

# Information DISPLAY

August 2008  
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**Rave Reviews  
for Display  
Week 2008**



- **2008 Directory of the Display Industry**
- **Display Week 2008 Review**
  - **OLEDs**
  - **Reflective Displays & E-Paper**
  - **Large-Area Displays**
  - **Systems & Components**
- **Optical-Enhancement Films for LCD Backlights**
- **A New Class of Inexpensive Notebook PCs**
- **Journal of the SID August Preview**

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# Information DISPLAY

AUGUST 2008  
VOL. 24, NO. 8

**COVER:** Display Week 2008 attracted 260 exhibitors occupying over 500 booths. For those who could not attend and for those who attended and just did not have the time to walk the entire show floor, this issue attempts to give the reader an overview of the highlights of what was showcased at Display Week 2008 — but you had to be there.



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### OLEDs Issue

- Oxide TFTs for Large AMOLEDs
- Manufacture of Flexible AMOLEDs
- OLED Displays for TV
- Evolution of Projection Displays: Part II
- JSID September Preview

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### A Little Inspiration Goes a Long Way

Welcome to our annual Industry Directory and Display Week Review issue. We've been producing this special issue for many more years than I have been involved with *ID*, and even before I became Executive Editor, this was the issue that always survived the longest on my desk. Frequently marked up with a highlighter and tagged with Post-it® notes scribbled with reminders, this issue inevitably becomes part of my action-planning process for the coming

winter season. It's during the Winter here in New England – when the weather precludes most outdoor activities – that I find the most time to pursue my own technology interests and explore ideas that never seem to get past the whiteboard stage at any other time. Usually those ideas are born during the veritable hurricane of activity at Display Week and then get renewed when I go back and read the reviews we publish later chronicling the highlights of the exhibition. There is an obvious synergy between publishing the extensive exhibit reviews and the Industry Directory in the same issue – the latest in display technology combined with the most comprehensive index of display-technology suppliers available anywhere. Invariably, I get re-inspired as I remember the exhibits I enjoyed most (as well as realizing the ones I missed), but at a much more relaxed pace.

Over the past few years, we've been examining our DisplayWeek coverage and asking how we can improve it. The clear message was that we should add more context and analysis to the mixture and help readers understand the relative maturity of the technologies being described. Therefore, this year our crack team of reporters were specifically encouraged to provide their own perspectives on each nugget and help you put the technology into better perspective. The reviews this year accomplished this quite well, and therefore are even more interesting to read than in past years.

Covering the field of reflective- and flexible-display technologies this year is newcomer Robert Zehner from E Ink Corp., who brought his first-hand knowledge and perspective to the effort. Rob noted that "... it is only a matter of time before this growing sector of the display market will take off." Well Robert, it already has, with several new commercial products either already announced or well under way for launch during 2008. E Ink's technology certainly figures prominently in those recent announcements, but as you will see when you read his article, there is a very diverse and vibrant field of competing technologies in this space, and most of them have unique benefits that ensure their continued path to commercial adoption.

Meanwhile, the LCD community was hard at work making size matter even more than ever before. This year, however, size went beyond screen size into metrics such as thickness and carbon footprint, where larger was clearly not better. Veteran reporter Alfred Poor was assigned the task of documenting all the large-format displays being exhibited. As Alfred explains, LCD manufacturers are hearing the call for greener products and responding with advanced techniques for reducing power consumption through the use of advanced light-management films and wider adoption of LED backlights. LED backlights have the additional advantage of not containing mercury, unlike conventional CCFL backlights, making the products in which they are used much easier to recycle and more eco-friendly. Displaying large images with very small projectors was also an important endeavor this year, and the progress being made on power-stingy lightweight pico-projectors is particularly noteworthy.

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# industry news

## USDC Changes Name to FlexTech Alliance; Expands Mission to Include Flexible, Printed Electronics

**SAN JOSE, Calif.** - The U. S. Display Consortium (USDC) announced July 9 that it is formally expanding its mission to support the emerging flexible, printed electronics market—subsequently changing the organization's official name to the **FlexTech Alliance** to reflect this new activity and opportunity. The USDC board took this action to signal its intent to commit resources to the increasingly synergistic technologies driving advances in the flexible and printed electronics sector, according to a press release. At the same time, the board recommitted its support for supply-chain development for next-generation displays, such as OLEDs, flexible displays, MEMs-based displays and 3-D displays.

USDC officials stated that the move is a natural progression for the organization based

on the success of the Flexible, Printed and Organic (FPO) Electronics Initiative that it launched in December 2006, which was designed to gauge potential development and growth of this new market. Since the launch of that initiative, industry interest has grown steadily with a definite need for programs dedicated to the sector. Based on substantial industry and academic support, as well as the growing synergies between all of its served markets, the USDC board has now officially broadened the consortium's mission to serve the common interests of the display industry and the flexible, printed electronics industry.

As part of this effort, the USDC and all of its programs will be absorbed under the broader FlexTech Alliance umbrella. In addition to continued strong emphasis on elec-

tronic display supply chain R&D, the FlexTech Alliance will focus on creating a flexible, printed electronics infrastructure within North America that will ultimately enable the production of active, ubiquitous devices. These devices will be manufactured using new, flexible form factors that deliver high functionality at low cost. Near-term applications for this market include RFID tags, sensors (chemical/biological), energy (e.g., solar cell panels and flexible batteries), solid-state lighting, medical/healthcare, disposable electronics and displays. Given their myriad applications, FPO electronics hold tremendous potential, with experts predicting that the market for some applications could exceed \$50 billion by 2017, according to the press release.

"There is tremendous overlap between what USDC has undertaken in the display industry and the work needed to support the flexible, printed electronics industry," stated **Michael Ciesinski**, USDC's former CEO, who will now lead the new FlexTech Alliance in the same capacity. "The tools our consortium has at hand—pre-competitive R&D funding, technical roadmapping forums and a strong set of conferences and workshops—will help set an aggressive pace of innovation. The goal set by the Governing Board is to accelerate the transition from R&D to prototype manufacturing, and then to commercialization and market acceptance."

The FlexTech Alliance will be overseen by a seasoned management team that includes **Dr. Mark Hartney** as CTO; **Kay Mascoli** as director of development and planning; **Dr. Kevin Cammack** as director of technical marketing and development; and **Heidi Hoffman** as director of events and marketing communications.

"The FlexTech Alliance is poised to address the need for an organization dedicated to facilitating and promoting the flexible, printed electronics and display industries in North America," said **Dr. Dan Gamota**, director of printed electronic platforms at **Motorola**. "The fact that USDC has changed its name and expanded its mission to be inclusive of these emergent markets speaks volumes to the future potential that is just waiting to be tapped."

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## Esquire Magazine to Feature E Ink Electronic-Paper Display on its October Cover

**NEW YORK** - *Esquire*'s October issue, which will celebrate the iconic magazine's 75<sup>th</sup> anniversary, will be the first magazine ever to embed electronic paper into a mass-produced print product.

The *Esquire* cover is being produced in collaboration with **E Ink Corp.**, and in partnership with the **Ford Flex Crossover**.

According to a press release, the cover "will make a profound statement about how the print medium can expand its capabilities while continuing to exploit its own unique strengths." Ford will prominently feature its Ford Flex on the inside cover, utilizing the same E Ink Vizplex flexible display technology in a double-page advertisement.

"This cover is both a breakthrough for magazines and an expression of the theme of our anniversary issue," said **David Granger**, editor-in-chief, *Esquire*. "We've spent 16 months making this happen as one of the ways we're demonstrating that the 21<sup>st</sup> century begins this fall. The entire issue is devoted to exploring the ideas, people and issues that will be the foundation of the 21<sup>st</sup> century."

In the summer of 2007, *Esquire* and Hearst, *Esquire*'s parent company, contracted E Ink to develop a version of its elec-

tronic-paper technology that could be used in a magazine. Throughout 2008, E Ink and Hearst's manufacturing division worked to surmount the myriad manufacturing challenges the project presented. When the cover appears on newsstands in September, words and images will scroll across the flexible electronic-paper display.

The team at Ford was made aware of the 75<sup>th</sup> Anniversary Edition by *Esquire* last year, and there was an immediate link to the launch of the new Flex Crossover.

"Flex is a breakthrough product for Ford and the *Esquire* opportunity offered us the chance to show the vehicle in a way we could never previously have imagined," said **Jim Farley**, Ford's Group Vice President of Marketing and Communications. "This is an industry first. Ford has a long and rich history of breaking down barriers and bringing to market new technologies for the masses, so this opportunity fits our brand perfectly."

*Esquire* will distribute 100,000 issues with the special cover on newsstands. They will be available at Borders, Barnes & Noble and select newsstand vendors.

— Staff Reports



### We're Going Green

Veterans of the display industry use SID's Display Week to identify trends in the electronic-display industry. While the emergence of touch panels, 3-D technologies, and OLED display products gathered the bulk of the publicity at Display Week 2008, there was another emerging trend that was perhaps less apparent but, in the long run, probably more important. Electronic displays are starting to go green, and it was exciting for me to see the innovations starting across multiple areas.

Why is this important? It's because the electronic-display industry is big business, with a significant global impact. The industry is now at a size in which its environmental effects cannot be ignored. For example, the power consumed by watching television dwarfs any other usage of electricity by consumer electronics in households in the United States. As displays get larger and electricity more expensive, power consumption becomes a much more serious issue. The good news is that the electronic-display industry has innovation in its lifeblood, and companies in this industry can treat environmental challenges as a means to differentiate from competitors and to drive profitability.

One of the keynote addresses at Display Week 2008 was delivered by Shaung-Lang (Paul) Peng of AU Optronics Corp (AUO), which has aggressive development targets in multiple areas of environmental impact. Peng's talk provided a rich set of opportunities in a more sustainable display industry, two of which I will discuss here: reduced energy consumption in liquid-crystal displays (LCDs), and the reduction of toxic components in electronic-display manufacture.

AUO plans to develop and introduce technologies to reduce the average power consumption of its LCD TVs by 50% by 2010. According to AUO, a 50% reduction in power for LCD TVs across all manufacturers by 2010 will save 3 terawatt-hours each year, or the equivalent output of three nuclear power plants! With rising energy costs and increased concerns about the impact of greenhouse gases on the environment, reducing the energy required to watch television provides a major positive benefit, and also improves the sustainability of large display sizes in a world where energy consumption may become more expensive with time.

How can these improvements be made? AUO (and others) are examining all aspects of the LCD. Backlights can be made more efficient; light-control films and color filters can increase the efficiency of light channeled into the panel; pixel designs can be improved; and the energy used in "standby" mode can be reduced. While some of these challenges seem daunting, they are no more difficult than other problems the electronic-display industry has addressed and solved by in the past.

Another major initiative is the reduction of toxic materials, such as heavy metals, as components in electronic displays. Most companies have recognized that the conventional cold-cathode fluorescent lamp (CCFL) backlights in LCD TVs contain high levels of mercury. When CCFL-backlit displays reach their "end of life" and are discarded, that mercury can migrate into the environment in an undesirable way. Reduction of the heavy-metal content in electronic displays can have a major positive impact in the life cycle of these products.

In the case of AUO, Peng described a multi-pronged approach. In the near-term, mercury levels in LCDs are being reduced through the use of low-mercury backlights and by redesigning the module to use fewer backlights. AUO has a goal to replace all LCD backlights with light-emitting-diode (LED) technology by 2011. They estimate

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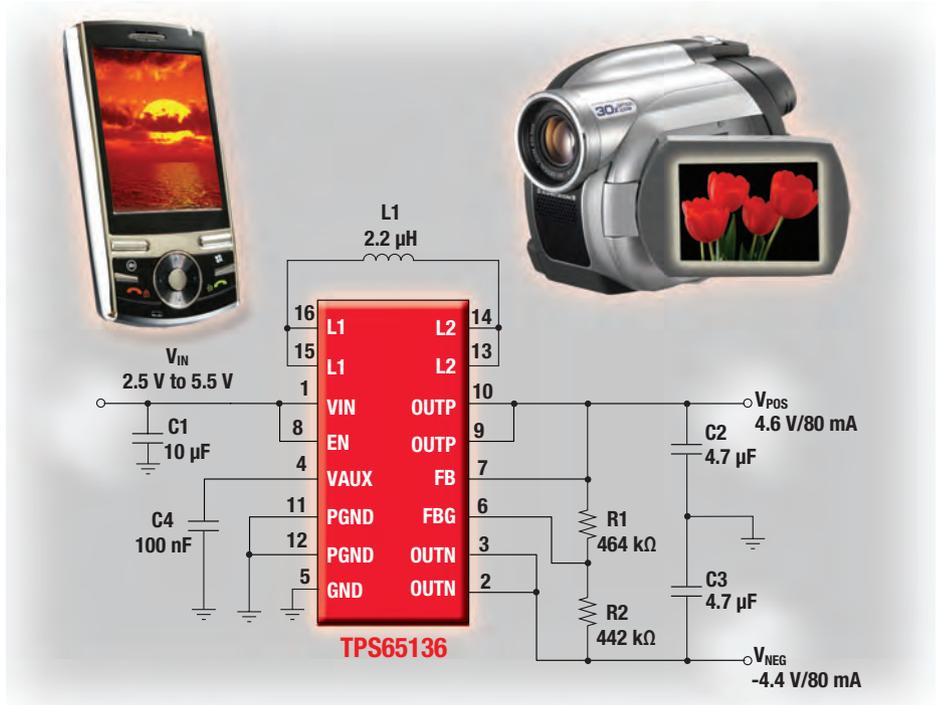
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TPS65131	2.7 to 5.5	-15 to 15	1.95	89	24-pin QFN
<b>TPS65136</b>	2.3 to 5.5	-6 to 4.6	0.7	70	16-pin QFN



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### High-Tech Low-Cost Displays Enable a New Class of Inexpensive Notebook PCs

by Ken Werner

A hot emerging product category is cheap notebook PCs. Market research firm IDC predicts the Netbook/Nettop market could be worth US\$3 billion by 2012, but Intel CEO Paul Otellini has predicted the market will be much larger.

Because the display industry is not known for ignoring popular new applications, display makers are enthusiastically gearing up to produce more of the 7-, 8.9-, and 10-in. displays favored by manufacturers of these new systems.

Taiwan's Asustek Computer has an early success in this category with its Eee PC, which consists of a 7-in. LCD, 802.11b/g WiFi, 10/100 LAN interfaces, 512 MB of memory, a 4-GB flash drive, built-in Webcam, 40 built-in applications, and Linux OS. In early June, this 2-lb. package was selling for \$399 at J&R Electronics in New York.

But that's just the beginning. Micro-Star International was expected to use Computex Taipei, held during the first of week of June, for the official launch of its 10-in. Wind Series of notebooks, and Acer was planning to launch a low-cost 8.9-in. Aspire PC in Europe for €299 (US\$470) early this summer. Asustek looked at all this activity and decided to accelerate its plans to launch a 10.2-in. version of the Eee PC. The Eee PC 1000 was launched at Computex, as was an 8.9-in. version called the Eee PC 901. All of these systems use Intel's new Atom N230 CPU. Industry sources said Asustek is preparing lower-priced versions of its current models.

An Asustek spokesperson said in June that the Eee PC 1000 would be available in Taiwan later in the month for the equivalent of US\$560, with introduction in other markets to quickly follow. The company plans to ship 5 million Eee PCs this year, with the 8.9-in. version accounting for 50% of all shipments.

