for the micro-machining of hard substrates, ceramics, and various metals or as a CW option for high-resolution lacquer and resist processing. ALE's Maestro technology was first released in 2009 as a 1- μm laser wavelength technology. Working closely with the ever-faster evolving laser industry, ALE is pleased to offer its Maestro Green engraving technology which benefits from a shift in wavelength to 532 nm. For applications where a 1- μm -wavelength laser-focus spot size is just too big, the

Maestro Green technology can deliver that finer spot for smaller feature creation. Maestro Green short-pulsed systems produce clean, dry engravings with reduced burr and engraved surface roughness.



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Advanced Interactive Collaboration Displays

The Avnet Executive Touch series of advanced interactive collaboration displays allow for unparalleled performance when compared to any other interactive technology. Available in 48, 55, 65, and 84 in., the displays features include:

- Superior palm rejection algorithm to accurately detect shape and size of touch objects and create a user experience that is unrivaled in the marketplace.
- Experience enhanced unified communications with multi-party platforms such as Microsoft Lync and Skype.
- Works perfectly in high and low ambient light, even direct sunlight.
- Seamlessly integrated with all Microsoft Office One-Note, PowerPoint, Journal, and other software packages out of the box, with no drivers.



BOE TECHNOLOGY GROUP CO., LTD.

Shenzhen, China
www.boe.com
Booth 118

110-in. 8K \times 4K LCD

BOE will be featuring their 100-in. ultra-high-resolution ($8K \times 4K$) LCD. The development was accomplished by breaking through the challenges of high-resolution panel design, such as panel-related materials and process and system development for high-resolution panels. This product has been adopted by Samsung and debuted at CES 2015.

Innovative key technologies used include:

- Development of ultra-large-sized LCDs, including large-sized-panel TFT arrays and a color-filter stitching exposure technique
- Mechanical design with high strength, heat radiating, and low cost
- Direct LED BLU with local dimming
- Driving solution for ultra-large-sized $8K \times 4K$ display

Engineering capabilities for such high-end products are expected to be carried out in a Gen 8.5 fab of BOE Technology Group, thus enhancing the competitiveness of display products.



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Corning Iris™ Glass is a glass light-guide plate for large-sized edge-lit LCDs. Due to its intrinsic rigidity and dimensional stability, it allows TV manufacturers to reduce set thickness significantly and design TVs with slimmer bezels. Compared to alternative flat-glass light-guide plates, Iris Glass features outstanding transmission and low color shift, delivering bright displays with accurate colors.

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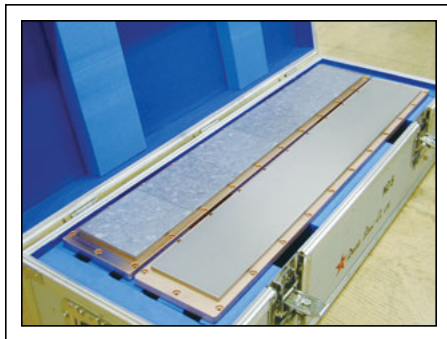


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Cu-Alloy Sputtering Targets for Metal-Mesh Material

Cu mesh is one of the promising alternatives to ITO for large-format capacitive touch displays for its low resistivity and low cost. However, some issues of adhesion, corrosion, and reflectance still exist. Daido Steel has developed new Cu alloys that satisfy these critical requirements and opened the possibilities for applications such as mobile PC, electronic blackboards, as well as next-generation flexible displays and circuits.



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Adhesives for Display Bonding

DELO has developed an optically clear, light-curing liquid adhesive that combines strong adhesion and

durability with high transparency. They enable a fast and flexible bond for touch panels or cover glasses directly bonded onto LCDs or for mobile-phone repair. DELO's optically clear adhesives drastically reduce internal reflections and improve shock and vibration performance. Furthermore, fogging, condensation, and other contaminations are avoided. The curing is carried out with the DELOLUX 20 LED lamp, which is characterized by its consistent irradiation over large areas. With LED technology, the lamp can typically achieve a lifetime of 20,000 hours.



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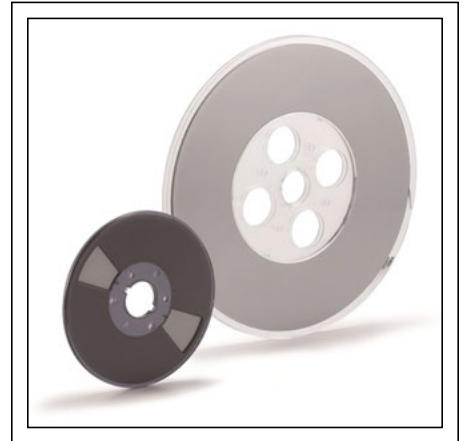
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Particle Arrayed Film

Dexerials will feature its newly developed Particle Arrayed Anisotropic Conductive Film for chip-on-glass interconnect, which connects the glass substrate of flat-panel displays with driver ICs of next-generation smartphones and tablet PCs. Using Particle Arrayed ACF, the risk of short circuits is reduced when the driver IC has a lower bump height. This new technology allows fine-pitch interconnect with 10- μ m minimum space between IC bumps. Particle arrayed ACF can control numbers of captured conductive particles in a bump and ensure stable interconnect reliability.

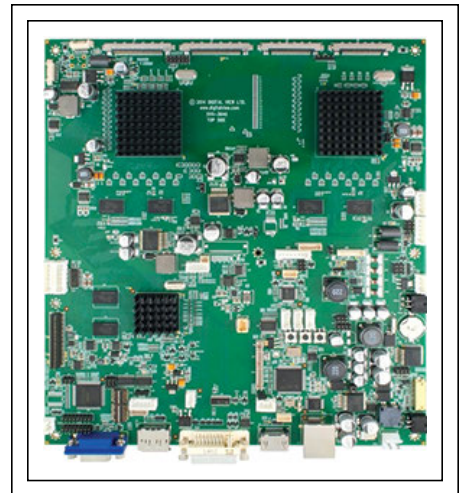


DIGITAL VIEW

Morgan Hill, CA, USA 1-408-782-7773
www.digitalview.com
Booth 1016

LCD Controllers

Digital View will be introducing more than half a dozen new LCD controller and related products at Display Week 2015 with the focus on the SVX-3840 LCD controller for 4K UHD support with 3840 \times 1920 resolution LCD panels. With 10-bit color, 60 and 120 Hz, 8- and 16-rail V-By-One panel connection support, the SVX-3840 supports most of the current and upcoming large 4K panels.



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DISPLAY LOGIC

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www.displaylogic.com
Booth 544

High-Performance High-Brightness LCDs

Display Logic will feature their xTremeLCD™ family of high-performance high-brightness LCDs that are purposely designed to meet visual, reliability, longevity, and support expectations for outdoor-display-based applications. Each display from 7 to 15 in. offers 1500 nits of minimum brightness, 100 khours of backlight life, amazingly low power consumption at less than 1 W/diagonal in., a wide operating temperature range up to 80°C, is available for 3 years, and comes with a 2-year warranty. Display Logic's xTremeLCDs™ are in stock. High-efficiency backlight solutions for LCDs from 3.5 to 80 in. are also available.

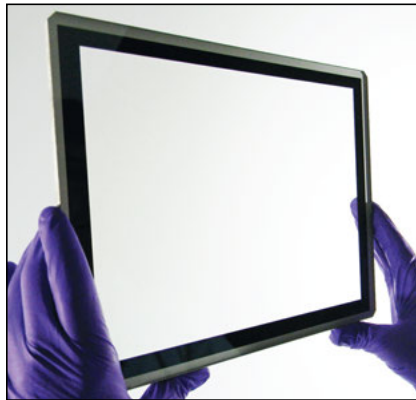
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Booth 426

Precision Glass Optical Filters

Utilizing the latest in glass fabrication and thin-film vacuum-deposition technology, Dontech's VCG-Series™ glass filters provide exceptional optical transparency and environmental durability. These precision glass optical filters are utilized in demanding military, medical, industrial, and avionic applications. For high-end display programs, VCG-Series™ filters optimize display clarity and high-ambient light contrast (e.g., sunlight readability). VCG-Series™ filters can be assembled into frames or bezels or optically bonded to LCDs or touch screens by using Dontech's proprietary IMO-bond™ optical bonding process to improve impact resistance and display contrast. Available filter sizes range from less than 1 in. to greater than 42 in. on the diagonal and can be sold as a stand-alone display cover-glass product or integrated into a higher-level assembly. VCG-Series™ filters can be fabricated from a variety of glass substrates, such as chemically strengthened (soda lime, Corning® Gorilla®, or Asahi Dragontrail™) borosilicate, fused silica, or optical glasses (e.g., Schott nBk-7).



ELDIM

Herouville, Saint Clair, France +33-2-31-94-76-00
www.eldim.fr
Booth 1034

Fourier Optics Measurement System

Based on its experience in Fourier optics measurement systems, ELDIM now proposes the VCProbe series. The VCProbe includes a viewing-angle sensor mounted on a robotic arm. The viewing-angle measurements are performed with high accuracy and high speed.

- Viewing-angle measurement up to $\pm 80^\circ$ with a 12MPix sensor.
- Flat, curved, or flexible display up to 150° ; no more need for Huge XYZ Stages
- Innovative Multi-OS software development platform (useable with Android, IOS, Linux, Windows, etc.)



ELLSWORTH ADHESIVES

Germantown, WI, USA 1-800-888-0698
www.ellsworth.com
Booth 1245

Design Flexibility with New HotMelt Adhesive

The adhesion strength of Dow Corning EA-4600 is consistent among a wide variety of substrates. The adhesion is largely unaffected by immersion in most liquids that commonly come in contact with electronic devices. Dow Corning EA-4600 offers easy removal and reapplication within 24 hours, instant initial adhesion without primer, and long open time and pot life. The ability to create precise micro-beads offers greater design flexibility.



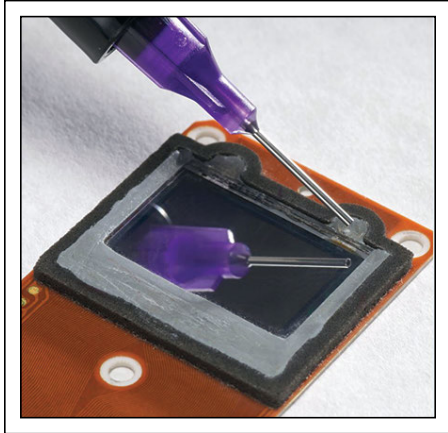
EPOXY TECHNOLOGY

Billerica, MA, USA 1-978-667-3805
www.epotek.com
Booth 1120

Epoxy-Based UV-Curing Product

Epoxy Technology (EPO-TEK®), a recognized global leader in advanced adhesives, has many specialized products for display applications. One of our most popular and versatile adhesives for displays is an epoxy-based UV curing product, OG116-31, which is thixotropic and designed for perimeter and plug sealing of LCDs. This robust UV epoxy is compatible with several liquid crystals, has low WVTR, and can be thermally post-cured for added enhanced properties.

trade-show preview

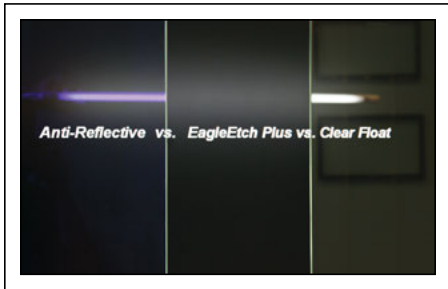


EUROPTec USA

Clarksburg, WV, USA 1-304-624-7461
www.europtecusa.com
Booth 934

Anti-Glare Anti-Reflective Glass

EuropTec USA will feature EagleEtch Plus™, the best performing anti-glare anti-reflective (AR/AG) glass. Our chemical etched glass along with an anti-reflective coating is ideal for high-resolution sunlight-readable applications in adverse conditions which require the best in anti-glare properties, low sparkle, low haze, and lowest possible reflection. EagleEtch Plus™ is already in over 3 million automobile displays which demand the highest quality cover-glass solution. New this year, the glass can also be offered with an oleophobic coating making it easier to clean and durable enough for touch-screen applications.



FLEX LIGHTING

Chicago, IL, USA 1-773-295-0305
www.flexlighting.com
Booth 1146

Front Light Panel

The FLEx Front Light Panel provides illumination for small/medium-sized reflective displays using the

world's thinnest film-based light guide. FLEx's front light incorporates only a single LED coupled to an optically engineered film. This provides the most elegant and most efficient front light on the market and also significantly enhances the new line of color reflective displays. The FLEx Front Light Panel can be bonded directly to reflective LCDs, transfective LCDs, and reflective e-Paper displays.



FRAUNHOFER FEP

Dresden, Germany +49-351-2586-0
www.fep.fraunhofer.de
Booth 222

Background Lighting for Holographic Display

Fraunhofer FEP's SeeReal Demonstrator is an interesting example of optical anti-reflective coatings: A background lighting for a holographic display! When thinking of "tomorrow's display," most people think one step further than just 3D. A lot of them think of "holography"! For the background lighting of a holographic display, a special anti-reflective coating is needed that avoids reflections nearly completely for the three relevant laser wavelengths. A bundled laser light, which is required for holographic displays, will be fed in via a compact deflection system at a very steep angle (85°) into the coated glass. Due to the coating, the light can radiate through the glass, in contrast to uncoated

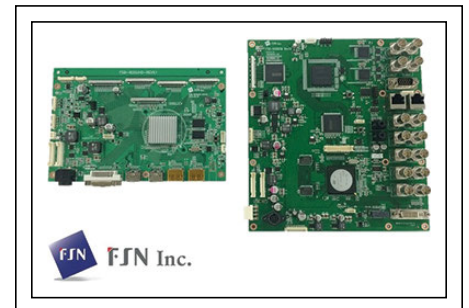
glass, where almost all of the light would be reflected. This steep angle expands the laser beam in such a way that the entire display can be illuminated.

FSN

Gyeonggi-do, South Korea +82-31-903-6812
www.fsndisplay.com
Booth 1820

4K × 2K and Broadcasting AD Board Solution

FSN's will feature the FSB-800UHD, a professional 4K × 2K AD board solution that provides high-quality images from HDMI, DP, and DVI inputs supporting up to 3840 × 2160 at 60 Hz and a various range of LCD panel interfaces, not only LVDS and eDP but also V-by-One having a compact size of 190 × 115 mm. Also, FSN's newest board, FSB-600BCM, is the best solution for broadcasting displays such as broadcasting monitors in studios, reference (video) monitors, and field monitors on site, supporting up to WUXGA at a size of 190 × 210 mm.