Intel is promoting its new low-power ATOM processors at Computex and projects a big market for ultra-low-cost PCs that can fit in a pocket and for Netbooks – PCs selling for about US\$250. Intel announced the availability of two Atom processors, the Atom N270 processor and the Atom 230 chip. The company also described two new chip sets – the 945GSE for Netbooks and the 945GC for Nettops – that feature integrated graphics and support for numerous I/O ports. There are already shortages of ATOM CPUs, so Asustek may launch a 10-in. NPC later this year that uses an Intel Celeron M, company sources say.

The netbook category is new and very much in flux, with makers defining and redefining product sub-categories and product features as they go. Asustek, for instance, is planning to launch a 9-in. Eee PC with a larger keyboard. Acer's 8.9-in. "Aspire One" for the European market offers a choice of an 8-GB solid-state drive (SSD) or an 80-GB hard drive and will ship with either Linpus Linux Lite or Windows XP. It will initially ship with Wi-Fi support, but Acer will offer WiMax and Gen 3 options later in the year.

We are just at the beginning of this new product category, and the interaction between its evolving products and the displays, processors, and architectures that will enable them. We look forward to following their evolution.

*Ken Werner is a Senior Analyst at Insight Media (Norwalk, Connecticut) and the Principal of Nutmeg Consultants (Norwalk, Connecticut). This "Business of Displays" column was adapted from his "Display Daily" that appeared on-line on June 5, 2008. For more information, see [www.displaydaily.com](http://www.displaydaily.com) or contact Ken directly at [kwerner@insightmedia.info](mailto:kwerner@insightmedia.info).*

We are always interested in hearing from our readers. If you have an idea that would make for an interesting Business of Displays column or if you would like to submit your own column, please contact Mike Morgenthal at 212/460-9700 or email: [mmorgenthal@pcm411.com](mailto:mmorgenthal@pcm411.com).



# SID

## DISPLAY WEEK

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ELECTRONIC-PAPER ISSUE

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Has E-Paper Finally Arrived?

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## Quality Test & Measurement Tools



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# Can't See It?

## The PR-810L Can Measure It



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Apertures	3°, 0.5°, 0.25°, 0.125° or 2°, 1°, 0.2°, 0.1°
Optics	Pritchard Mirror

### Features

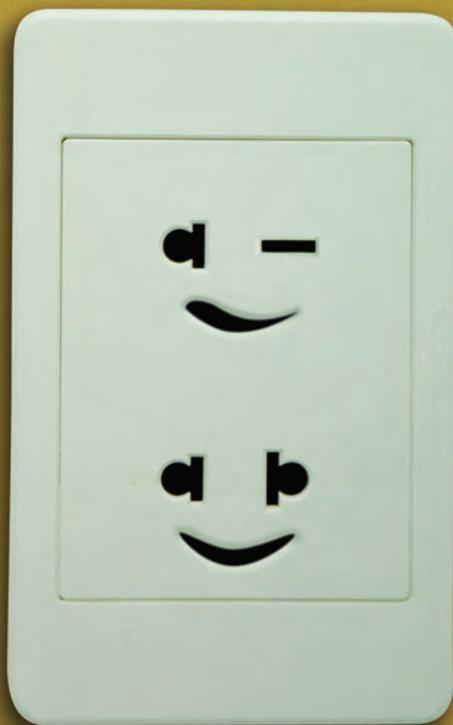
### Applications

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# Display Week 2008 Review: Reflective Displays and E-Paper

*In the wake of Display Week 2008, which showcased an explosion in reflective displays and e-paper products, it is clear that it is only a matter of time before this growing sector of the display market will take off.*

by Robert Zehner

**T**HE CONTINUING GAIN in popularity of reflective displays was in full evidence at Display Week 2008 in May, as at least 15 companies and organizations exhibited some form of electronic-paper product or concept. Technologies that were still in the laboratory 5 years ago are now entering mass production, spawning a variety of new display applications. Once the domain of a handful of start-up ventures, reflective-display suppliers have by now shipped tens of millions of units to big-name customers such as Amazon, Motorola, Sony, and Tesco. While smaller active-matrix manufacturers such as Prime View International have staked an early claim to the field, larger players such as LG Display and Samsung have clearly taken notice, showing prototypes of their own future products. In discussions with the many exhibitors of reflective displays, the key question for this market segment is no longer “if,” but “when.”

## Particle- and Dye-Based Reflective Displays

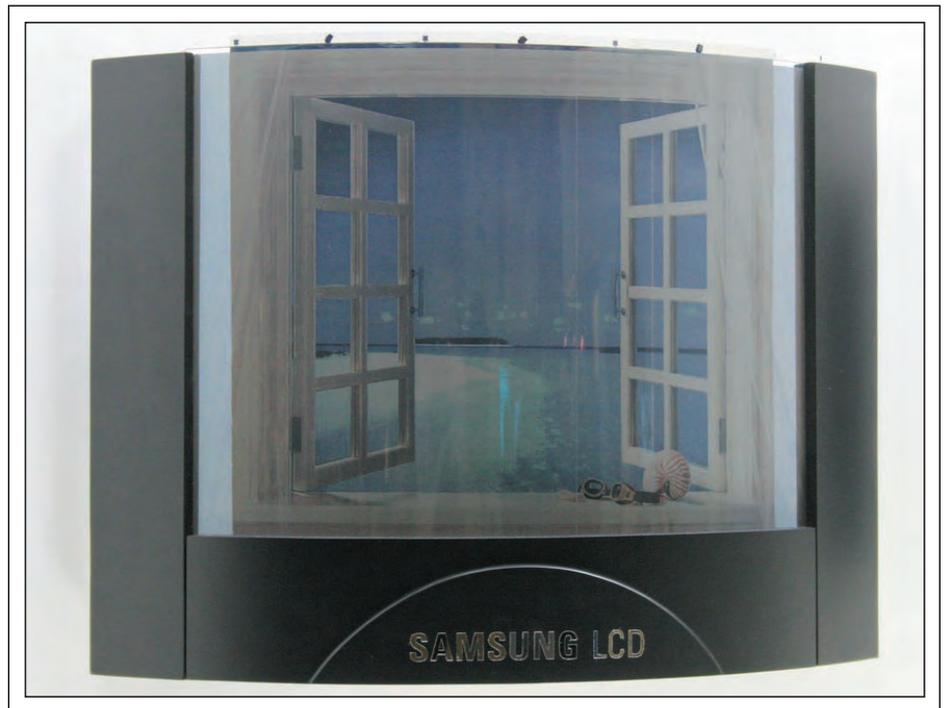
Particle- or dye-based reflective displays accounted for a large majority of the e-paper exhibitors, led by materials developers *E Ink*, *SiPix Imaging*, and *Bridgestone*, as well as electrowetting-display designers *Liquavista*

*Rob Zehner is the Application Engineering Manager, Global Sales, at E Ink Corp. 733 Concord Ave., Cambridge, MA 02138-1002; e-mail: rzehner@eink.com.*

(which did not exhibit its products publicly), and *adt Deutschland GmbH*.

Samsung and LG Display appear to have extended their long-standing rivalry into the electrophoretic-display (EPD) space as well.

*Samsung's* booth included a prototype 14.3-in. color electrophoretic display on a flexible plastic substrate (Fig. 1), while *LG Display* showed off an 11.5-in. UXGA monochrome EPD on thin stainless-steel foil (Fig. 2), as



**Fig. 1:** Samsung's prototype 14.3-in. color electrophoretic display on a flexible plastic substrate. The substrate is curved and shows a picture of a window opening to the sea.

well as samples of a production 6-in. SVGA monochrome AMEPD module. Immediately across from LG Display, **Prime View International (PVI)** promoted an array of EPD product sizes from 1.9 to 9.7 in. on the diagonal, both glass-based and on flexible plastic substrates (Fig. 3). Eindhoven-based **Polymer Vision** showed off a 127-ppi color rollable display as well as a 254-ppi monochrome display. The color rollable display had a roll radius of 6 mm and compared very favorably alongside a color front-page photo from the *Los Angeles Times* newspaper (Fig. 4).

All of the aforementioned products were built using **E Ink's** Vizplex™ electrophoretic imaging film. In fact, E Ink's products were featured in nine different booths, from driver-IC manufacturer **Solomon Systech**, to **Arizona State University's Flexible Display Center**, to **Epson Research's** stunning 13.5-in.-diagonal 385-ppi e-newspaper (Fig. 5). E Ink's product consists of a film of microencapsulated "electronic ink," coated onto a thin plastic substrate. When laminated onto a pixelated backplane, the particles within the microcapsules can be rearranged with an applied electric field to display an image.

"With over 10 different manufacturers in Asia, Europe, and North America launching over 15 different eBook products, **E Ink** has become the *de facto* display standard for e-reader applications," said Sriram

Peruvemba, E Ink's Vice President of Marketing. "E Ink's Vizplex™ film, launched in 2007, offers a maximum reflectivity of nearly 40% and a response time significantly faster than that of E Ink's previous-generation product.

"E Ink has also had an opportunity to fine-tune its products and processes by shipping millions of segment-type displays to customers such as Motorola, for the Motorola F3C phone, and Lexar, for its Mercury series of USB drives with integrated capacity meter. These features clearly appealed to companies such as Sony, iRex, Amazon, Jinke, Bookeen, Neolux, Polymer Vision, and Plastic Logic."

Not to be outdone, Taiwan-based **SiPix Imaging** showed improved versions of its microcell-based electrophoretic display material, including a large number of active-matrix prototype displays. Like E Ink, SiPix generates images by moving charged particles in an electric field; instead of containing the particles within microcapsules, SiPix forms an array of embossed "microcups," which it then fills and seals to make its display film.

"We have a bigger focus on active matrix this year," said Bryan Chan, Director of Marketing for SiPix Imaging. "Through constant improvement of our materials, we have achieved white-state reflectivities of between 30% and 35% in our latest prototypes." This improvement, achieved by optimizing the

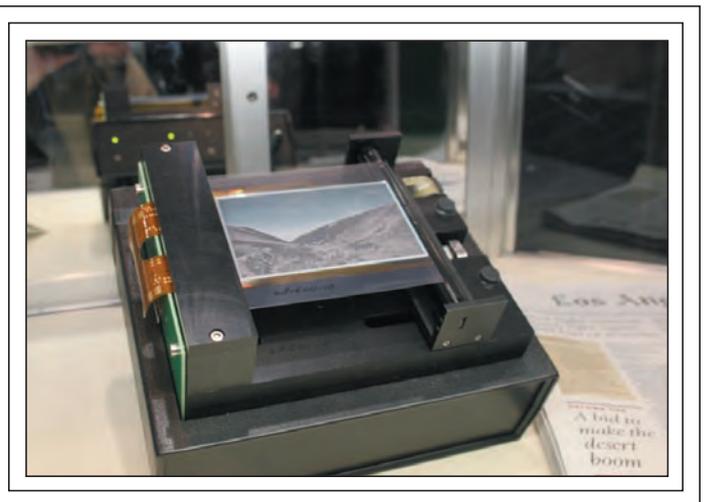


**Fig. 2:** LG Display's 11.5-in. UXGA monochrome EPD on thin stainless-steel foil.

composition of their electrophoretic fluid, makes for brighter displays. While SiPix Imaging was not advertising its partner for production of active-matrix products, a SiPix AMEPD module was also on display in the booth of Taiwanese manufacturer Wintek (Fig. 6).



**Fig. 3:** Prime View International (PVI) showcased several EPD product sizes from 1.9 to 9.7 in. on the diagonal, both glass-based and on flexible plastic substrates.



**Fig. 4:** Polymer Vision's 127-ppi color rollable display with a roll radius of 6 mm compared favorably alongside a color front-page photo from the *Los Angeles Times*. The display is stored in a rolled up position and then is unrolled to present the image.

## reflective displays & e-paper



**Fig. 5:** Epson Research's stunning 13.5-in.-diagonal 385-ppi e-newspaper was one of myriad EPD products at Display Week 2008 that utilize E Ink's Vizplex™ film.

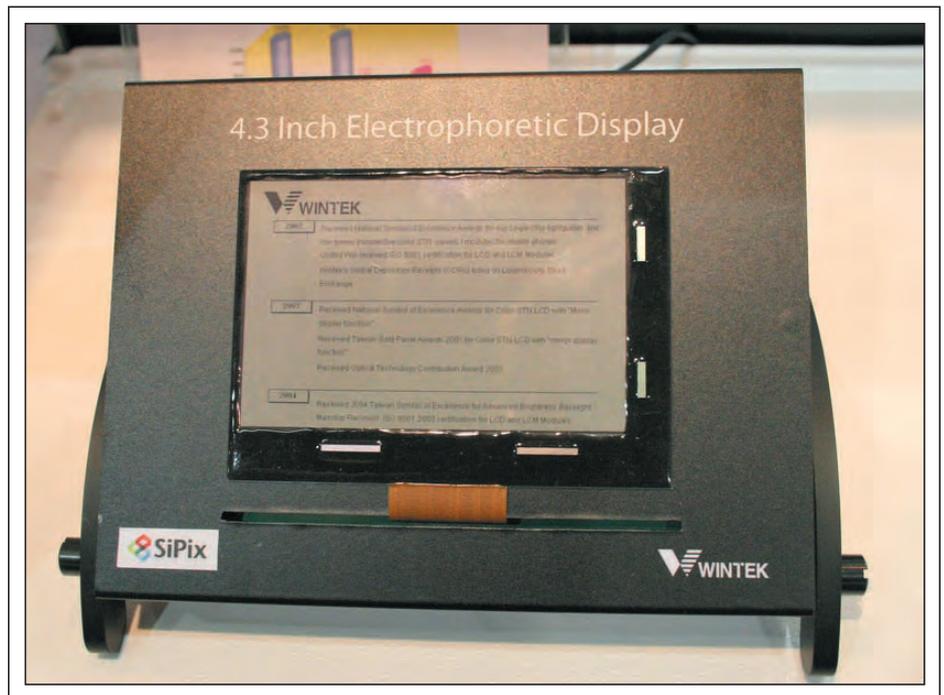
For its part, **Bridgestone's** offerings of its QR-LPD™ air-gap electrophoretic display focused on signage products, ranging from 20-in.-diagonal (A3 paper size) color and monochrome displays with 1920 × 2560 pixels down to postcard-sized electronic-shelf-label (ESL) modules. While Bridgestone displays also move charged particles to form an image, the QR-LPD™ uses air, not liquid, as the carrier for the particles. According to Bridgestone's Natao Satake, Bridgestone and ESL module integration firm Pricer are currently conducting field trials with the Japanese supermarket chain Mainichi. Bridgestone and Dai Nippon Printing also unveiled an active-matrix QR-LPD™ display fabricated using organic semiconductors (Fig. 7). Hiroki Maeda, a DNP researcher responsible for developing the matrix back-plane, explained that organic TFTs are well-suited for this application because they can support the large drive voltages (80 V or more) required by the QR-LPD™ material. While this was only an early prototype, adding active-matrix capability would presumably help Bridgestone to shorten the switching time of its large matrix displays, which took more than 10 sec to change from one image to the next.