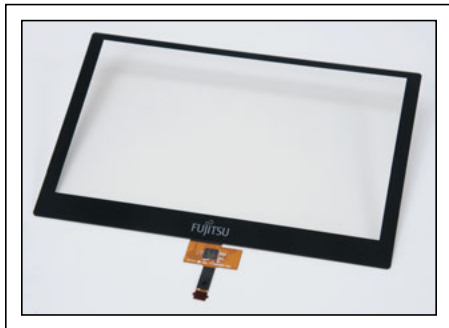


FUJITSU COMPONENTS AMERICA

San Jose, CA, USA 1-408-745-4900
www.fujitsucomponents/us
Booth 1625

Projected-Capacitive Touch Panels

Fujitsu Components America, Inc., will exhibit the FID-154, its first series of projected-capacitive touch panels. Volume production is expected to start in June. The FID-154 expands beyond Fujitsu's current analog-resistive touch panel offering to provide OEMs with additional touch-input options for increasing applications in industrial and medical applications. Specifications include 90% (typical) transparency, 10 simultaneous inputs, and an operating life of 10-million taps. A Chip-on-Film (COF) controller IC requires minimal mounting space and provides USB or I2C output. Custom bezel and logo printing are included, and technical support, such as system tuning, is also available.



FUTABA CORPORATION OF AMERICA

Schaumburg, IL, USA 1-847-884-1444

www.futaba.com

Booth 1140

Capacitive Touch Panels

Futaba's capacitive touch-panel products were developed using the thin-film formation technology perfected in our electronic-component manufacturing processes. With their outstanding sensitivity and resistance to harsh environmental conditions, they are finding an increasing number of applications; in general, household products and in-vehicle equipment that requires a high level of reliability.



GAMMA SCIENTIFIC

San Diego, CA, USA 1-858-279-8034

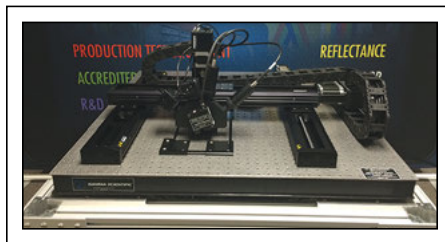
www.gamma-sci.com

Booth 129

Automated Reflectance Measurement Systems

Gamma Scientific provides a unique high-performance option for reflectance and transmission testing. These systems capture complete spectral and colorimetric properties of thin-film coatings with scan times typically less than one second. When measuring reflectance, Gamma Scientific's unique technol-

ogy allows manufacturers to perform single-sided non-destructive testing on the first surface while excluding the second surface. These systems are ideal for manufacturers who need to obtain fast and accurate measurements of flat-panel-display glass, anti-reflection coating inspection, photovoltaic (solar cell) coatings, optical filters, lens coatings, paint samples, diffuse plastics, and more.



HENKEL CORP.

Rocky Hill, CT, USA 1-860-571-5266

www.henkelna.com

Booth 534

Temporary Bonding Adhesive

Henkel is a total solution provider for adhesives, sealants, and functional coatings. Through close customer partnership, industry know-how, and engineering support, we enable innovative design. Henkel Advanced Research is always seeking new solutions to meet market demand. Henkel's High Temperature Debondable Adhesive is designed for applications where sheets of flexible substrates on a carrier need to hold during the deposition process or temporarily bond precut glasses to a carrier in a piece-type deposition process. Benefits include adaptability to flexible substrates, high-temperature resistance, easy to cure (UV), low outgassing, withstands harsh chemicals, and easy to debond

IMRA AMERICA

Ann Arbor, MI, USA 1-734-930-2560

www.imra.com

Booth 1524

Femtosecond Fiber Laser Sources

IMRA America provides complete concept to manufacturing solutions with Femtosecond Fiber Laser Sources. Such lasers offer the benefit of high precision material processing without thermal effects and are capable of producing high precision at high-throughput results. Some application areas include thin-film removal, via-hole drilling, surface and sub-surface material processing, texturing, waveguide writing, and much more. With femtosecond

sources, softest to hardest materials (from polymers to single crystal diamond) can be processed with the same laser. IMRA manufactures its own femtosecond fiber laser sources and has a applications solutions laboratory.



INSTRUMENT SYSTEMS

Munich, Germany +49-89-454953-0

www.instrumentsystems.com

Booth 818

Imaging Photometer and Colorimeter

Instrument System's new LumiCam 1300 Advanced, an imaging photometer and colorimeter designed for the highest accuracy when analyzing the characteristics of displays and electronic panel graphics. The innovative camera concept is based on six filters. The patent-pending procedure allows very accurate adjustment to the eye-sensitivity functions using the data recorded from the six channels. The LumiCam 1300 Advanced provides excellent accuracy for the color coordinates particularly when taking LED color measurements. Therefore, it offers a good alternative to spectroradiometric instruments with significantly shorter measurement times. The software provides a comprehensive range of tools for evaluating the test results.



trade-show preview

I-PEX

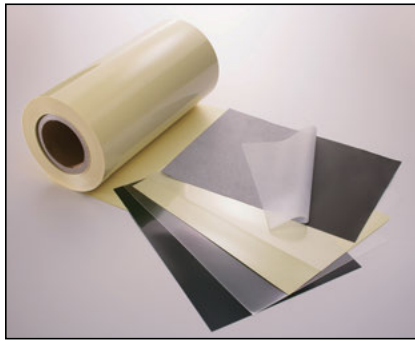
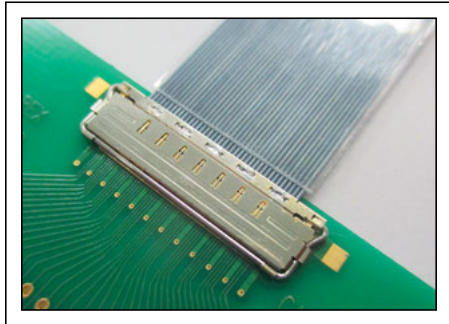
Austin, TX, USA 1-512-339-4739

www.i-pex.com

Booth 142

Shielded Display Connector

The I-PEX Cabline®-CA-II improves the 0.4-mm pitch display connector by covering the solder tails with a shield. The added shielding eliminates EMI emissions from the high-speed graphics signals as they pass through the solder tails into the circuit boards. The Cabline-CA receptacle was already designed with additional shell grounding contacts under the connector to squelch any common mode energy. The CA-II design completes the shielding of the entire microcoaxial wire interconnection eliminating any interference with WiFi antennas. Additionally, the contact design has been enhanced to accept the AWG34 diameter center conductor delivering more power for display backlights.



JDI DISPLAY AMERICA

Buffalo Grove, IL, USA 1-847-484-7096

www.j-display.com

Booth 1124

UHD TFT-LCD Module with Integrated Touch

Japan Display Inc. (JDI) will feature advanced displays for mobile, automotive, and industrial applications, including an ultra-high-resolution (550 ppi) 8.0-in. 4K × 2K (3840 × 2160 pixels) TFT module with fine integrated touch, designed for mobile use. The ultra-high-resolution display allows users to enjoy clear high-definition images and features low-power-consumption thin module design and narrow borders. The integrated touch function enables smooth input with a fine stylus or brush only 1 mm in width. The display also features a wide color reproduction range of 95% NTSC.



IWATANI CORP.

Tokyo, Japan +81-3-5405-5797

www.iwatani.co.jp

Booth 1240

Silicon Optically Clear Adhesives

Iwatani Corp. provides specialized high-performance film and industrial tape products for electronic devices. The ISR-SOC series, a product of Iwatani's silicon optically clear adhesive (OCA) technology, has high durability, heat resistance, and flexibility suitable for specialized displays such as reflective, flexible, and OLED displays. Its low refractive index improves the visual quality of the display. With its innovative technologies and superb performance, the ISR-SOC series allows customers to freely develop custom design concepts. Iwatani also provides various types of industrial tape products.

KONICA MINOLTA SENSING AMERICAS

Ramsey, NJ, USA 1-888-473-2656

www.sensing.konicaminolta.us.com

Booth 816

2D Color Analyzer

Konica Minolta will feature its CA-2500 2D Color Analyzer used for high-resolution two-dimensional measurements of luminance distribution and chromaticity distribution, ideal for evaluation, inspec-

tion, and quality control of color for LCDs, PDPs, OLEDs, rear projectors, and a variety of display technologies. This instrument uses XYZ filters that closely match the CIE 1931 color-matching functions to provide luminance and chromaticity measurements that have high correlation with the spectral response of the human eye. The compact and lightweight design of the CA-2500 allows it to be used in a wide variety of fields, such as display, illumination, automotive, and aviation.



KOPIN CORP.

Westborough, MA, USA 1-508-870-5959

www.kopin.com

Booth 1116

Compact Display Module

Kopin Corp. will feature White Pearl™, a compact display module aimed for emerging wearable computing/communication devices. Integrating a transmissive LCD (428 × 240 resolution, 0.20 in. on the diagonal), efficient backlight, and curved prism optics with nano-structures, White Pearl provides a bright full-color image with less than 0.5% distortion in a 14.5° field of view and comfortably large eye box (8 × 5 mm) and eye relief (22.5 mm). White Pearl and Kopin's A230 display-driver ASIC together consume less than 100 mW at a display brightness of 1000 nits, sufficient for outdoor usage. A frame buffer memory residing in the ASIC offers further power savings.



KYOCERA DISPLAY DIVISION

Plymouth, MN, USA 1-734-416-8500
www.kyocera-display.com
Booth 1040

On-Cell Touch

Kyocera Display Division will introduce its new 7.0-in. WVGA (800 × 480) and 12.1-in. WXGA (1280 × 800) TFT-LCD featuring on-cell touch (OCT) technology. With the projected-capacitive (PCAP) touch-sensor layer integrated inside the LCD structure, it achieves superior optical performance in a compact and lightweight structure. The touch controller mounted inside the LCD module improves EMI performance dramatically. Both products feature Advanced Wide Viewing (AWV) Technology achieving 170° viewing angle in both vertical and horizontal directions. Cover-glass versions are also available for various industrial applications.



LEIA

Menlo Park, CA, USA 1-650-847-1872
www.leiainc.com
Booth 1924

Holographic Display Module

LEIA will feature its holographic display module. The company plans to make these modules available for sale before the end of 2015 as part of a mobile holography development kit.



LITEMAX TECHNOLOGY

Fremont, CA, USA 1-510-509-7506
www.litemax.com
Booth 245

Resized Sunlight-Readable LED Backlit LCDs

Litemax USA will be featuring the SSF/SSH2735-A, an innovative resized sunlight-readable LED-backlit LCD. The 27.3-in. resized panel demonstrates a brightness of 1000 nits with a 945 × 1080 square-screen aspect ratio of 8:9. The panel is durable with specific aspect ratios for digital signage, public transportation, exhibition halls, department stores, vending machines, and industrial applications. Bundled with an AD control board and backlight design, it can display high-quality high-clarity video and is energy efficient.

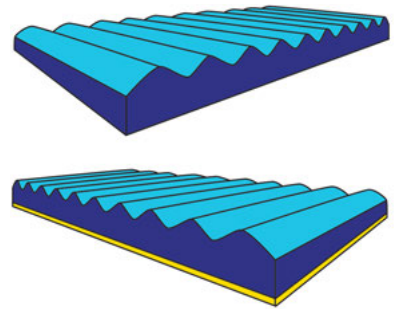


LUMINIT

Torrance, CA, USA 1-310-320-1066
www.luminitco.com
Booth 1424

Round-Tip Display Film

Luminit's Round-Tip Display (RTD) film increases the brightness of a display by recycling wasted light and directing more light to the viewer. Typically, applied within a display stack, RTD film uses reflected and refracted light to increase gain between 30% and 40%. More rugged than sharp-tip prisms that can break and contaminate the display, the round-tip pattern is embossed on a polycarbonate substrate that has higher-temperature durability than polyester films. RTD film is available with or without an integrated diffuser but can reduce the number of films in the display stack when combined with a diffuser.

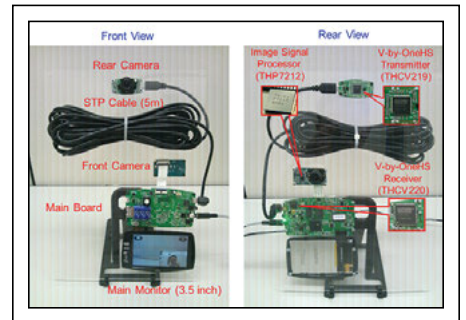


MACNICA AMERICAS

San Jose, CA, USA 1-408-325-8710
www.macnica.com
Booth 1740

Drive Recorder

Macnica Americas will demonstrate their Drive Recorder consisting of high-quality cameras and 5-m-long cable featured by THine Electronics V-by-One® HS solution.

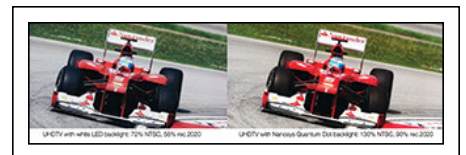


NANOSYS

Milpitas, CA, USA 1-408-240-6745
www.nanosysinc.com
Booth 1045

65-in. Quantum-Dot LCD TV

Quantum dots were one of the hottest disruptive TV technologies at CES 2015 in Las Vegas. Stop by the Nanosys booth to see why with Nanosys' latest breakthrough display – a stunning 65-in. television that covers over 90% of the rec.2020 color gamut using QDEF® quantum-dot technology and standard color filters.



trade-show preview

NIPPON ELECTRIC GLASS CO.

Osaka, Japan +81-6-6399-2711

www.neg.co.jp

Booth 1634

Ultra-Thin Glass

G-Leaf is NEG's ultra-thin glass with a thickness of 0.2 mm or less, developed by overflow forming technology. G-Leaf is extremely light, smooth, and excellent in flexibility that makes the glass bendable while keeping the conventional characteristics of glass. G-Leaf is a new material expected to contribute to the advancement of technologies and products in a wider range of fields. Coating with various functions (ITO, anti-reflection, anti-glare, and anti-fingerprint) can be added to the glass.



**VISIT
INFORMATION
DISPLAY ON-LINE**

www.informationdisplay.org

nLIGHT

Vancouver, WA, USA 1-360-566-4460

www.nlight.net

Booth 548

Laser Scanning Module

Enabled by nLIGHT's proprietary picosecond fiber laser technology, beam-shaping optics, and software suite, nTouch™ delivers lowest cost per patterned layer, highest throughput, and optical quality to enable equipment makers to accelerate their time to market for precision thin-film patterning. nTouch™ is optimized for the high-growth touch-sensor market that includes touch-sensor modules, displays, flexible electronics, photovoltaics, wearable electronics, medical, and automotive.