Electrowetting-display manufacturer **Liquavista** did not participate in this year's exhibition, but Liquavista CTO Rob Hayes gave an excellent overview of the current status of the company's product development in an invited symposium talk (Paper 44.1). Liquavista's electrowetting displays work by electrically adjusting the wetting properties of colored oil drops on an electrode surface. Depending on the applied voltage, the oil drops shrink or spread to cover more or less of the viewing surface. Hayes explained that Liquavista plans to launch single-color segmented-type displays in the latter half of this year, followed by monochrome active-matrix displays in 2009 and full-color displays formed by using black dye droplets with a color-filter array in 2010. Back at the exhibit hall, **adt Deutschland GmbH** was demonstrating an electrowetting-display device that functions by moving a dye droplet to opposite ends of an hourglass-shaped container. The unique shape of adt's display physically traps the dye droplet at one end of the cell or the other, generating bistability. One drawback to this structure is that each display pixel must be paired with a hidden storage well where the droplet can hide in the "off" state, limiting the

fill factor of the display device. Still, the engineers at adt believe that this may not be a big issue for large signage products or for mobile devices where a single row of droplets could be used to show wireless signal strength or battery capacity.

### Bistable Reflective LCDs

Particle/dye displays were not the only reflective technologies represented at Display Week; bistable reflective LCDs continue to move forward in developing new markets and applications. In a tour of the booth of cholesteric-LCD manufacturer **Kent Displays** with CEO Albert Green, I was surprised to see that two of the products he chose to highlight were not displays at all (or perhaps they are single-pixel displays). The first is an electronically erasable message board that exploits the well-known ability to change the state of a cholesteric film with pressure to write images with a fingernail or stylus. In order to erase the image, the control electronics drive the film back to the fully transparent state. The second product, which Kent has dubbed eGo™, is a 60-µm-thick multilayer film that can be wrapped around the exterior of a cell phone or other gadget (Fig. 8). At the touch



**Fig. 6:** This SiPix AMEPD module was also on display in the booth of Taiwanese-manufacturer Wintek.

of a button, the film is addressed to one of 4000 possible colors to create, in effect, an electronic skin. While not a display in the traditional sense, the eGo™ concept uses cholesteric's strength at creating bright colors to appeal to industrial designers – and, in the age of the iPhone, industrial design matters. In the past, Kent was primarily known for licensing its patents to display companies seeking to make cholesteric-display modules, but these two products will be produced and sold directly by Kent. “We are not a licensing company any more,” said Green. “We are a manufacturing company.”

British display maker **ZBD** began 8 years ago with a new method for creating bistability in a twisted-nematic LCD. In that time, the company has not only brought a new display technology to commercial reality, but has also developed a vertically integrated ESL product it calls epop™. To bring this point home, ZBD created a mosaic of 560 epop™ display units, each fully functional and controlled wirelessly from a nearby laptop PC (Fig. 9). The overall effect was quite impressive, especially after approaching the array up-close and watching individual signs update wirelessly. Owing to their bistability, these modules can run for up to 5 years off of the enclosed batteries, making them practi-

cally maintenance-free. Cliff Jones, ZBD CTO, explained that the display cells are manufactured through a partnership with Chinese display manufacturer Varitronix and that ZBD has landed a contract with Tesco, a leading international retail chain, to outfit one of its stores with several thousand of the ESL devices.

Although *Nemoptic* uses a different approach for generating bistability in its displays, the French display developer is equally focused on display modules for retail applications, according to Daniele Cognolato, the company's Sales and Marketing Manager. Nemoptic's ESL and point-of-purchase display devices can be updated using infrared or wireless signals to display product information and pricing. Display cells are produced through a partnership with Seiko Instruments, Inc. In addition to its focus on the retail market, Nemoptic has also received a grant of 2 million euros from the French government to support its SYLEN e-book reader project. SYLEN aims to deliver not only a reader device, but also a content-delivery system to fill the e-reader with books, newspapers, and magazines. Although the prototypes on display were of high quality, Nemoptic did not share details of any volume customers for their product.

### MEMS-Based Reflective Displays

Last, but certainly not least, *Qualcomm's* mirasol™ displays belong in a category all their own. Instead of particles, dyes, or liquid crystals, Qualcomm's display technology (microelectromechanical systems, commonly known as MEMS) uses arrays of microscopic reflectors that move under the influence of an electric field to increase or decrease their reflectivity. The micromirrors can change position in microseconds, allowing extremely fast switching; at the same time, the mirrors can be held in place by applying a bias voltage to the display, creating an ultra-low-power image stable state.

Qualcomm acquired the fundamental technology behind mirasol™ when it purchased Iridigm, a 3-year-old display start-up, in 2004. Four years later, Qualcomm's customers are launching seven different products with mirasol™ displays, including a stereo Bluetooth headset, three different mobile handsets, a cellular video transmitter, and a “Dick Tracy”-inspired watch-phone. All of these devices feature small displays (the largest, in the phone, is 1.2 in. on the diagonal) that make good use of the sunlight readability and low-power capabilities of mirasol. Brian Galley, Engineering Director for Qualcomm MEMS Technologies, explained that a cell-phone handset maker is



**Fig. 7:** Bridgestone and Dai Nippon Printing unveiled an active-matrix QR-LPD™ display fabricated using organic semiconductors, which are well-suited for this application because they can support the large drive voltages (80 V or more) required by the QR-LPD™ material.



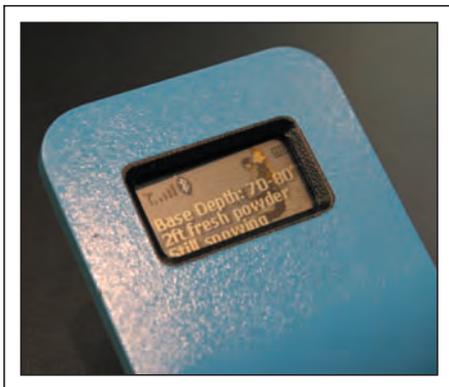
**Fig. 8:** Kent Displays' eGo™ is a 60-µm-thick multilayer film that can be wrapped around the exterior of a cell phone or other gadget. At the touch of a button, the film is addressed to one of 4000 possible colors to create, in effect, an electronic skin.

## reflective displays & e-paper



**Fig. 9:** ZBD dramatically demonstrated its vertically integrated ESL product, “epop,” with a mosaic of 560 epop display units, each fully functional and controlled wirelessly from a nearby laptop PC. Their bistability allows these modules to run for up to 5 years off of the enclosed batteries, making them practically maintenance-free.

able to deliver two additional days of standby time by replacing an AMLCD with a Qualcomm display. From a visual perspective, these black-on-silver monochrome mirasol™ displays have a very similar appearance to more conventional reflective STN-LCD modules, albeit with substantially better power consumption and low-temperature performance.



**Fig. 10:** Qualcomm’s mirasol™ display technology uses arrays of microscopic reflectors that move under the influence of an electric field to increase or decrease their reflectivity. The micromirrors can change position in microseconds, allowing extremely fast switching; at the same time, the mirrors can be held in place by applying a bias voltage to the display, creating an ultra-low-power image stable state.

Qualcomm also exhibited samples of color mirasol modules (Fig. 10). The on-off nature of the MEMS mirrors limited the color palette for these demonstrators, but Galley explained that future product generations will take advantage of subpixel dithering to produce a full range of colors.

### Conclusion

With customer interest growing across a wide variety of applications and technologies, it is clear that reflective displays have found their place in the overall display market. It is interesting to note that, in contrast to the transmissive-LCD segment that is dominated by a handful of multi-billion-dollar corporations, the average reflective-display company is small, privately held, and has been in business for a decade or less. This small handful of companies is managing to turn out an increasing number of products each year, targeting entirely new markets such as color-changing skins for cell phones, electronic-book readers, and credit cards with integrated displays. With demographics such as these, it seems certain that each year will continue to bring surprising developments in reflective displays.

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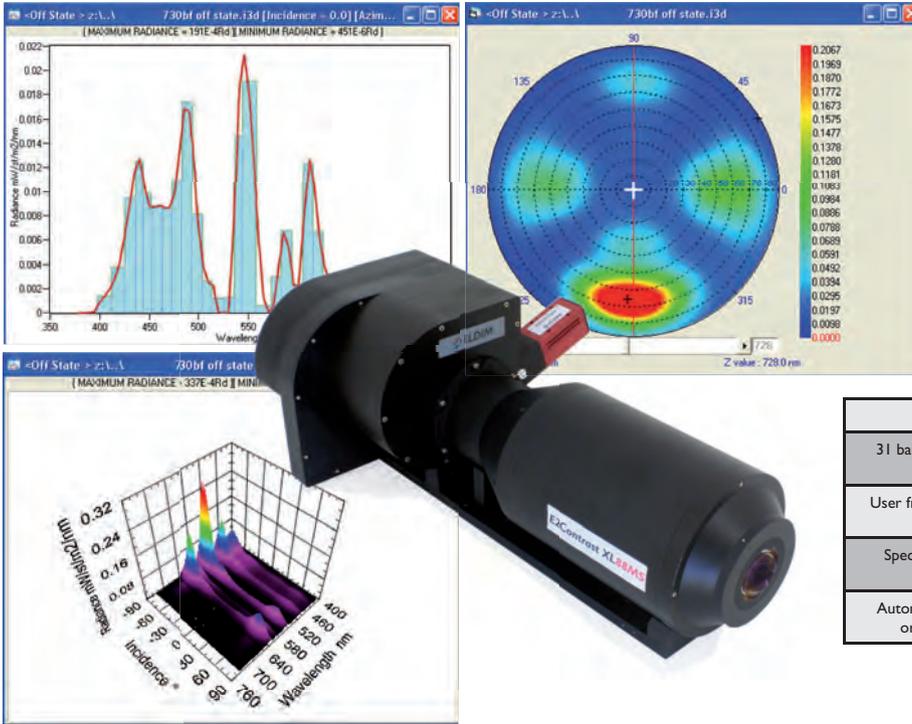
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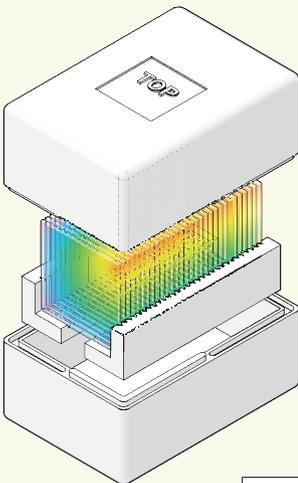
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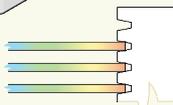
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# Big, Lean, and Green Pixel Machines: Large-Format Displays at Display Week 2008

*Often the most talked about products shown at Display Week year after year, the large-format displays that were showcased in 2008 featured sharper resolutions, thinner form factors, and more eco-friendly designs.*

by Alfred Poor

**T**HE large-format display technologies exhibited at Display Week 2008, The SID 2008 International Symposium, Seminar & Exhibition, can be summed up in a few simple words: big, lean, and green pixel machines. Manufacturers are finding ways to make their designs not only bigger, but thinner, better for the environment, and with increased resolution. There were few revolutionary developments, but clearly the state of the art in the display industry is evolving steadily on many fronts.

Consisting of more than 260 exhibitors and hundreds of technical papers, it's impossible to list them all in this limited space. As the saying goes, "you had to be there." But here's a rundown of some of the highlights among the large-format displays.

## Big LCD Panels

The vast majority of the large-display exhibits – and the lion's share of the technical papers – were devoted to LCD technology. Although there were plenty of small-format displays intended for mobile applications, the show-stoppers were the large LCD panels.

The first stop for any discussion of the big panels had to be at the booth of a company

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**Fig. 1:** Samsung's 82-in. QuadFHD multi-touch LCD panel provided impressive detail, even up close.

that does not even make LCDs, but makes them possible. **Corning Incorporated** had a mock-up showing just how large a Gen 10 substrate will be when it starts producing them in 2010. Towering over the already impressive Gen 8 sheet, the 2850 × 3050-mm Gen 10 sheet was larger than the walls in some rooms.

Clearly, the LCD manufacturers are eager to take advantage of larger substrates, because they will provide increased production efficiencies. They will also make it possible to make improbably large demonstration panels, though one would think that the ones they have already are large enough.

Several companies showed QuadFHD panels having resolutions of 3820 × 2160 pixels, equivalent to four 1080p panels combined into a single screen. **Samsung** showed the largest one at Display Week: an 82-in. monster that incorporated a fast 120-Hz refresh rate. **Sharp** featured a 64-in. model having a CCFL backlight. **Chi Mei Optoelectronics (CMO) Corp.** showed a 56-in. model, while **LG Display** demonstrated a 52-in. model. The detail was exquisite in each of these displays – one could stand within touching distance and not see individual pixels.

This last fact is significant – the Samsung 82-in. QuadFHD model incorporated a multi-touch feature, allowing the data on the screen to be manipulated by hand movements (Fig. 1). Clearly, the display used by Tom Cruise's character in the movie *Minority Report* is closer to becoming reality. **LG Display** also showed a multi-touch tiled display made of four FHD panels (Fig. 2).

### The Big 3-D

Perhaps the biggest story at this year's Display Week was 3-D. In recent years, we have seen many panels that require glasses or active goggles, as well as autostereoscopic displays. The increasing popularity of 3-D movies at local cinemas has helped drive interest in developing 3-D displays for consumer applications, beyond the conventional niche professional markets.

The big 3-D news – with the emphasis on the word “big” – was the 3-D in Cinema Special Session on Wednesday afternoon, where companies made presentations and live demonstrations of their stereoscopic projection technologies. The session was held in the large Petree Hall, where more than 1000 attendees had the opportunity to view clips



Fig. 2: LG Display's tiled four 42-in. panels results in an 84-in. multi-touch display wall.

from recent 3-D movie projects, including the *U23D*, *Beowulf*, and a special 3-D version of *Kung Fu Panda* that had only been seen inside of **Dreamworks Animation**, one of the session's presenters. Other presenters from **Dolby Laboratories**, **Quantel**, **Real D**, **Sony Pictures Imageworks**, and **3ality Digital Systems** gave a broad insight into the 3-D cinema industry. (Editor's Note: For more on 3-D cinema, see the March 2008 issue of *Information Display* magazine. For more on 3-D in general, see the July 2008 issue of *Information Display*. Both issues are available at [www.informationdisplay.org](http://www.informationdisplay.org)).

The show floor featured a mix of stereoscopic and autostereoscopic displays. **Samsung** showcased one of the largest 3-D panels, a 52-in. autostereoscopic FHD panel. **NEC Displays** featured a 9-in. WVGA autostereoscopic display, as did **Kerner Optical**.

On the stereoscopic side, **LG Display** showed a 42-in. panel that required polarized glasses to see the 3-D images, as well as a 17.1-in. panel that could be switched between 3-D and 2-D modes – electrical charges are used to change the alignment of the liquid-crystal material. **Planar Systems** showed its two-panel 3-D monitor that requires glasses.

### Thin Is In

One way that flat-panel makers are trying to differentiate their products from the competition is to come up with thinner designs. One of the most novel displays was a 42-in. WXGA panel made by **AU Optronics (AUO)** that was double-sided. The two LCD panels share the same backlight, resulting in two portrait WXGA displays that are rated at 550 nits, but draw only a combined 350 W – and the entire unit is just 57 mm thick.

**Samsung** showed a 52-in. LCD panel that was 19.5 mm thick and a 40-in. panel that was only slightly more than half the thickness, at just 10 mm. **AUO** had an LCD panel that was slightly larger at 42 in. and demonstrated an edge-lit LED backlight that was also just 10-mm thick (Fig. 3).

### Seeing Green

The environmentally friendly green theme was stronger than ever at this year's Display Week. The **LCD TV Association** launched its new GreenTV program. Models meeting the group's current standard save energy by incorporating an ambient-light sensor that automatically dims the backlight of an LCD TV.

**CMO** demonstrated an LCD panel with a high-gain optical film and a high-efficiency

## large-area displays



**Fig. 3:** AUO's 42-in. FHD LCD panel uses an LED backlight, slimming down to just 10 mm thick.

lamp. Through dynamic control of the backlight, this panel was able to reduce power consumption by about 50% compared with that of a conventional panel.

**LG Display** showed multiple 14.1-in. LCD panels. The lower-power version could operate in one of three modes: global dimming, entertainment dimming, and "spotlight" dynamic dimming that relies on data modulation.

Other designs used materials that are more environmentally friendly. One popular approach was the use of LEDs for LCD backlights. This eliminates the mercury used in CCFL backlights. **Global Lighting Technologies**, **Luminus**, and **Jabil Circuit** teamed up to demonstrate a novel approach to LCD-panel backlighting. By combining Luminus Phlat-Light high-brightness LEDs in concert with Global Lighting's expertise in backlight diffusers and Jabil's integration experience, they

were able to demonstrate a 46-in. LCD HDTV that was backlit by just 24 LEDs – an RGB triad on each of just eight "blades" produce 500 nits while drawing less than 240 W. Although the panel is edge lit, the backlight is less than 20 mm thick and supports a thin bezel design. This backlight is scheduled to go into production in the fourth quarter of 2008.

**Sharp** showed a variety of LED-backlit WXGA panels up to 20 in. on the diagonal. **NEC Displays** demonstrated a 21.3-in. QuadXGA panel with a tricolor LED matrix backlight that had the ability to adjust the color temperature of the backlight. This makes it feasible to actively maintain color temperature and luminance over time. The **Applied Science Technology Research Institute (ASTRI)** showed a 42-in. WXGA LCD panel with a white LED backlight that they claimed results in about a 30% power savings

compared to that of conventional designs. ASTRI also showed a 47-in. FHD LCD panel that had an RGB LED backlight with local dimming to increase contrast and a luminance rating of about 500 nits.

One unusual display using an LED as a light source was the Ostendo curved monitor that was on display in the **OSRAM** booth (Fig. 4). This double WXGA display relies on rear projection using Texas Instruments DLP microdisplays, with OSRAM providing Ostar high-brightness LEDs used as the light source. The monitor will be marketed by **NEC Displays** for financial and industrial applications and by Dell's Alienware Division for PC gaming. It is scheduled to ship in the last quarter of 2008.

**Samsung** demonstrated a 52-in. LCD TV that has less environmental impact than conventional ones, although it still uses a CCFL backlight. The design uses 14 tubes instead of the typical 24, and the fluorescent lamps are designed using less mercury than the standard lamps.

Companies were also demonstrating ways to make manufacturing more eco-friendly. For example, **LG Display** showed 15-in. TFT-LCDs that used roll-to-roll printing for both the TFT and the color filter. This approach could cut the cost of these production steps in half compared with current techniques.

### Higher Speeds and Integration

The 120-Hz refresh rate that was a technology demonstration just a few years ago has become old hat, with many manufacturers showing production models with this feature. **Samsung** took this a step further with their new Blue Phase technology that relies on a new liquid-crystal material that is self-aligning, eliminating the need for an alignment layer and thus may lead to reduced manufacturing costs. The technology supports up to a 240-Hz refresh rate.

**LG Display** showed a 120-Hz 37-in. FHD LCD panel that has the gate drivers integrated into the panel itself, using an a-Si substrate (Fig. 5). This Gate-in-Panel (GIP) technology results in half the number of panel connections. This not only reduces assembly costs and part counts, but increases the unit reliability. **Samsung** also had a 46-in. LCD panel with integrated gate drivers, featuring 120-Hz McFi technology.

**AUO Corp.** demonstrated a 20.1-in. WSXGA+ panel using Single Connection

**Fig. 4:** OSRAM's LEDs provide the light source for the panoramic 2880 × 900-pixel rear-projection monitor that is marketed by NEC and Ostendo.

Cascade technology, a chip-on-glass technology. The thinner panel also has a greatly reduced interconnect count, which simplifies assembly and increases panel reliability.

### OLEDs: Ready for Prime Time?

CMO had a 25-in. WXGA AMOLED demonstration panel on display, using low-temperature polysilicon (LTPS) for the TFT substrate. According to a company representative, commercial production is planned for 2009.

During one of the keynote presentations, Yoshito Shiraishi, General Manager of Sony's TV Business Group, spoke of the company's plans to increase OLED production capacity in 2009, with the aim of creating "middle- and large-sized" OLED TVs. He did not make any specific predictions about sizes, prices, or target-delivery dates.

Samsung SDI showed a 12.1-in. AMOLED intended for use as a notebook display, with production scheduled for the end of 2009. The company also demonstrated 14.1-in. WXGA and 31-in. FHD OLED panels, but there were no statements made about possible commercial production or ship dates. The company also demonstrated an AMOLED with oxide TFTs, which uses a low-temperature deposition technique that they expect will be scalable to Gen 10 substrates.

### Pico Projectors

There is a great deal of interest in the new "pico projector" segment. These tiny projectors are targeted for business and personal applications and will be small enough to be incorporated into mobile phones (although some of the first models will be designed as separate companion devices). Apparently, a number of companies had off-site demonstrations, but there were two exhibits on the floor. ASTRI showed a companion pico projector that used LEDs as the light source. Microvision, Inc., showed the SHOW pico-projector prototype that uses three lasers as the light source along with a MEMS scanning mirror imager. With WVGA resolution and rated at



**Fig. 5:** LG Display's 37-in. FHD panel demonstrated Gate-in-Panel (GIP) technology.

## large-area displays

10 lum, this prototype demonstrated improved speckle management compared with prior models (Fig. 6).

**Corning Incorporated** announced its G-1000 laser module, intended for pico-projector applications. The 530-nm green laser requires only about 60 mW and occupies a volume of 0.7 cm<sup>3</sup>. The company is aiming

for a 10,000-hour usable lifetime and has already started providing samples.

### The Big Picture

While the emphasis was decidedly on LCD technology, Display Week 2008 delivered the clear impression that large displays are getting bigger and better all the time. This segment

of the display industry shows strong development in many areas, and many companies – large and small – are actively engaged in advancing the state of the art. We are only left to wonder what Display Week 2009 will bring. ■



**Fig. 6:** Microvision, Inc.'s SHOW pico-projector prototype uses three lasers as the light source along with a MEMS scanning mirror imager to achieve WVGA resolution and a luminance of 10 lum. Photo Courtesy of Microvision, Inc.



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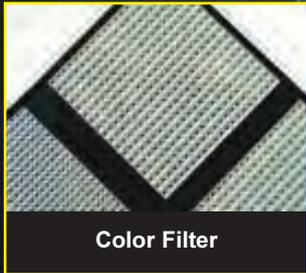
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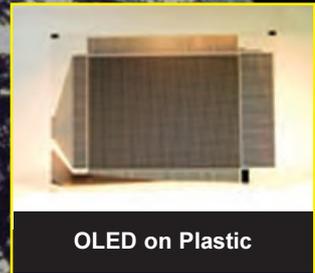
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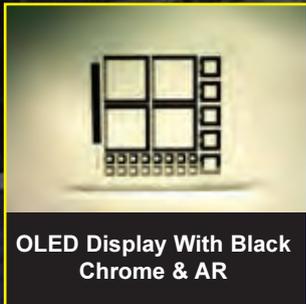
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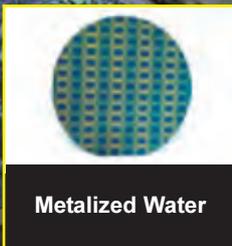
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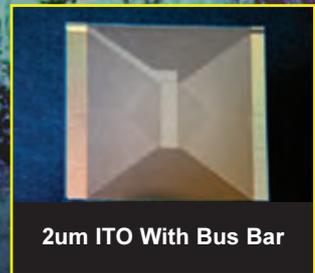
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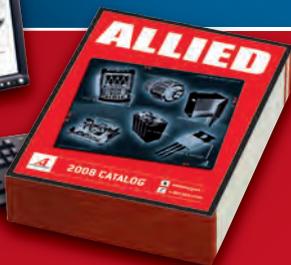
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# LCD Backlight Methodology and Applications Using Optical Enhancement Films

*A good backlight unit is essential to the performance of any AMLCD, but it is often not enough to achieve optimal optical performance. Light must be properly managed regardless of the source. This article details the vital role played by backlight enhancement films in the performance of AMLCDs.*

by Adi Abileah

**A**CTIVE-MATRIX liquid-crystal displays (AMLCDs) are transmissive devices. They do not produce luminance, but rather they act as light valves forming the image under an array of color filters and transparent regions of liquid-crystal material. Viewing an image on the front of an AMLCD panel requires a very bright and uniform source of light from behind the panel, which spreads over the entire surface area of the AMLCD. Uniformity in this case is generally defined as the same amount and color of luminance at any location in two dimensions ( $x,y$ ) behind the LCD panel. This light source is commonly known as the backlight unit (BLU).

The BLU can consist of one or multiple light sources, ranging from stick fluorescent lamps and U-shaped lamps to flat lamps or light-emitting diodes (LEDs). Most BLUs in use today use cold-cathode fluorescent lamps (CCFLs), but these are increasingly being replaced with LEDs. Other sources such as powder electroluminescent (EL) devices, field-emission devices (FEDs), and organic light-emitting diodes (OLEDs) to be used as flat lamps have been proposed and in some

cases demonstrated, but in general have rarely been used. From an optical point of view, these light sources can be divided into four categories:

1. **Line sources**, where the light emits continuously along one axis of the lamp.
2. **Multi-line sources**, where there are two or more continuous lines of emission.
3. **Area sources**, which can be envisioned as two-dimensional flat emitting surfaces.
4. **Point sources**.

However, achieving a two-dimensional uniformly lit area from these light sources is sometimes challenging. This article is concerned with methods that properly manage light from these various types of sources and specifically describes the latest technology in one of the most critical components of today's AMLCD panels: backlight enhancement films.

## Basics of BLUs

The basic steps designers use to generate uniform light from BLUs are easy to appreciate and can be summarized as follows:

- Distribute the light over an area (by multiple light sources or a light guide).
- Extract the light forward.
- Improve the area uniformity.
- Shape the angular distribution of the light.

- Control or improve the polarization state of the light to match the LCD polarizer.

However, while these steps seem simple, accomplishing these within a very thin mechanical package and maintaining an acceptable level of light loss in the process can be a daunting challenge. BLU architectures can be generally summarized as follows:

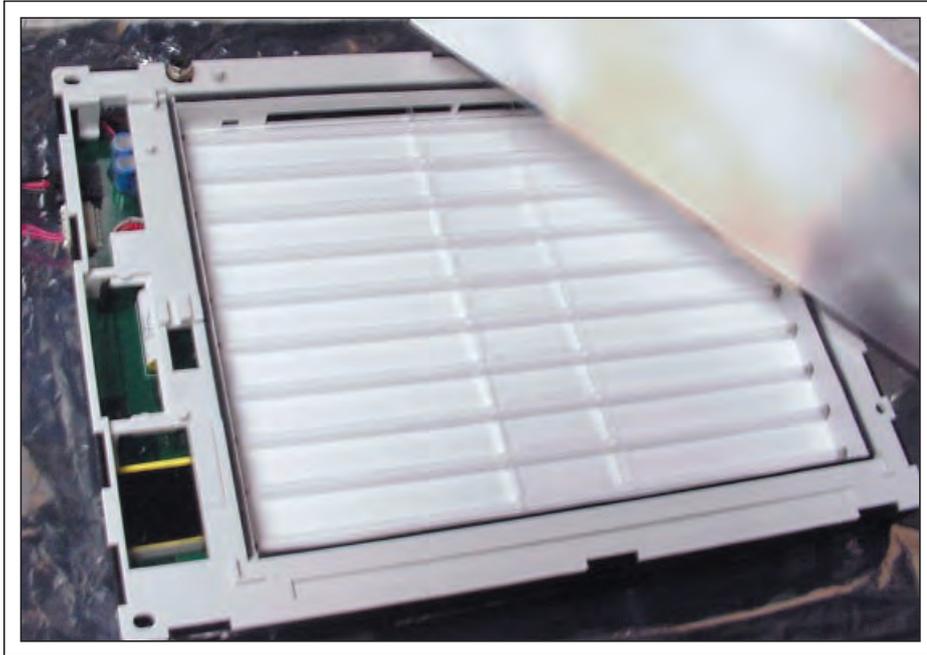
1. Multiple stick lamps in a cavity surrounded by reflecting materials – this is commonly called a “direct” or “cavity” backlight (Fig. 1).
2. Multiple two-dimensional arrays of LEDs in a cavity – this approach has been used recently for high-brightness displays for outdoor applications and for high-dynamic-range (HDR) backlights.
3. A light guide that is illuminated with edge illumination of one or multiple stick lamps where the light guide transfers the illumination from the edge to the rear of the BLU (more details on this below).
4. The same light guide as in item 3 above, but with a strip of LEDs in place of the stick lamp.

## Cavity Backlights

The cavity backlight approach (items 1 and 2 above) demands the use of a good reflecting material in the sides and rear of the cavity to capture most of the light emitted from the lamps. Here, a simple white matte reflective

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**Fig. 1:** An example of a cavity backlight with a multiple “stick” CCFL.

paint can be used, but more often designers turn to engineered diffusing white reflector films that exhibit reflectivity values better than 98% while being more stable over time and temperature than painted coatings. There are a few films on the market that can do this job, one of the most common being Enhanced Specular Reflector (ESR) film produced by 3M.

The light reflected by the rear reflector includes not only the original emission from the lamps, but also any light that is reflected back into the cavity from higher surfaces. If that light is not reflected, it will be lost, thus affecting efficiency. Therefore, in many cases, the rear reflector also serves as a recycling function as well. Some optical models based on actual designs show that some light will be reflected back and forth as often as six times. Hence, it is very important that the reflectivity of the diffuse reflector will be as close to 100% as possible. For instance, reflectivity of a mere 98% will yield only 88% of the original light component remaining after the sixth reflection. For 95% reflectivity, this recycling efficiency will drop to 74%, a 26% loss in efficiency.

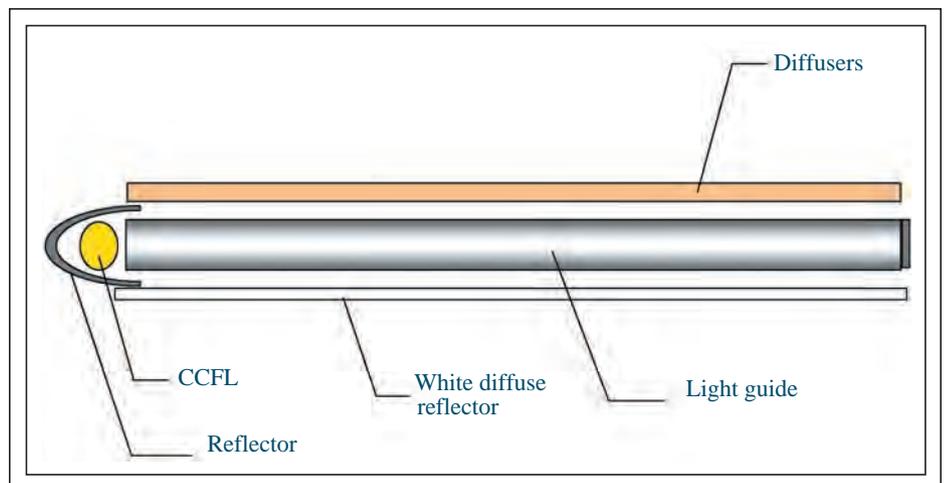
Some designs utilize mirror-reflecting surfaces (true specular reflectors). These surfaces do have a higher reflectivity than diffuse reflectors. Unfortunately, during

recycling, they can cause light to be trapped bouncing back and to the edges, thus never allowing it to escape to the front of the system. Hence, the original reflectivity advantage is negated by the lack of scattering advantage, and little measurable recycling seems to occur. Specular reflecting materials are either shiny metal or PET coated with shiny organic material. Most BLU designs today incorporate diffuse reflectors.