OPTICAL FILTERS

Meadville, PA, USA 1-814-333-2222

www.opticalfiltersusa.com

Booth 915

EMI/RFI Shielding Solutions

Optical Filters will feature its EmiClare MicroMesh 2. As displays continue to evolve in size and definition, the new-generation MicroMesh 2 offers the combination of high light transmission and shielding effectiveness that is not achievable with ITO coatings. EmiClare MicroMesh 2 combines a fine-line conductive printing process with the display-optimized pattern that has made EmiClare MicroMesh the leading solution for shielded displays and touch screens. Like other filters and display components, MicroMesh 2 can be combined with our unique display bonding process, Viz-Bond, to create a cost-effective scalable display enhancement stack. Viz-Bond activates at 390–500 nm and can therefore cure through polarizer and materials containing UV inhibitors.

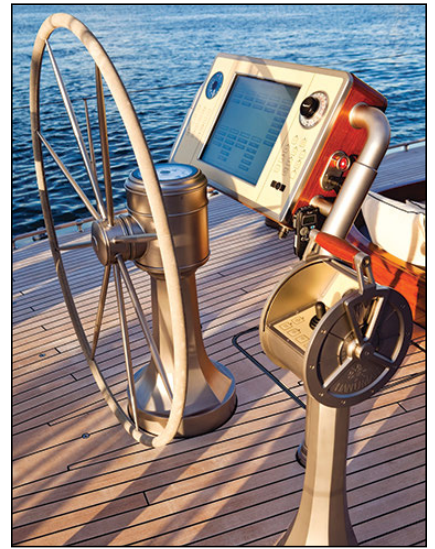
SAVE THE DATE

Display Week 2016

SID International Symposium, Seminar & Exhibition

May 22–27, 2016

**Moscone Convention Center,
San Francisco, CA, USA**



OPTRONIC LABORATORIES

(dba Gooch & Housego, Orlando)

Orlando, FL, USA 1-407-422-3171 x206

www.GHinstruments.com

Booth 1421

NIST-Traceable White-LED-Based Integrating-Sphere Calibration Standard

The OL 458-4F is a NIST-traceable white-LED-based integrating-sphere calibration standard, designed for accurately calibrating micro- and telephotometers, image intensifiers, and imaging photometers. A proprietary design allows for true continuous spectrum across the visible range. Precision source temperature control delivers extremely stable output over long periods of usage. The design and output are customizable upon request.



OSTENDO TECHNOLOGIES

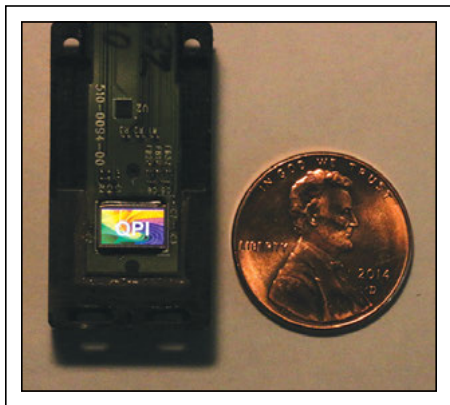
Carlsbad, CA, USA 1-760-710-3000

www.ostendo.com

Booth 1319

Quantum Photonic Imager

Ostendo has created the next innovation in light technology, the Quantum Photonic Imager (QPI) integrated light processor, combining the power of solid-state light with a microprocessor. For the first time ever, a commercial process utilizing nanotechnology fabrication has been developed to bond a CMOS processor with an LED. QPI has the miniature size, efficient power consumption, and the intense brightness to allow it to not only empower many of the existing light products, such as projectors and displays, but also be the basis for a wave of new applications, such as glass-free holographic 3D displays, wearable displays, and more.



PILKINGTON NORTH AMERICA

Toledo, OH, USA 1-800-221-0444

www.pilkington.com

Booth 445

Ultra-Fine Cover Glass

Pilkington North America will feature NSG Glanova™, an ultra-fine cover glass specifically produced for the digital-display market. Available at a competitive price point, this new product is extremely durable, high quality, and ideally suited for chemical strengthening. NSG Glanova™ has 91% optical transmittance and is suitable for a variety of applications such as smartphones, tablets, touch panels, PCs, and automotive displays, and it can even be mounted on industrial equipment.



QUADRANGLE PRODUCTS

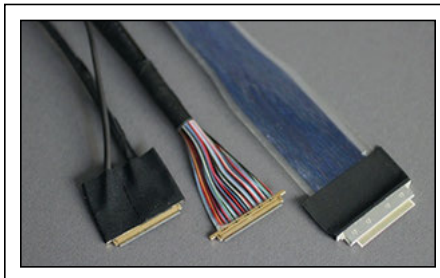
Englishtown, NJ, USA 1-732-792-1234

www.quadrangleproducts.com

Booth 541

Interface Solutions

Quadrangle Products provides interface solutions between LCD panels, backlights, drivers, motherboards, touch screens, and other related devices. Of particular interest are the turnkey solutions in the Micro Coaxial Cable arena. Quadrangle supports a range of offerings: Twisted Pair Micro Coax (LVDS Transmission), complete custom Micro Coax Cable assemblies, standard hookup wire (28AWG) transition boards (LVDS), Micro Coax to 28AWG flying leads (via transition board — LVDS), and value-added services (such as EMI shielding). Popular connector manufacturers such as I-PEX, ACES, UJU, JAE, and others are supported. Quadrangle will help guide customers through the various design and construction challenges associated with micro coax cables and micro-coax-based transitions.



RADIANT VISION SYSTEMS

Redmond, WA, USA +1-425-844-0152

www.RadiantVisionSystems.com

Booth 834

Imaging Colorimeter

Radiant Vision Systems will feature the ProMetric® I29, the newest I Series Imaging Colorimeter. The 29-Mpixel I29 joins the existing I2, I8, and I16 to deliver a full range of fast high-resolution colorimeters for production applications. ProMetric® I is ideal for inspecting large high-resolution displays, as well as multiple panel testing in a single shot for smaller tablets and phones to increase throughput. ProMetric® I offers high-dynamic-range mode, optional integrated spectrometer, USB/Ethernet communication, Smart Touch™ on-camera operation, Smart Control™ electronically controlled lenses, and Smart Calibration™ automatic flat-field correction. TrueTest™ Automated Visual Inspection Software provides versatile test control and data analysis.



SARTOMER AMERICAS

Exton, PA, USA 1-610-594-7360

www.americas.sartomer.com

Booth 916

Urethane Acrylate Oligomer Resin

Sartomer Americas will feature CN9070, a urethane acrylate oligomer resin offering moisture barrier and low-k dielectric properties. This oligomer has high hydrophobicity but good compatibility with hydrophilic materials. CN9070 also features high clarity and superior chemical resistance.



Submit Your News Releases

Please send all press releases and new product announcements to:

Jenny Donelan
Information Display Magazine
411 Lafayette Street, Suite 201
New York, NY 10003
Fax: 212.460.5460
e-mail: jdonelan@pcm411.com

SEEFront GmbH

Hamburg, Germany +49-40-4162264-80
www.seefront.com
Booth 419

Autostereoscopic 3D Monitor

SeeFront will highlight the SF3D-240CP, 24-in. autostereoscopic 3D monitor that delivers a cutting-edge 3D experience at the utmost freedom of movement for a single user. SeeFront 3D® Technology combined with an ultra-high-definition (UHD) display panel with 3840 × 2160 pixels offer color fidelity, high brightness, and true 3D depth at the highest possible resolution. 3D photos, animations and videos, 3D movies, and 3D live video streams all appear on the SeeFront SF3D-240CP the way they are meant to be seen. The SeeFront SF3D-240CP will work with all 3D-enabled applications supporting 1080p side-by-side (half) and 720p frame packing according to HDMI standards.



SENSOR FILMS

Victor, NY, USA 1-585-738-3500
www.sensor-film.com
Booth 1724

Touch Sensors

Sensor Films is changing the way touch sensors are made and will introduce a high-volume low-cost manufacturing process that enables touch interfaces to be utilized everywhere. SFI offers a family of production-equipment solutions that patterns flexible, transparent conductive films with a variety of functional materials. SFI has introduced the Starlight Digital Printer that provides a scalable production path to make low-cost resistive and projected-capacitive touch sensors. Imagine all the new product applications in appliances, automotive, medical, wearable devices, consumer devices, interactive toys, and books that will drive exciting new products needing flexible low-cost touch.

SEVASA

Barcelona, Spain +34-9382-80333
www.sevasa.com
Booth 1517

Anti-Glare Cover glass

SEVASA manufactures high-quality acid-etched anti-glare cover glass for the touch and/or display industry. The product line of HapticGlas includes HPT-TEC and custom productions. Available at the market's largest size (up to 154 in. on the diagonal) and large volumes.

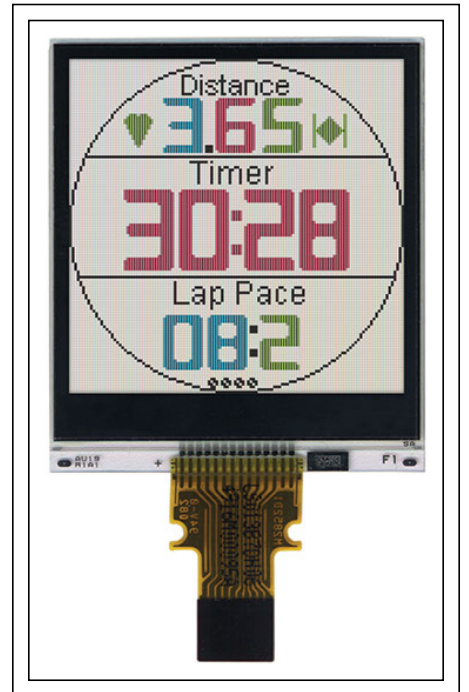


SHARP MICROELECTRONICS OF THE AMERICAS

Camas, WA, USA 1-360-834-2500
www.sharpsma.com
Booth 434

Always-On Color Memory LCD

Sharp's 1.33-in. (diagonal) Color Memory LCD (LS013B7DH06) graphics display provides "always-on" color with ultra-low power consumption for wearable technology and other small-screen applications. Its high-resolution 8-color stripe display delivers smooth graphics and the flexibility to showcase rich custom content. Transmissivity allows the addition of a backlight for visibility in virtually any ambient lighting condition. Its octagonal footprint makes it ideal for wrist-top applications.



SILVACO

Santa Clara, CA, USA 1-408-567-1000
www.silvac.com
Booth 344

TFT-Specific Simulation Software

Silvaco provides a complete well-integrated simulation software for all aspects of TFT technology. The TFT-specific software includes technology simulation, SPICE model extraction, interconnect parasitic analysis, SPICE circuit simulation, and traditional CAD. The TCAD Driven CAD approach provides the most accurate models to

both device engineers and circuit designers. Silvaco enables device-technology engineers to simulate the electrical, optical, and thermal behavior of semiconductor devices. Atlas device simulator provides a physics-based easy-to-use, modular, and extensible platform to analyze DC, AC, and time-domain responses for all semiconductor-based technologies in two and three dimensions.



SINGULUS TECHNOLOGIES AG

Kahl am Main, Germany +49-(0)-61-88-4-40-156
www.singulus.de
Booth 343

Electromagnetic Shielding for Mobile Applications

Mobile applications demand a very high functional density for Electromagnetic Shielding Interference. Cover shields do not provide the shielding quality required for the next generation of products. Singulus Technologies offers a modular vacuum sputtering system providing the best solution to produce high-quality metal layers in a cost effective and economical way. The Singulus Technologies inline sputter deposition system is designed for cleanroom production with loading and unloading of the substrates from one side and processing in a cleanroom environment and a minimized footprint. In the different process modules, plasma treatment, RF sputtering, and DC sputtering can be implemented as well as cooling and heating modules. The cooling systems maintain a low temperature without compromising on throughput. Essential is the exact temperature control which is required processing plastic substrates.



SLENCIL COMPANY

Orange, MA, USA 1-978-544-2171
www.slencil.com
Booth 1416

Ruggedized Tethered Stylus

SLENCIL will feature the SL1100-KRH8, a ruggedized tethered stylus for resistive touch screens with a 4-in. (10-cm) unbreakable elastomeric tether with a Kevlar® filament comfortably extending 40 in. (100 cm). The cushion stylus tip (0.040 D) may be adjusted at the factory for preferred deflection pressure. An adhesive-back H8 stylus cup-holder securely anchors the unit in preferred locations. Optional ring-terminal allows for connection using screw-down fasteners. High security braided-steel straight cable available. SLENCIL manufactures tethered SAW, IR, and P-CAP units for today's high-performance touch-screen platforms. Stylus may be imprinted with corporate logo or brand.



SOLOMON SYSTECH LIMITED

Shatin, Hong Kong +852-2207-1111
www.solomon-systech.com
Booth 917

Full In-Cell Touch IC

While Hybrid In-Cell and Apple In-Cell are still the key in-cell solutions available on the marketplace, Solomon Systech has introduced the game-changing innovation of SSD6600, a Full In-Cell Touch IC. SSD6600 is a touch master controller, a sensor hub, as well as a general microcontroller. Embedded with a customized display driver IC, SSD6600 plays as a standalone MCU to collect all touch-related data and to perform signal processing. It also supports LCM solutions of different resolutions, including FWVGA, HD, FHD, etc. With cutting-edge design technology, the SSD6600 features extra-low consumption during sleep mode, making it a perfect solution for low-power wakeup gesture application.



SUN-TEC AMERICA

Scottsdale, AZ, USA 1-480-922-5344
www.sun-tec.net
Booth 1534

Compact Sheet-to-Sheet Laminator

Sun-Tec's TMS-S3 is the smallest and most compact of the Sun-Tec sheet-to-sheet laminators. This bench-top model is ideal for low-volume production or R&D work that involves a flex-on-flex or flex-on-rigid substrate lamination for sizes from 1 to 8 in. on the diagonal. The placement accuracy of the TMS-S3 is ± 0.2 mm using manual loading and X/Y edge-alignment guides. Adjustments can be made for lamination speed, pressure, and substrate thickness.



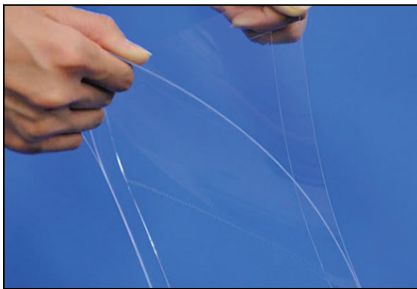
TAICA NORTH AMERICA CORP.