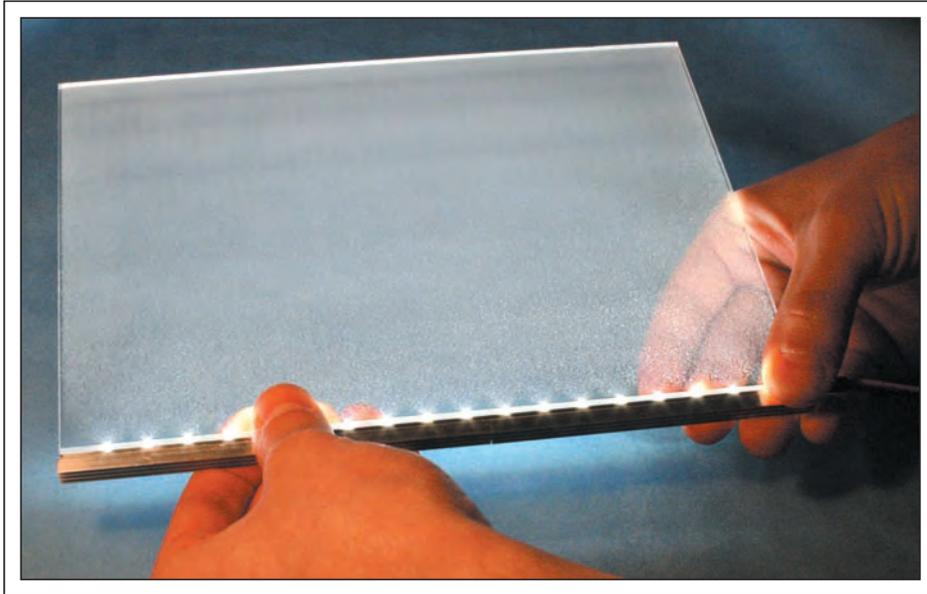
### Edge-Lit Light-Guide BLUs

In the edge-lit light-guide approach (Fig. 2), the major challenge is to capture most of the light from the source into the edge of the light guide. Collection efficiencies can range from as low as 25% to as high as 85%, which means a significant part of the optical design is affected in this first area. Higher collection efficiency can be achieved by matching the directed angles of the light source with the light-guide acceptance angles (the numerical aperture). A CCFL emits light in all directions along the long axis. In order to capture that light, a mirror reflector is typically put behind the lamp to direct all the light opposite the light-guide direction into the light guide. This reflector is usually a shiny, curved material and should have a parabolic shape with the lamp at its focal point. However, these lamps are relatively wide in diameter and cannot truly be considered as a point in the focus. In addition, because they are opaque, they block some of the light reflected from the back. Hence, most simple stick-light-based designs have only been able to achieve collection efficiencies of 40–60%.

However, recently there have been improvements, some stimulated by the use of point-source LEDs that have been equally effective in improving the collection efficiency in all edge-lit configurations. When an array of LEDs is used as the edge-light source, such as that shown in Fig. 2, the light emitted takes the form of a linear array of point sources. Not only is it important to match the acceptance angle of the edge of the



**Fig. 2:** A cross section of an edge-lit backlight.



**Fig. 3:** This LED array strip is diffused into a thin light guide using material from Fusion Optix. Note the headlight effect along the edge of the glass.

light guide, it is now also necessary to address the linear non-uniformity, sometimes referred to as the “headlight” effect (Fig. 3). This is particularly acute in systems that employ red, green, and blue LEDs rather than white LEDs. In this case, even small non-uniformities in the light mixing can produce colored headlight patterns in the resulting BLU profile. Two new generations of optical films are now being used to make this problem easier to solve:

- Film-based enhanced specular reflectors can be shaped around the LED or CCFL light sources and formed to produce the best match to the acceptance angle of the light guide without the need for expensive tooling and molding. These films are available from a number of suppliers worldwide and are achieving higher reflection efficiencies all the time.
- A new generation of light-distribution films is being used between the light source and the leading edge of the light guide to match the acceptance angle and, in the case of LEDs, to efficiently spread out the light in the linear axis to eliminate the hotspots. Candidates for this are the Brightness Enhancement Films (BEF) from 3M, which provide image-doubling capabilities in a variety of optical distances; a directional diffuser by Fusion Optix (Fig. 3), which spreads

the light in a horizontal direction but concentrates it in the vertical direction; and similar materials from Luminit, which are holographic diffusers called Light Shaping Diffusers (LSDs) with variable parameters, depending on the specific design.

While it is hard to quote specific numbers for collection efficiencies in these cases, primarily because the results are so heavily design-dependent, one can expect a 20–50% improvement in light efficiency over a similar design not employing these materials.

Once the light is uniformly and efficiently delivered onto the edge of the light guide, the problem remains to effectively extract the light from the light guide uniformly in two dimensions. The most commonly used method is a dot pattern of white reflecting material that is painted through a screen mesh on the light-guide material. The density of the dots is inversely proportional to the light emitted without any pattern; therefore, achieving uniform extraction is a matter of simply calculating the light density needed and the remaining light available at each location. For a first approximation, the density of the dots should be linearly increasing going away from the light source, and uniform in the other dimension. A white reflector is usually placed behind the light guide to direct the light for-

ward. This can be a similar film material as mentioned above (e.g., ESR film from 3M) or paint on the bottom of the housing. In some designs (e.g., those made by Global Lighting Technologies), the dot pattern is made of dot etching in the light-guide material, giving the effect of tiny lenslets. Regardless of the methodology, there is still a need to optimize the dot density for each system in order to obtain the desired uniformity.

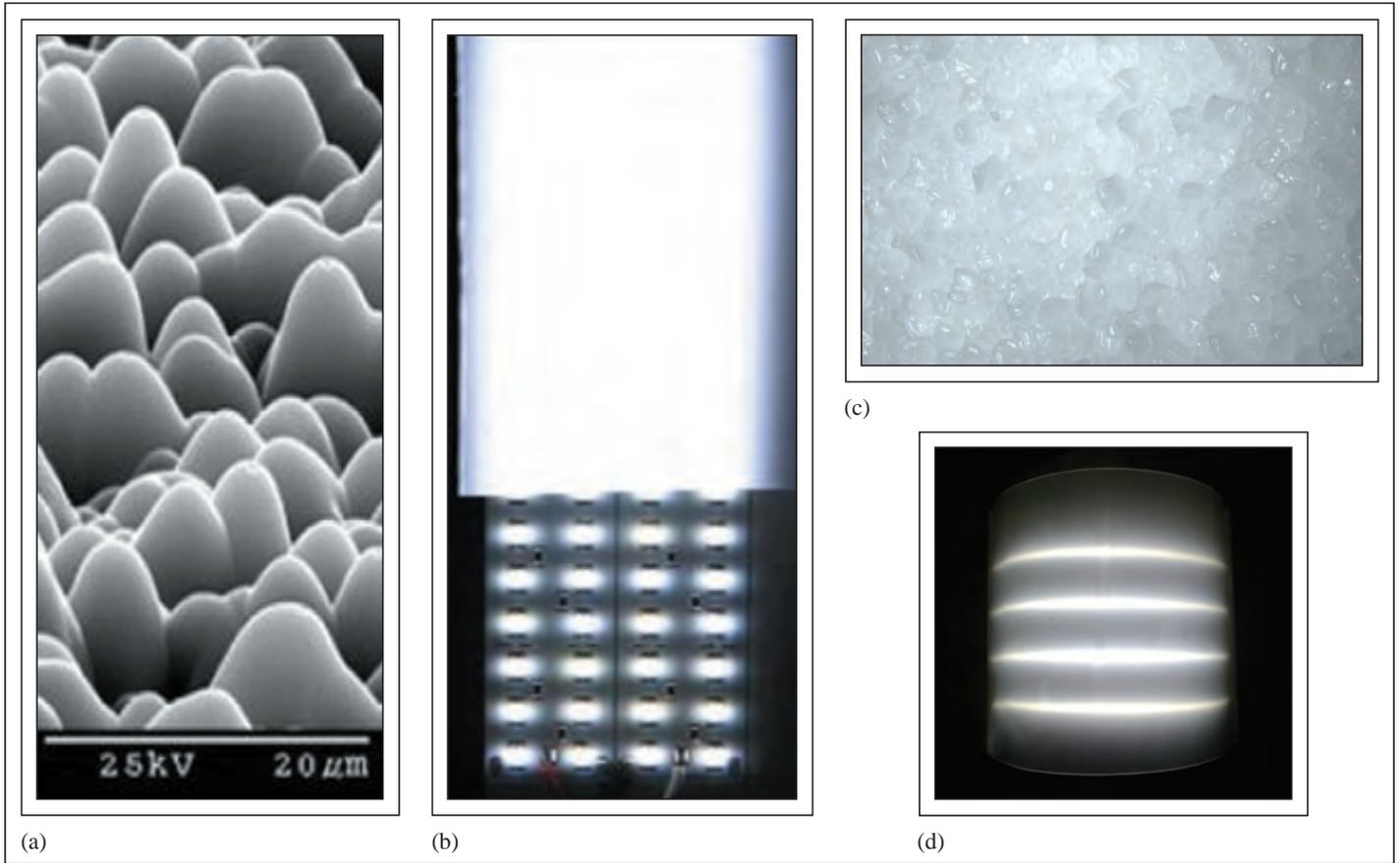
### Optimizing Uniformity and Efficiency

Now, the challenge becomes the management of the light to optimize its uniformity and to achieve the most efficient and uniform coupling possible into the LCD panel. There are usually three main steps required – diffusion, light shaping for angle correction, and pre-polarization – and they can be accomplished with as few as three or as many as six separate optical films.

First, diffusion is employed to randomize any spatial coherence in the light and make it as two-dimensionally uniform as possible, effectively re-directing the light to random directions in a distribution that is more or less Lambertian. Today, there are two main types of diffusers that both provide marked improvements over conventional frosted or “milky” glass diffusers that have been previously used.

- **Volume diffusers** are made from small pellets of plastic material that are compressed at high temperatures to generate a thin film. These films are semi-transparent and have several levels of haziness. An example is the Keiwa Shoko materials with choices of thickness and haze factors (higher and mild).
- **Surface diffusers** where the front surface of the plastic film is embossed to have multiple “hills and valleys,” which generates by refraction random orientations of light rays. For example, GE makes surface-diffuser films. Their distribution is mostly Lambertian. However, they could be designed to have preferred orientation. One example of this is the holographic diffusers being sold by Luminit, which can be made with a wide variety of image profiles and customized to a particular BLU design by optical imaging techniques (Fig. 4).

Once the light passes through the diffuser, it is presumably very uniform, but unfortu-



**Fig. 4:** (a) An electron microscope image of the surface of a holographic diffuser by Luminit. (b) A holographic diffuser from Luminit over an array of white LEDs. (c) An electron-microscope image showing the molecular structure of the bulk material of a Fusion Optix diffuser. (d) A Fusion Optix directional diffuser (elliptical) spreading light in one direction.

nately it is now very randomly oriented. Angle correction is employed next to direct the light in the desired angles through the LCD panel. In many cases, the viewing cone of the LCD is matched by the light direction from the BLU to maximize luminance in the intended viewing directions. This can be accomplished in several different ways.

**Brightness Enhancement Film (BEF).** Brightness Enhancement Film (BEF) by 3M is the most commonly used film in backlights. Its purpose is to concentrate the light in one direction. For instance, people view displays mostly horizontally from the center and not to the vertical extremes of the screen. Therefore, concentrating the vertically directed light into a narrower cone of luminance increases the efficiency significantly. BEF films are prismatic in nature and generally cause steering of light in one linear direction at a time. They behave similar to a

cylindrical Fresnel lens with a horizontal axis and focus at infinity.

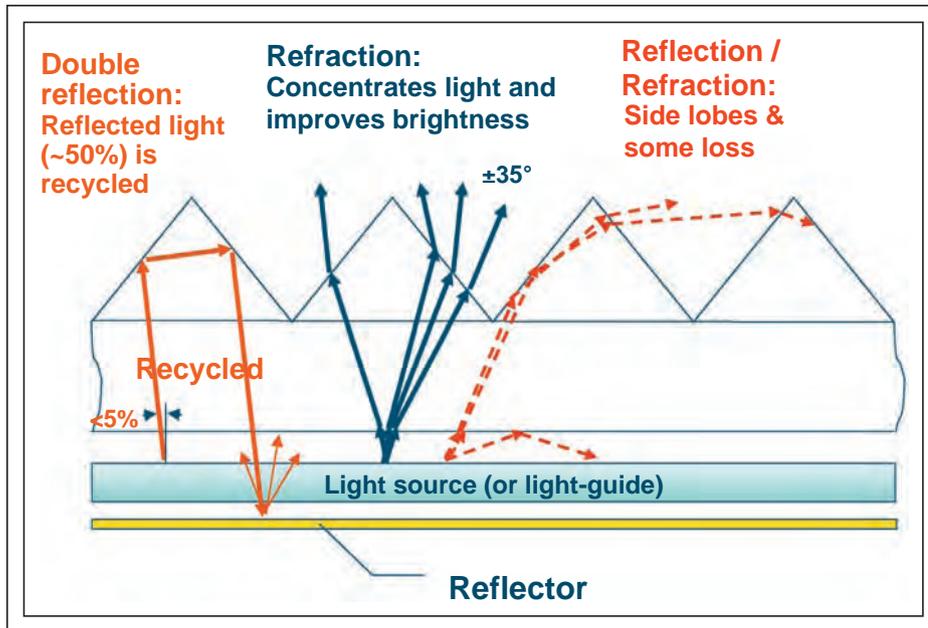
One additional property of the BEF is its image-splitting property, which makes each point appear to be a doublet of points. This fills the gaps and makes the light more uniform. The BEF materials have mostly grooves that have a top angle of  $90^\circ$  (a right angle). The facets are smooth and generate refractions to smaller angles of light coming from below, causing a concentration of light. However, at very small angles, the facets act as retro-reflectors, reflecting the light backwards. Therefore, it is important to have good reflectors at the bottom of the structure to capture this light and re-cycle it forward.

A variety of films are available, but all are characterized by a top angle ( $90^\circ$ ) and pitch between the grooves (e.g.,  $50\ \mu\text{m}$ ). BEF II is a polyester substrate having an acrylic resin prismatic structure that is coated. It comes in

top angle ( $^\circ$ ) / pitch ( $\mu\text{m}$ ) combinations of 90/50 or 90/24. The newest films (BEF III) come in variable (random) prism heights to reduce the Moiré effect caused by the pixel structure. The versions with notation M (Matte) indicate that the sharp edge of a prismatic structure is softened and the bottom surface is treated to give a softer fall-off in brightness as a function of the angles. The versions with notation T mainly indicate very thin film. The principle behind a BEF film is shown in Fig. 5.