Santa Clara, CA, USA 1-408-500-2971
www.taico.co.jp
Booth 1415

Advanced Silicone Optical Bonding Material

Taica North America's OPT Alpha-GEL delivers high optical transparency, excellent durability, and shock absorptivity. It is designed for a wide range of optical-bonding applications for flat-panel displays and touch screens. Key features:

- Improves visibility by decreasing light reflection.
- Shock resistance and stress release: Softness of OPT Alpha-GEL improves shock resistance and stress release of display panels.
- Parallax decrease: Improves touch-screen appearance and reduces optical distortion.
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- Reworkable in-situ: Cleanly and easily reworkable, especially compared to other OCA/OCR materials.



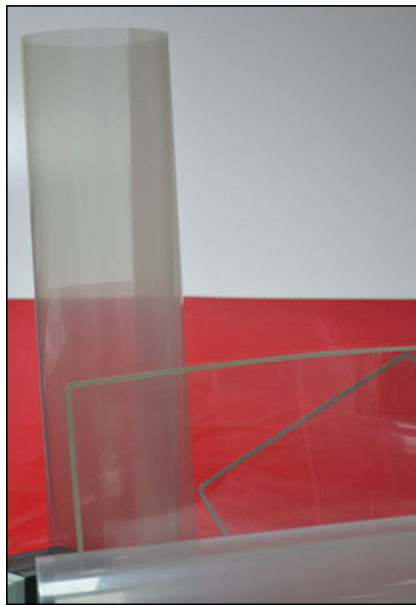
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TFD

Anaheim, CA, USA 1-714-630-7127
www.tfdinc.com
Booth 1015

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www.threebond.co.jp
Booth 246

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TIANMA MICROELECTRONICS USA

Chino, CA, USA 1-909-590-5833
www.tianma-usa.com
Booth 719

Automotive Cluster LCD

TIANMA will highlight their new 12.3-in. automotive cluster LCD for high-end cars in 2015. This product features 1920 × 720 pixels, a 1000-nits LED backlight, -30 to +85°C operating temperature, and wide 88° viewing all around using SFT technology. The trend for car makers is to integrate advance display technology into today's cars to enhance the driving experience, safety, and information available to its drivers.

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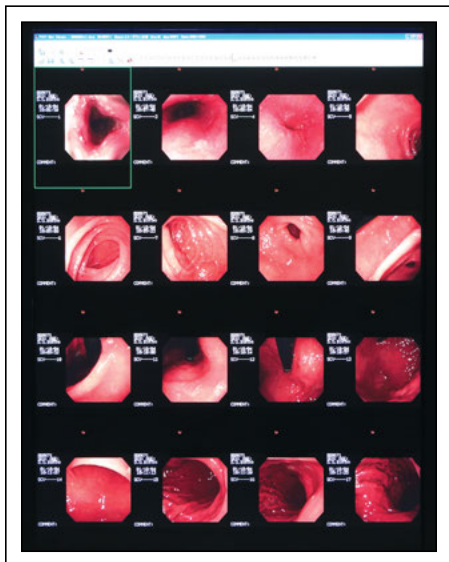
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TIANMA NLT AMERICA

Santa Clara, CA 1-408-816-7029
www.tianma-nlt.com
Booth 719

Quad Extended Graphics Array LCD

Tianma NLT America will be featuring the new 21.3-in.-diagonal QXGA (Quad Extended Graphics Array) LCD that features quantum-dot technology with NLT Technologies' proprietary new SFT2 (Super Fine TFT2) technology. SFT2 significantly improves the aperture ratio compared to conventional TFTs, resulting in high transmissivity and better image quality with deeper color saturation. The display achieves high luminance (700 nits) with low power consumption (45 W), high density, and 100% Adobe RGB coverage. The combination of SFT2 and quantum dots results in superior deep-red color reproduction – ideal for medical diagnostic applications.



UNIVERSAL DISPLAY CORP.

Ewing, NJ, USA 1-609-671-0980 x321
www.udcoled.com
Booth 920

Transparent OLED Panels

Universal Display Corporation will feature Triangle Light Object or Transparent Light Origami (TLO) made from 16 triangular, transparent, glass OLED panels. When turned off, the panels are clear; when on, they glow red, blue, or green but remain transparent. Each panel is connected to the next via a friction hinge, which allows the structure to be folded and bent into an endless variety of shapes. The design was inspired by the observation that colors emitted by overlapping transparent OLED panels combine in an additive way.



WESTAR DISPLAY TECHNOLOGIES

Saint Charles, MO 1-636-300-5110
www.westardisplaytechnologies.com
Booth 1516

Reflective/Emissive Display Measurement System

Westar Display Technologies' FPM-505R is perfectly suited for automated reflective measurement and optical performance assessment of reflective, emissive, and transmissive displays under a variety of lighting conditions. The FPM-505R includes options for diffuse hemispherical lighting and directed illumination to allow automated characterization of reflective displays or ambient contrast and sunlight-readability characterization of standard LC and OLED displays. The FPM-505R is housed in a light-safe enclosure and provides full 5-axis motion for viewing angle and uniformity characterization. The FPM-505R now provides a thermal chamber option to allow for characterization of display performance over temperatures ranging from -40°C to $+85^{\circ}\text{C}$. ■



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continued from page 2

One of the really innovative ideas we learned about for this issue comes from a company established in 1998 called Sun Innovations, and its creative way of producing a head-up display (HUD) by inserting red, green, and blue emitting layers of transparent phosphor directly into the lamination stack of a vehicular windshield. Those phosphor layers are then stimulated by various designated wavelengths of ultra-violet (UV) light from a projection engine. This technique has some unique advantages, as you will learn from the Frontline Technology article "Emissive Projection Technology Enables a Full Windshield Head-Up Display" by author Ted Sun. The light engine behind this innovative system is a Texas Instruments DLP, which should be familiar technology to anyone who has followed ID for the last many years.

In fact, DLP imaging systems have some special properties that may make them particularly well suited to achieving advanced vehicular HUD applications, or so is proposed by authors Alan Rankin and Jason Thompson, both from Texas Instruments DLP Products. In their Frontline Technology article, "Next Generation Head-Up Displays," we learn about the notion of "HUD 2.0" and the requirements for a display system suitable to convey augmented-reality data to drivers under all environmental conditions. The requirements are certainly challenging but so are the potential rewards to both drivers themselves and the innovators who will help realize these next-generation displays systems.

We have certainly seen an evolution in electronic displays penetrating and reshaping the classic dashboard layout over the last 40+ years. First, it was simple VFDs and a few passive LCDs, then it was full center console active-matrix displays, and now we are starting to see entire dashboard systems created virtually with complex backlit and emissive displays including OLEDs. If you are wondering why it has taken so long and why it is a challenging application space, read our guest editor Silviu Pala's article titled "Technologies and Trends for Vehicular Displays." Silviu walks us through the ergonomic, environmental, and functional requirements that drive designs for electronic displays in vehicles. Not only does he give us a good perspective of the history of these developments, but through his work at DENSO International, we can see what the latest trends and opportunities really look like, especially in the context of coming

trends like self-driving and semi-automated vehicle controls. No doubt you will come to appreciate as I have how exciting the potential for this application area is and how it may finally be poised to move more rapidly than we have seen in the past. Personally, I will always prefer to drive my own car and look directly out the windshield, but I could be persuaded to really enjoy a full wrap-around dynamically addressed OLED dashboard and various driver information assist systems like the ones described in this issue.