**Light-Shaping Devices (LSDs).** Light-shaping devices (LSDs) made by Luminit (a division of POC) is a family of films that serves as a diffuser with an embossed surface. However, the “hills and valleys” are programmed to have an angular behavior with concentration along one axis that is different relative to the other, generating an elliptical cone of concentration. In some cases, it is

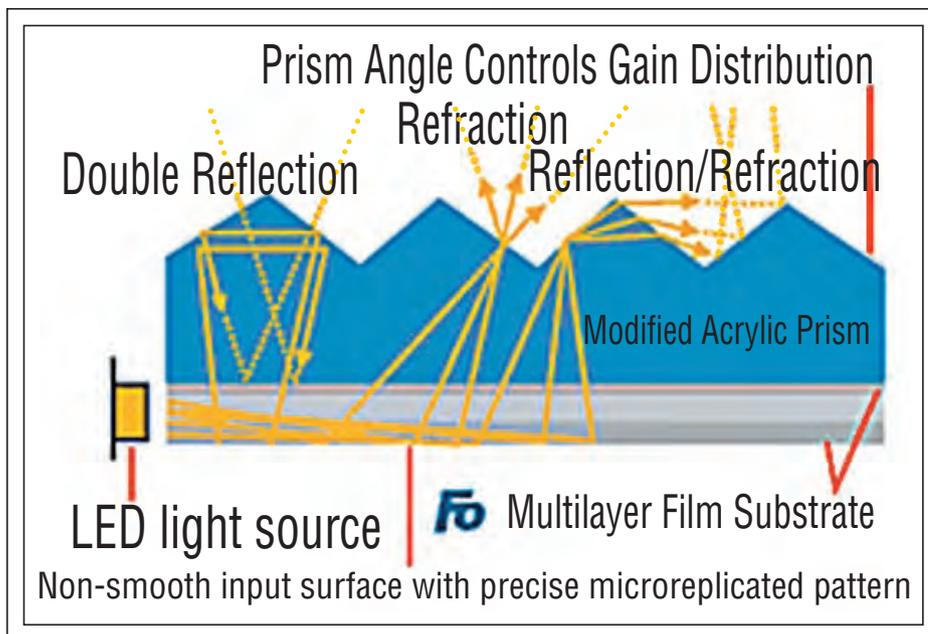
## components focus



**Fig. 5:** The basic behavior of optical rays in brightness-enhancement films (BEFs).

circular. The master pattern to the embossing is made by a hologram using a laser as a diffused light source. For this reason, this element is referred to as an holographic optical

element (HOE). One specific advantage of LSDs is that they can be tuned to a variety of two-dimensional distribution angles, reducing the total number of intermediate films required.



**Fig. 6:** A structure of a side-illuminated LED backlight using a Fusion Optix light-control material embedded with a prismatic structure to enhance the illumination.

**Alternate Prism Films.** Alternate prism films from companies such as Fusion Optix (Fig. 6) have recently entered the marketplace as a direct competitor to 3M's BEF. These combine two types of materials: volume diffusers and prism films. The volume diffusers, which in this case are the molecules of proprietary materials that behave non-symmetrically, are embedded within a resin that has a different index of refraction. With pre-defined recipes, they will achieve angular behavior as a concentration effect. The prism films are very similar to the BEF materials of 3M and behave as concentrators in one direction as explained above.

Often, designs employ two to as many as four intermediate light-steering films to tailor the angular distribution of the light to their needs. This is a relatively expensive process; in general, these materials cost many dollars per square foot. Many companies are actively working on further improvements that combine the properties of both diffusers and prisms. This is ongoing work that bears watching in the coming years.

As a final step, the light coming after the diffuser and BEF is mostly uniform over area and is concentrated in the preferred direction that it will be used after the display. However, the light has all directions of polarization. The bottom of an LCD has a polarizer that transmits in one direction and absorbs light from other orientations. To further improve the light efficiency, developers have been turning to reflective pre-polarizers that pass only the light with the correct polarization orientation and reflect all other orientations. 3M pioneered this material to reflect the unused polarization back to the light guide where it can hopefully be recycled. The material is called Double Brightness Enhancement Film (DBEF). This material needs to have a proper reflector underneath to recycle the reflected polarized light. When the light goes back into the light guide, it reflects against the rear surface and its polarization orientation is rotated. When it returns to the top of the stack, it is now in a suitable orientation to pass through the LCD. The recycling bounce can happen many times, but there are significant losses each time.

The BEF is a good reflector at small angles coming from the top because it has a retro-reflector characteristic (for small angles) and therefore the BEF helps to recycle light reflected by the DBEF. Polarizer-manufac-

urer Nitto Denko is making a product called Polarization Conversion Film (NIPOCS), which is a DBEF laminated to the bottom of a polarizer, applied directly to the AMLCD panel.

The amount of light efficiency improvement using the reflective polarizers is highly dependent on the overall BLU design. Theoretically, efficiency gains as high as 100% should be achieved. However, practically, the DBEF gain is between 30% and 60% (luminance increases to 1.3x-1.6x). The DBEF material is maintaining the angular behavior and neutral colors, but will work well only with proper reflections behind to recycle the reflected polarized component of the light.

### Conclusion

It is easy to imagine that a significant development effort is ongoing in the optical-films sector. In the past 10 years, the improvements realized with new materials have generally doubled the light efficiency of BLUs. It is conceivable that the next wave will be homogenized films that perform several functions at once, resulting in an overall reduction of individual layers and thus further reducing cost. While this article has noted the offerings mainly from several U.S.-based companies, several Asian companies are also producing similar competitive products and pursuing similar paths of innovation. ■

*We are always interested in hearing from our readers. If you have an idea that would make for an interesting Business of Displays column or if you would like to submit your own column, please contact Mike Morgenthal at 212/460-9700 or email: mmorgenthal@pcm411.com.*

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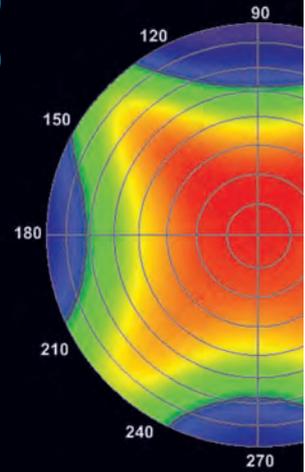
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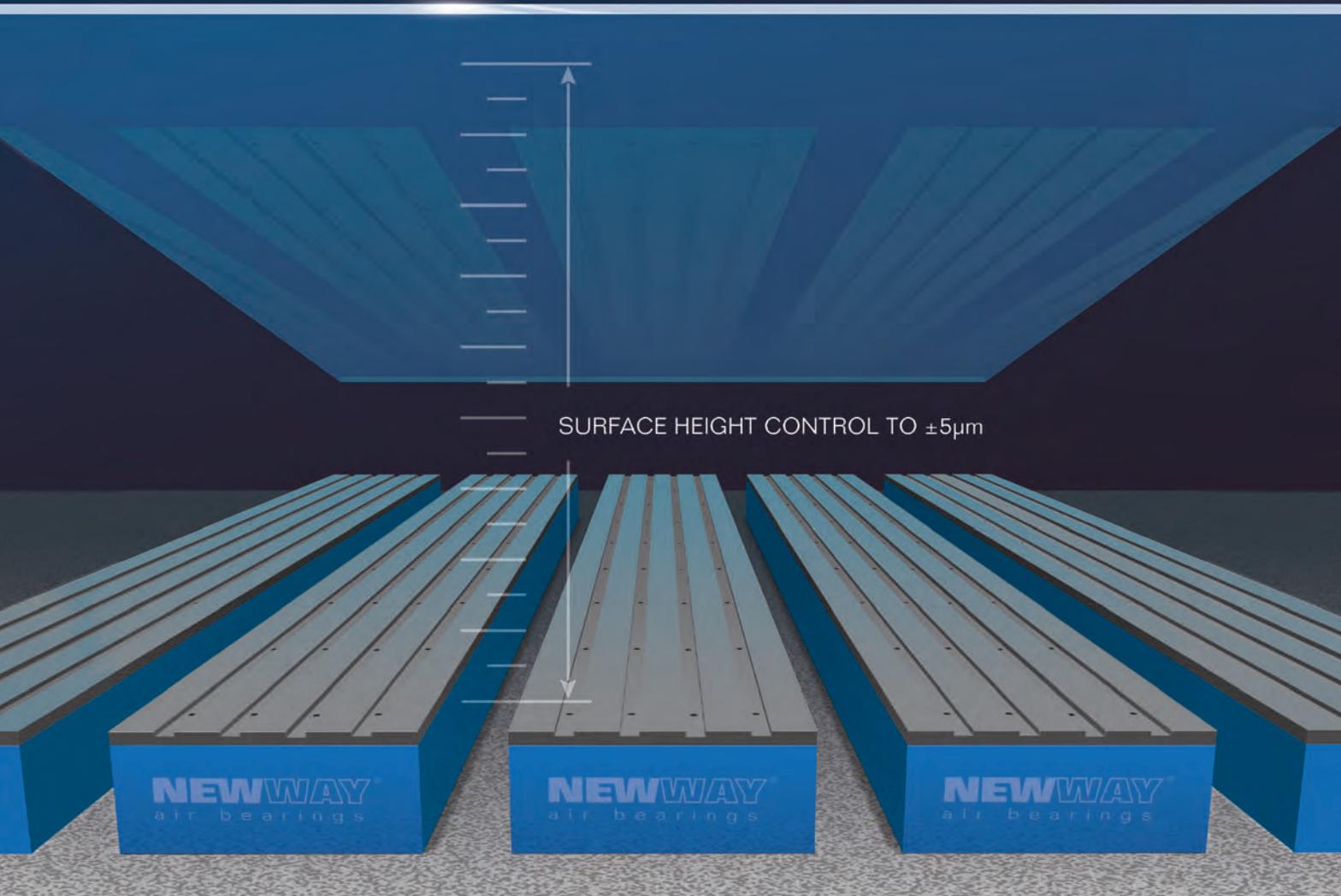
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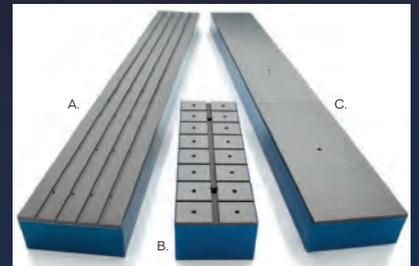
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# OLEDs Shift Up a Gear as Developers Get Creative

*The impressive array of OLED displays and prototypes at Display Week 2008 speak to the increasing acceptance of the technology as a legitimate display format. Developers are getting more creative with their offerings, and discussions are shifting from issues such as lifetime to overall performance.*

by Craig Cruickshank

**H**ISTORY MAY WELL JUDGE 2008 to have been a pivotal year for the evolution of organic-light-emitting-diode (OLED) technology commercialization, and Display Week 2008 certainly played a key role in bringing this to the attention of the display community. Technical progress in OLED displays was quite rapid in the 12 months leading up to Display Week 2008, with key advances in materials, device architecture, optical performance, and manufacturing processes, all coming to the fore this year, along with a serious attempt to prove that broad commercialization is finally close at hand. Certainly, the amount of money being invested in product development and manufacturing infrastructure for OLEDs is increasing faster than ever before, and the impact can be seen in the growing maturity of demonstrators and increasing focus on applications rather than the technology itself.

The consistent message from the likes of Sony, Samsung, and Seiko Epson was clear – the active-matrix OLED (AMOLED) is being positioned as a high-end display for applica-

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**Fig. 1:** Among the most talked-about OLED displays at the Samsung SDI booth was its 31-in.-diagonal full-high-definition (FHD) AMOLED, a 1920 × 1080-pixel display that utilized the company's super microcavity bottom-emission technology.

tions that demand superior image quality. Display Week 2008 featured numerous demonstrations of large-sized full-HD OLED-television formats as well as many innovative smaller-sized OLED prototypes in applications such as notebook computers, PDAs, electronic passports, and even wearable displays. The breadth of OLED products at Display Week 2008 was particularly impressive, ranging from large-area (31-in. on the diagonal) displays and smaller displays suitable for portable and mobile products, to microdisplays for head-up displays and viewfinders, to digital signage/lighting for information and illumination.

Another sign of growing industry confidence in OLED technology at Display Week 2008 was the notable shift away from debate over OLED lifetimes toward discussions of the look and feel of the actual OLED displays. With that in mind, here is a look at the most significant OLED developments at Display Week 2008.

**Samsung SDI** showed a wide range of OLED displays this year, from very small to very large displays. Its largest display was a 31-in.-diagonal full-high-definition (FHD) AMOLED, a 1920 × 1080-pixel display that utilized the company's Super Microcavity Bottom Emission technology (Fig. 1). This

display attracted a great deal of attention and buzz on the show floor because the overall quality of the display was simply stunning. The marriage of OLED displays and high-definition (HD) content creates an incredible viewing experience. OLED displays offer unique crispness and warmth not found in technologies such as LCD or plasma, while HD provides image detail beyond what most viewers have experienced. An attendee who was looking at the Samsung SDI display said it best: "It's like looking through a window that does not have any glass."

In addition to the large FHD display, Samsung SDI also showed several "concept applications" that used OLED displays in a novel way, including

- A rather stylish notebook computer (Fig. 2) featuring a 5-in. WVGA 800 × 480-pixel OLED display having a thickness of just 1.21 mm and power consumption of 828 mW (250 cd/m<sup>2</sup> at 30% on).
- A laptop with a 12.1-in. 1280 × 768-pixel AMOLED display (Fig. 3).
- A high-tech golf glove featuring a 3.1-in. WVGA (800 × 480) OLED display that consumes 434 mW of power (Fig. 4).
- An electronic passport concept developed in partnership with the Bundes-

druckerei in Germany, featuring a 2-in. QVGA AMOLED display (Fig. 5).

**LG Display** showed a 15-in. XGA (1024 × 768) AMOLED display that utilized a novel manufacturing process known as Dual-Plate technology, whereby the OLED display is made on the surface of the encapsulation glass and the a-Si active-matrix backplane is fabricated on the other glass substrate (Fig. 6). The two dependent parts are then joined together via contact spacers.

LG Display anticipates that the Dual-Plate technology will lead to an overall reduction in manufacturing costs for two reasons: it uses lower cost backplane technology and it increases yields. LG Display said that this technique is specifically for large-area displays and is not expected to be adopted for manufacturing small- and medium-sized displays. LG Display officials offered no confirmation on if or when this technique would be deployed in practice.

At Display Week 2008, the **Cambridge Display Technology (CDT)** booth had fewer displays than in previous years; however, two exhibits that caught my attention were the Add Vision fully screen-printed displays (see below) and the OSRAM OLED lighting tiles (Fig. 7). The fact that the OSRAM product



**Fig. 2:** Samsung SDI showed several concept applications featuring OLED displays, including this stylish notebook computer featuring a 5-in. WVGA 800 × 480-pixel OLED display with a thickness of just 1.21 mm.



**Fig. 3:** Samsung SDI showed several concept applications featuring OLED displays, including this laptop with a 12.1-in. 1280 × 768-pixel AMOLED display.

# OLEDs



**Fig. 4:** This golf-glove concept from Samsung SDI shows one potential use for AMOLED displays.

**Fig. 5:** Samsung SDI's electronic-passport concept featured a 2-in. QVGA AMOLED display.

was showcased at the CDT booth means that it is made of a polymer-based OLED (P-OLED).