Although some people are skeptical about the promise of OLED technology for automotive applications, authors Jeff Hatfield, Yoshiyuki Kobayashi, and Akihiro Nonaka, all with Futaba Corporation, certainly think the future is bright. In their Frontline Technology article, "Automotive Applications for Passive-Matrix OLEDs," they explain the advantages of PMOLED technology as well as some of the important application requirements that PMOLEDs must achieve in order to get a larger share of the dashboard. I was very impressed with their balanced and objective portrayal of the technology and its current state of performance. No doubt we will see more OLED technology in our cars soon.

In his Display Marketplace feature this month, author Paul Semenza suggests that we should consider alternatives to the highly entrenched technology of TFTs deposited via vacuum lithography for the next generation of active-matrix devices. His article titled "Can Advanced Assembly Techniques Alter the Dynamic of Display Manufacturing?" outlines a family of new technologies for building backplanes and displays separately and/or assembling pre-fabricated semiconductors directly onto display substrates. These new techniques could finally overcome some of the well-known challenges with making truly flexible displays on roll-to-roll processes. We are used to Paul giving us new perspectives and thought-provoking analysis of the industry and this article is no exception.

Before I finish this month, I want to offer my congratulations to a well-known and highly respected member of our display community. Dr. Larry J. Hornbeck recently received a Scientific and Technical Achievement Award from the Academy of Motion Picture Arts and Sciences for his work to develop the Digital Micromirror Device (DMD) used in Texas Instruments' DLP projectors. I had the privilege of meeting Larry

a few years ago when we invited him to be a special event speaker and recall the story of how the DMD was invented and developed. It was a very memorable evening and a story I have retold many times. It's nice to see one of our own recognized by the entertainment industry that benefits greatly from display technologies like DLP.

And so I hope to see you all here in San Jose and hope you enjoy your time at Display Week. ■

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2015 EDITORIAL CALENDAR

■ January/February

Flexible Technology, e-Paper, Wearables

Special Features: Wearables Update, Flexible Technology Market Overview

Related Technologies and Markets: e-Paper, substrates, films, coatings, OLEDs, manufacturing, wearables

Sept 1: Editorial content proposals due

Jan 5: Ad closing

■ March/April

Display Week Preview, Topics in Applied Vision

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

Related Technologies and Markets: Projection, LCDs, OLEDs, metrology, wearables

Nov 3: Editorial content proposals due

Mar 6: Ad closing

■ May/June

Display Week Show Issue, Automotive

Special Features: Display of the Year Awards, Products on Display, Market Overview of Automotive Trends

Related Technologies and Markets: LCDs, OLEDs, projection, ruggedization, manufacturing, automotive, marine

Jan 5: Editorial content proposals due

May 1: Ad closing

Special Distribution: Display Week 2015 in San Jose and IMID in Korea

■ July/August

Interactivity/Touch/Tracking, Portable Technology

Special Features: Portable Devices Study, Touch Market Update

Related Technologies and Markets: Materials, ITO, ITO replacements, backplanes, glass, films, tablets, smartphones

Mar 2: Editorial content proposals due

June 30: Ad closing

Special Distribution: Vehicle 2015 and EuroDisplay in Belgium

■ September/October

Display Week Wrap-up, Metrology

Special Features: Display Week Technology Reviews, Best in Show and Innovation Awards, Metrology Update

Related Technologies and Markets: Measurement, spectrometers, LCDs, OLEDs, quantum dots, manufacturing

May 4: Editorial Content Proposals due

Sept 2: Ad closing

Special Distribution: IDW in Japan

■ November/December

3D/Holography, Television

Special Features: Consumer TV Roundup, State-of-the-Art 3D Survey

Related Technologies and Markets: OLEDs, LCDs, TVs, Retail Electronics

July 1: Editorial content proposals due

Nov 3: Ad closing



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iMID 2015 Takes Place in Daegu, Korea

iMID, the 15th International Meeting on Information Display, will take place August 18–21, 2015, in Daegu, the fourth largest city in Korea. iMID is organized by the Korean Information Display Society, the Society for Information Display, and the Korea Display Industry Association. This year's event will feature tutorials, workshops, oral and poster technical sessions, a three-day exhibition, and social events including a Korean tea ceremony.

The keynote speakers will include Nobel Prize winner Shuji Nakamura and Sang Deog Yeo, President of LG Display Co., Ltd. Nakamura, a professor in the Materials Department at the University of California at Santa Barbara, won the Nobel Prize in Physics

in 2014, along with Isamu Akasaki and Hiroshi Amano, for the invention of efficient blue LEDs. He will speak at iMID on how blue, green, and white LEDs and laser diodes were invented and discuss the future of solid-state lighting. Yeo will describe the huge potential of OLED displays in terms of picture quality, design, and expandability, and how OLEDs are beginning to create entirely new markets.

A preliminary program is available at <http://imid.or.kr/2015/program.asp>

The host city of Daegu (Fig. 1) is a hub for education and industry and is also located conveniently near four UNESCO designated World Heritage Sites, including historic villages and the 9th century Haeinsa Temple. Information about lodging and sightseeing is available at www.imid.or.kr. ■



Fig. 1: iMID 2015 host city Daegu, Korea, is surrounded by mountains and located near four UNESCO designated World Heritage Sites. Image: Thorfinn Stainforth

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continued from page 4

future: readability, head-up displays, augmented reality, non-standard shapes (Sharp), “dead-front” displays with basically no luminance for black (Futaba), and small packages with high optical performance that use integrated touch (Kyocera).

Two additional authors contributed sidebar articles to my piece. Shannon O’Day, Core Ergonomics Research Engineer at Ford Motor Co., summarizes the key points for display legibility in her sidebar article titled “Legibility and Aging Eyes.” And Zahir Y. Alpaslan and Erhan Ercan of Ostendo Technologies describe a new technology that could hasten the progress of head-up displays in their sidebar article “QPI Benefits for HUD Designs.”

Many key trends for vehicles today are related to the autonomous drive capabilities that are predicted for tomorrow. HUDs and AR will be very important in the “robot/driver” paradigm of the future. This is why I solicited two articles on HUD, “Emissive Projection Technology Enables a Full Windshield Head-Up Display” by Ted Sun of Sun Innovations, and “Next-Generation Head-Up Displays” by Alan Rankin of Texas Instruments, which describes how HUDs will eventually function as primary displays rather than ancillary ones. Last “Automotive Applications for Passive-Matrix OLEDs” by Futaba’s Jeff Hatfield and team describes how PMOLED technologies offer some excellent advantages for automotive designers.

I hope you enjoy these articles and they give you an idea not only of the challenges that automotive-display makers face, but of the kinds of display technology we’ll be enjoying in our vehicles very soon. ■

Silviu Pala is Director of Technology Planning at DENSO International America in Southfield, Michigan. He has also been chairman of the SID Metro Detroit Chapter since 1998 and of the SAE VFPD group since 1999. He can be reached at silviu_pala@denso-diam.com.

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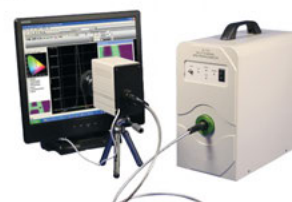


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ELDIM.....	35	Masterbond.....	51
Electronic Assembly	50	Merck.....	C3
EuroDisplay 2015	50	Panasonic	10
EuropTec USA	C4	Radiant Vision Systems	C2
Futaba Corporation of America.....	50	Rockwell Collins	54
Global Lighting Technologies.....	16	TFD	27
Goouch & Housego Orlando.....	55	Touch Display Research	21
		WPG Americas	11

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