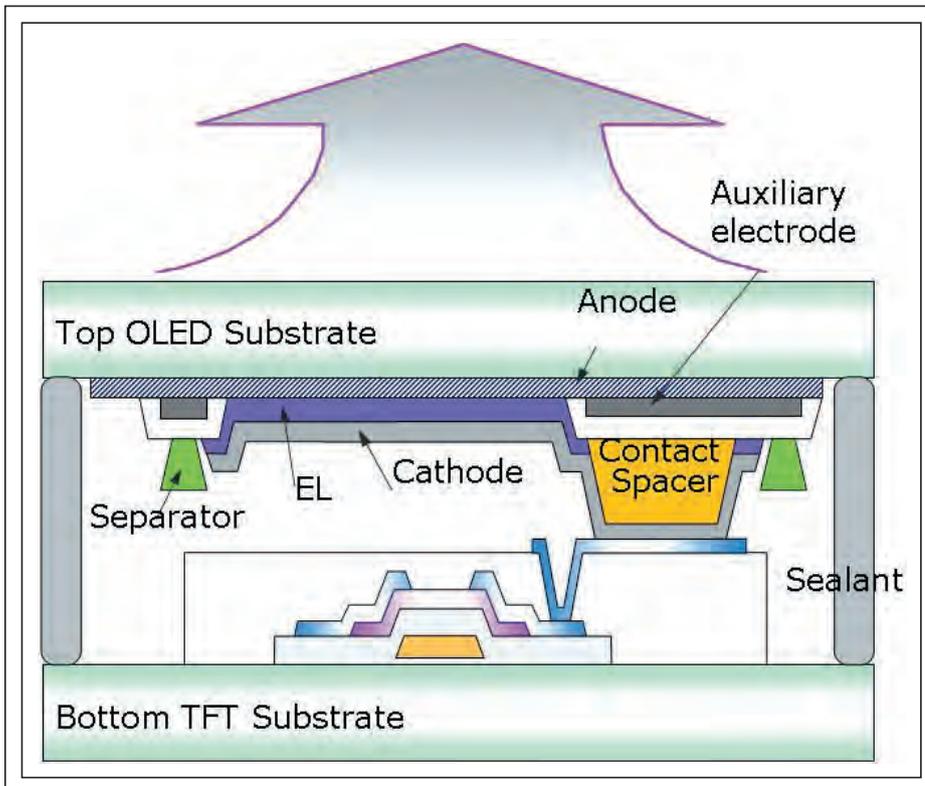
CDT CEO David Fyfe stated during the investor conference that the recent OSRAM "future wave" OLED lighting demonstrator was based on polymer materials – an interest-

ing development. Does that now mean that polymer-OLED (P-OLED) technology will soon be hitting the market in OLED lighting? Perhaps not just yet, as the recently announced OSRAM OLED lighting product "early wave" is, according to OSRAM literature, based on small-molecule materials and not polymer.

Given the rapid performance improvement of P-OLED technology over the past few years, it may not be long before P-OLED lighting products are commercially available. CDT was actively promoting its total matrix addressing (TMA) and top-emission P-OLED technology.

While most OLED displays at the show were of high quality, made on glass and expected to last several years, it is not the only option available. CDT's Add-Vision (Fig. 8) offers flexible screen-printed P-OLED displays for low-resolution and specialty-lighting applications. These fully printed segmented displays have an impressive high-quality look and feel about them, especially considering that they are not expected to last long.

**DuPont Display** finally announced and presented its novel deposition technique known as the "Nozzle" printing process (a combination of coating and printing), which it developed in partnership with Dai Nippon Screen. This certainly generated lively discussion among attendees on the pros and cons of this novel deposition technique. DuPont's philosophy is to achieve superior performance at low cost via the close matching of materials and process – in this case, phosphorescent solution-processed materials and nozzle printing. Displays produced by this novel deposi-



**Fig. 6:** A schematic of how LG Display's Dual-Plate manufacturing process works.

tion technique seem to be of high quality (Fig. 9). DuPont plans to make the materials, process, and equipment available as a complete package commencing in 2010. DuPont Display will be installing Dai Nippon Screen Gen 4 equipment at the company's pilot-line facility in Santa Barbara, California.

The OLED displays shown by *Seiko Epson* featured what can only be described as superb contrast. Seiko Epson believes that achieving such high-contrast images is vital for positioning OLEDs in consumers' minds as the must-have display technology. The company describes this contrast as the "Ultimate Black." The OLED displays shown at its booth were 8 in. on the diagonal with a resolution of  $800 \times 400$  pixels, a luminance of  $200 \text{ cd/m}^2$ , and a contrast ratio of  $>100,000:1$ . The company plans to accelerate efforts to develop uses for OLED displays that benefit from superior image quality.

Seiko Epson started research and development of OLED technology way back in the mid-1990s. The company has been a long-term advocate of polymer solution-processing, but the displays on show were fabricated by vacuum deposition. Furthermore, Seiko Epson reports that it has successfully achieved OLED lifetimes (T50) in excess of 50,000 hours. The device architecture consisted of a white emissive layer coupled with a RGB color filter.

The company has already installed and commenced operation of a development and manufacturing facility in Nagano, Japan, capable of small-scale production. A Seiko Epson spokesperson said that the company might enter the market in a year's time, most likely using solution-processing as its production technology.

*Kodak* showed a portable AMOLED TV known as the EliTe Vision KTEL-30W. Currently available only in Japan and Brazil, this product, having a 3.0-in. QVGA AMOLED display, is a great example of the potential of OLED displays in consumer products (Fig. 10).

Flexible OLED displays, OLED lighting, and transparent OLED displays could all be found at the *Universal Display Corp. (UDC)* booth this year. The top-emitting flexible display, made in collaboration with LG Display, was fabricated on a metal-foil substrate and was shown on a rotating fixture, convincingly showcasing many of OLED's strongest attributes: thinness, viewing angle, and no color shift. UDC also reported progress with printable phosphorescent materials in Paper



*Fig. 7: OSRAM's P-OLED lighting tiles at the CDT booth.*

22.2, presented in conjunction with Seiko Epson Corp. In terms of material performance, UDC continues to improve lifetime, efficiency, and color of its printable phosphorescent materials. Lifetimes of red ( $100,000$  hours at  $500 \text{ cd/m}^2$ ) and blue ( $6000$  hours at  $500 \text{ cd/m}^2$ ) have doubled since last year, and green is now  $63,000$  hours at  $1000 \text{ cd/m}^2$ . However, the long-life blue material has not yet reached a suitable "deep blue" as required for commercial adoption.

OLED lighting also featured prominently at the UDC booth. The company presented performance data on two white OLED devices achieved by optimizing materials and device structures and including outcoupling. The first device achieved  $30 \text{ lm/W}$ , at a luminance of  $1000 \text{ cd/m}^2$  with more than  $200,000$  hours of lifetime and appeared as a "warm" white ( $0.45, 0.46$ ). According to UDC, this performance is suitable for market entry of simple lighting products. The second device achieved

# OLEDs



**Fig. 8:** CDT's Add-Vision offers flexible screen-printed P-OLED displays for low-resolution and specialty-lighting applications.

higher efficiency – 72 lm/W at the same luminance (1000 cd/m<sup>2</sup>), although at a different and unspecified lifetime. **LG Chem** supplied both transport and injection materials.

OLED microdisplays also appear in both flavors: small-molecule and polymer versions. **MicroEmissive Displays (MED)** showed a range of headsets having Eyescreen™

P-OLED microdisplays. These QVGA 6-mm-diagonal microdisplays use silicon active-matrix backplanes with a white P-OLED emitter and color filters and require less than 25 mW of power. MED reported it has now shipped 60,000 units for use in the Estar headsets. At the time of the show, these headsets were only available in Asia.

In contrast to MED, **eMagin Corp.** offers higher-resolution small-molecule active-matrix OLED microdisplay technology. eMagin announced its SXGA OLED-XL microdisplay, requiring less than 200 mW under typical operation. This 0.77-in.-diagonal display has a resolution of 1280 × 1024 pixels.

**Ignis Innovation** has positioned itself as an independent open-source provider of active-matrix-backplane technology for the emerging AMOLED market. The company has developed in-pixel compensation circuit technology coupled with pixel drivers that reduce the “image sticking,” improves lifetimes, and eliminates brightness variations – “mura” was experienced by both LTPS or a-Si backplane technologies. The company envisages that such an open-source approach effectively eliminates the need for a vertical structure manufacturing approach, opening up the market for AMOLED displays. No longer are manufacturers reliant on the need to build their own active-matrix capacity; instead, they can purchase active-matrix backplanes via Ignis Innovation partners.



**Fig. 9:** This AMOLED display from DuPont Displays utilizes a Chi Mei Optoelectronics LTPS backplane.



**Fig. 10:** Kodak's EliTe Vision KTEL-30W portable TV, currently available in Japan and Brazil, features a 3.0-in. QVGA AMOLED display.

## Conclusion

Display Week 2008 once again provided attendees with the latest developments in OLED displays. The products on the exhibition floor and the papers presented at the symposium continue to demonstrate that there is growing confidence that developers of OLED displays understand the basic technology, understand its nuances, and are beginning to master the process of creative design. The opening speaker at the Business Conference was Gildas Sorin, CEO of *Novaled*, who said that "OLEDs are the new LCDs." Looking at the products at the show, I would tend to agree. Sorin also made the statement that the OLED industry would benefit from greater cooperation among the major OLED developers. The launch of the OLED Association is clearly a move toward creating the necessary framework for collaboration. I am already looking forward to next year's show to see what progress the next 12 months brings in terms of OLED display development. ■

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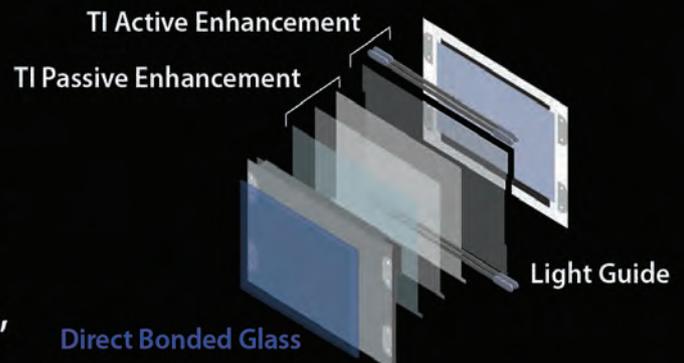


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# Display Components Focus on Energy Savings at SID's Display Week 2008

*As with every industry, there is a terrific focus currently in the display industry on manufacturing more environmentally friendly products. The components showcased at Display Week 2008 showed how far the industry has come in addressing this vital issue.*

by David Eccles

ONE of the major themes at SID's Display Week 2008 in May was energy savings for LCDs, and components and systems shown on the exhibit floor are leading the charge for increased brightness and power savings. Recent improvements in transmission efficiency for LCD panels and backlight systems with brightness-on-demand have reduced operating power in some cases by as much as 50%. Now it seems that LCD component suppliers have teamed up to deliver higher brightness with less power for less cost – to quote the 1980s TV series “A-Team,” “I love it when a plan comes together!” So does that mean we are going to save money on the ever-increasing cost of energy, or will we simply spend it on new and better displays?

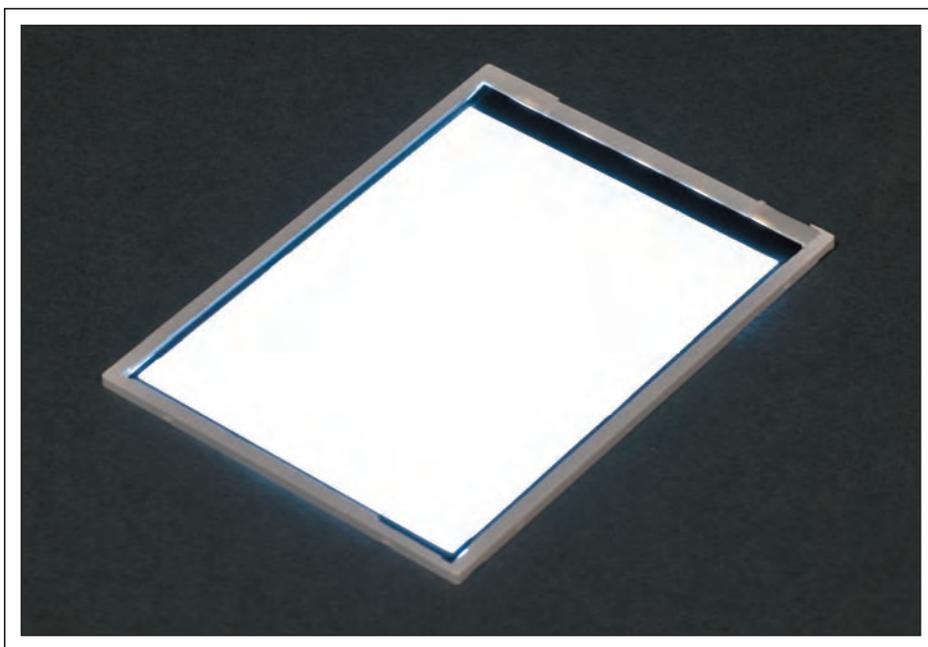
Dramatic improvements in backlight units (BLUs) and optical filters have resulted in increased light transmission from the backlight through the LCD panel and to the viewer's eye. Product designers now have the option of either increasing the brightness or saving power compared to existing products. Typically, only about 5% of the backlight luminance makes it out to the viewer, so any improvement in diffusers, films, and coatings can result in brighter displays that use less

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power. In the case of portable displays, it can mean longer battery life.

The revolution in light-emitting-diode (LED) backlight units has led to more than just deeper color compared to old cold-cathode fluorescent (CCFL) backlights; it has led to brightness-on-demand which basically results in power-on-demand. LED BLUs

allow designers to segment individual backlights into zones and to dynamically adjust their brightness levels as the particular video scene demands. By turning down the LCD backlight in dark scenes and locations when and where it is not needed to be fully on, power savings of as much as to 50% can be realized.



**Fig. 1:** In its booth, GLT showed a 46-in. LCD TV demonstrating its MicroLens™ edge lighting consisting of eight edge-lit light guides called “blades” that utilize a total of only eight PhlatLight LED modules, with excellent uniformity and color mixing.

**Luminus Devices** and **Global Lighting Technologies (GLT)** teamed up to win the 2008 SID Display Component of the Year Gold Award. The PhlatLight BLU integrates Luminus's PhlatLight LEDs with Microlens™ light guides from Global Lighting Technologies, thus requiring only eight RGB chipsets to illuminate a large-screen LCD. Other LED backlight units require hundreds, or even thousands, of conventional LEDs to achieve adequate brightness and uniformity. By requiring fewer LEDs, the PhlatLight BLU dramatically reduces the cost and complexity of LED backlighting for large-screen TVs, enabling enhanced brightness and color uniformity over the life of the TV. Moreover, because it is edge-illuminated, the PhlatLight BLU also enables thinner LCD-TV designs.

**GLT** demonstrated its new MicroLens™ light-extraction technology, which allows fewer LEDs to be used in ultra-thin edge-lit backlights for products ranging in size from smart phones to 50-in. TVs (Fig. 1). In its booth, GLT showed a 46-in. LCD TV demonstrating MicroLens™ edge lighting. Working with **Luminus Devices**, supplier of PhlatLight™ LED modules, and **Jabil Circuit**, GLT has developed a 46-in. LCD-TV backlight consisting of eight edge-lit light guides called "blades" that utilize a total of only eight PhlatLight LED modules, with excellent uniformity and color mixing. GLT also demonstrated some impressive products that have been enabled by the improvement in backlight efficiency, including the use of only one LED to light the Ford Mustang gear shifter and only one LED to light Honeywell thermostats (enabling longer battery life).

**FujiFilm** won the 2008 SID Display Component of the Year Silver Award for its WV-EA film, which improves the viewing angle for twisted-nematic-mode LCDs (TN-LCDs) (Fig. 2). TN-LCDs are notorious for having a narrow viewing angle, but adding the WV-EA film improves the angle and also reduces the gray-scale inversion. The improved viewing angle at a contrast ratio of 10:1 is 160° in both the horizontal and vertical directions. The film, which can be added without any change in the panel manufacturing process, also improves the light transmission to 7% vs. 4% typical for vertical-alignment (VA) LC panels. The impact to the industry is that lower-cost TN-LCD panels can match the performance of some higher-cost VA panels. And most customers are indeed concerned about cost.

Have you ever dropped your cell phone and broken the display? **Corning** learned that the leading cause of failure was a sharp object hit on the screen, leading the company to develop Gorilla Glass. The new thin-sheet glass with chem-strengthening provides a highly durable scratch-resistant LCD cover. It is an environmentally friendly alumino-silicate glass produced with Corning's proprietary fusion-draw process without any heavy metals. Fusion-draw technology enables the production of

uniform thin sheets with a pristine surface. By making a deep compression layer in the ion-exchange process, they develop stronger glass for cell-phone, automotive, and TV applications. Corning claimed one other added bonus – Gorilla Glass is "Wii proof" (who hasn't let a Wii game controller slip out of your hand as you threw it at the TV?).

**3M Optical Systems Division** is into recycling – recycling light. Its dual brightness-enhancement film (DBEF) is the world's first



**Fig. 2:** FujiFilm's WV-EA film improves the viewing angle and reduces gray-scale inversion for twisted-nematic-mode LCDs (TN-LCDs). At a contrast ratio of 10:1, the improved viewing angle is 160° in both the horizontal and vertical directions. The film also improves light transmission to 7% vs. 4% typical for vertical alignment (VA) LC panels.

## display components



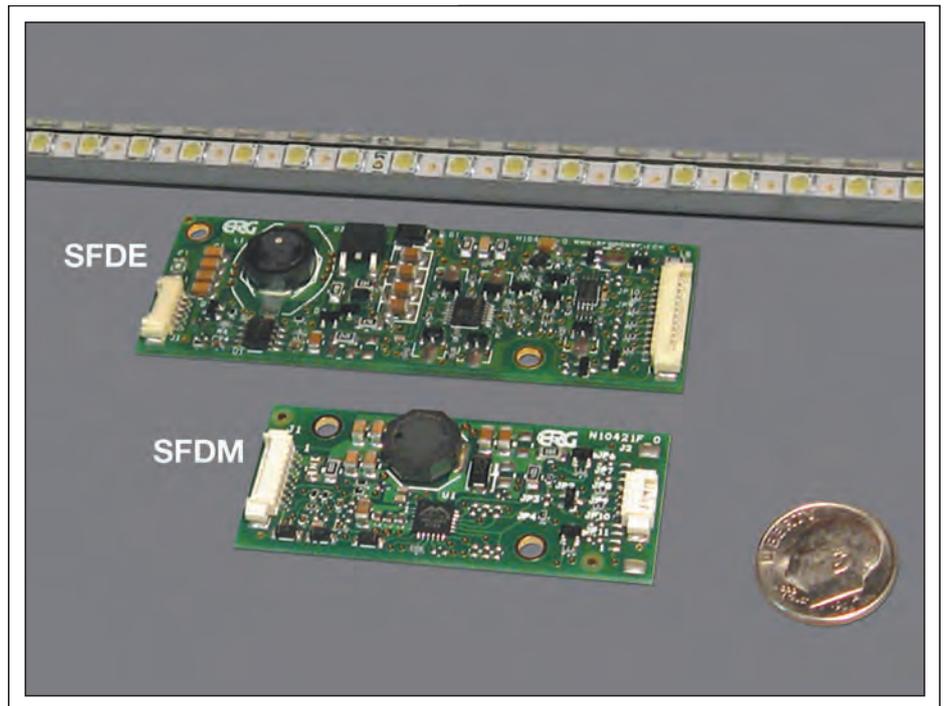
**Fig. 3:** Digital View controllers allow digital-signage displays to be monitored remotely and adjusted for varying conditions, including saving power by turning down the brightness at night.

reflective polarizer. As a multilayer film, it increases the efficiency of LCDs by recycling light for higher brightness. At Display Week, 3M introduced the highest-gain prism film on the market, the Vikuiti Brightness Enhancement Film (BEF)-G2, which increases brightness up to 10% over their current prism film. 3M showed a 32-in. LCD TV optimized with its various films that ran on 60 W – a 50% savings compared to similar-sized TVs. The company claimed that by recycling light, it can provide 30% energy savings for monitors and up to 50% for TVs.

**Digital View** demonstrated new products designed to aid in compliance monitoring of digital-signage applications. Digital View provides both networked and remote internet access to serial devices including an advanced LCD controller and a variety of add-on enhancement products providing monitoring and control of temperature, power, ambient light, cooling, and general-equipment status. Their products allow digital-signage displays to be monitored remotely and adjusted for varying conditions, including saving power by turning down the brightness at night (Fig. 3). Digital View also provides LCD controllers up to high-resolution (1920 × 1080 pixels) for harsh environments.

**Microsemi** has not been content with its market lead in CCFL BLU controllers, so the company introduced the DAZL (digital advanced zone lighting) LED BLU family of controller chips. The DAZL chips monitor and control voltage and current for LED strings and can provide the advanced features of scanning backlights and zone dimming. Microsemi's LED controller chips were featured in the **Chi Mei Optoelectronics (CMO)** booth, where a standard 42-in. LCD TV with a CCFL backlight was compared to the new version with an LED backlight with 80 zones. The power meters showed that the CCFL LCD consumed 187 W while the LED version with zone control consumed from 60 to 90 W, depending upon scene material – once again, power savings of about 50% were achieved by using intelligent LED backlight controls.

**Solomon Systech**, a leader in display controllers for portable devices, launched a series of new single-chip TFT-LCD drivers with dynamic backlight control that can reduce backlight power consumption by as much as 50% for portable devices. Since the backlight consumes the most power in portable applica-



**Fig. 4:** ERG's new SFDE (Economical) and SFDM (Mini) Series of LED driver boards provide full-function power supplies with optimum power for high brightness as well as lower power consumption and lower cost in exceptionally compact sizes. Both are less than 5 mm in height, can power up to six LED strings, and provide brightness stability over a wide input voltage.

tions, this savings translates into longer battery life. Solomon Systech also introduced the SSD1961, a new multifunction display-controller IC. It is a low-cost low-power display controller for mobile and handheld applications and has an embedded frame buffer for seamless integration between the host processor and LCD panel, as well as incorporating Solomon's backlight power-saving technology. The company also provides bistable display drivers for e-paper products, which offer the ultimate in power savings.

**Endicott Research Group (ERG)** introduced new product lines of dramatically smaller driver boards for LED and CCFL LCD backlights. The new drivers are less than 5 mm in height, can power up to six LED strings, and provide brightness stability over a wide input voltage.

"The demise of CCFL backlights has been exaggerated," said ERG Sales & Marketing Director Bill Abbott. "They will be around for a while for a number of applications that do not require the higher performance and higher price of LED backlights."

The CCFL inverters also come in single- and dual-lamp versions with dimming and feature a low profile (< 6 mm high) and a ruggedized transformer for wide temperature ranges. ERG demonstrated 8.4- and 10.4-in. LED-backlit TFT-LCDs with a luminance of 1000 nits driven by new Smart Force™ driver boards, as well as a 6.5-in. OEM LED-backlit LCD with 800 nits of luminance powered by the new miniature SFDM driver board (Fig. 4).

**Earth LCD** provides a display subsystem that makes it easy for designers and OEMs to develop a display product with a graphical user interface (GUI) using an embedded processor. Its eLCD development kits help system designers to go to market with customized products for medical or small-kiosk applications without having to re-do the design from scratch.

### Conclusion

With gas prices climbing higher and higher and energy costs at a premium, it is excellent timing for the display component and systems industries to provide dramatic improvements. More-efficient LCD films give the option of brighter displays or getting the same brightness with less power. The revolution in LED backlights not only provides deeper colors, but up to 50% reduction in power as well as darker blacks for contrast-ratio improvement. Now if only the auto industry would follow suit. ■

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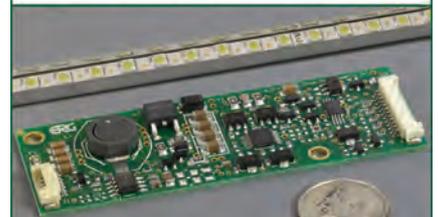
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Edited by Aris Silzars

### Optical compensation for two stereoscopic distortions

Konstantin A. Grebenyuk  
Vladimir V. Petrov

Saratov State University

**Abstract** — A stereoscopic display configuration for presenting stereoscopic images without keystone and depth-plane-curvature distortions is proposed. The main idea of the proposed configuration is to perform optical compensation for these distortions by presenting left and right perspective images at two intersecting screens. The possibility of such distortion elimination was proven by two independent ways: analytically and graphically.

In a converged configuration, the camera sensors are not parallel to the plane of convergence, which yields incorrect values for the horizontal and vertical parallaxes of the stereopair. Incorrect values of the horizontal parallax result in incorrect locations of the observed 3-D image points, so that the 3-D image of the scene looks curved. This is called depth-plane curvature. Incorrect values of the vertical parallax (*i.e.*, non-zero vertical parallax) make it difficult for the fusion of the left and right perspective images into a single stereoscopic image.

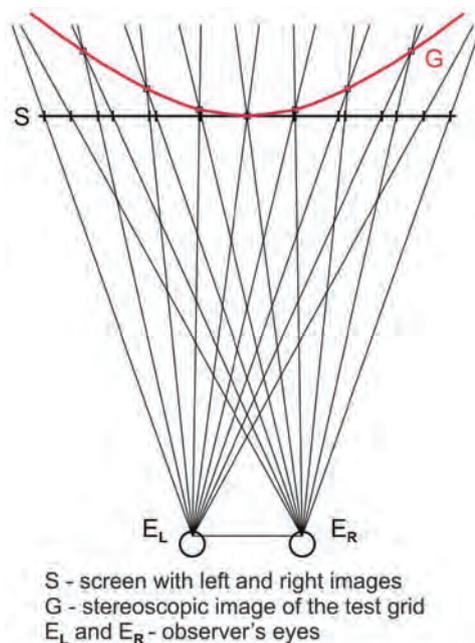


FIGURE 3 — Detecting depth-plane curvature in a stereoscopic image on the test grid.

## Color-separating backlight for improved LCD efficiency

Martin J. J. Jak

Robert Caputo

Eefje J. Hornix

Luciano de Sio

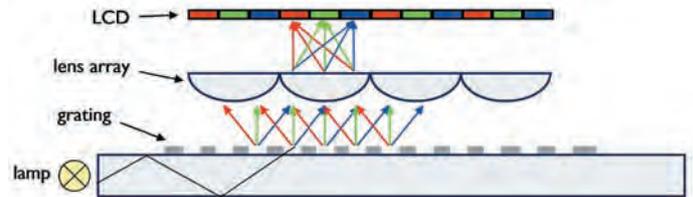
Dick K. G. de Boer

Hugo J. Cornelissen (SID Member)

Philips Research Laboratories

One can eliminate the color filter by spatially separating the colors. This can be achieved with diffractive components that can separate white light into its spectral components. The basic principle of such a backlight is shown in Fig. 1. As in a normal side-lit backlight, white light is coupled into a light guide. A grating is used to diffract the extracted light into different directions, corresponding to the different colors. In our case, the diffraction grating itself is used to extract the light from the light guide. Since, in practice, the grating is separated from the liquid-crystal layer by a glass plate of approximately 1 mm thick, a lens array is used to focus the light onto the pixels.

**Abstract** — A large part of the light generated in a backlight is usually absorbed in the color filters of the liquid-crystal display. A new backlight system that uses a grating to split the white light into different colors and a lens array to focus this light onto the pixels is presented. The absorbing filters can be eliminated and efficiency is improved. The system is characterized, as well as its different components.



**FIGURE 1** — Schematic representation of a color display without color filters. The grating on top of a light guide extracts light from the light guide and separates the light into the red, green, and blue components. A lens array focuses the colors onto the appropriate pixels.

## Optical characterization of autostereoscopic 3-D displays

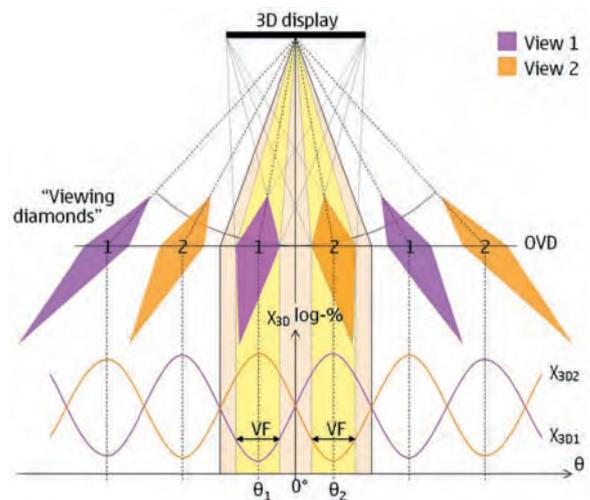
Toni Järvenpää (SID Member)

Marja Salmimaa (SID Member)

Nokia Research Center

**Abstract** — Display-measurement methods different from conventional 2-D display measurements are needed for verifying the optical characteristics of autostereoscopic (3-D) displays and for comparing different 3-D display technologies. Industry is lacking standardized measurement methods, and the reported results can not always be compared. The selected set of characteristics discussed in this paper and partly defining the quality of the 3-D experience are crosstalk, viewing freedom, and optimum viewing distance. Also, more conventional display characteristics such as luminance are discussed, since the definitions for these characteristics in 3-D mode usually differ from those used for the 2-D displays. How these chosen 3-D display characteristics can be objectively measured from transmissive two-view and multi-view 3-D displays have been investigated. The scope of this article is to generally define those basic characteristics as well as the different measurement methods. Most of the 3-D characteristics can be derived from the luminance and colors versus the viewing angle. Either a conoscopic or a goniometric measurement system can be used, as long as the angular and stray-light properties are suitable and known. The characteristics and methods are currently discussed in the display-quality standardization forums.

Viewing freedom is the movement within which the user can comfortably move in front of the 3-D display, and it is a very important yet complicated three-dimensional characteristic, similar to that of virtual displays. With two-view 3-D displays, at least crosstalk, luminance difference, and color shift all confine the movement and at least a five-point measurement (center and corners) of all these parameters must be made. Figure 9 illustrates the cross-section of the repeating “viewing cones” in the horizontal plane and the exemplary viewing freedom (VF) for each eye based on only center measurement.



**FIGURE 9** — Viewing freedom for a two-view display and the minimum crosstalk angles  $\theta_1$  and  $\theta_2$ .

# Antiferroelectric and ferroelectric liquid-crystal display: Electrically controlled birefringence color switch as a new mode

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E. P. Pozhidaev (SID Member)  
V. E. Molkin  
N. M. Shtykov

Moscow State University

**Abstract** — A mixture with intermediate biaxial (ferroelectric) smectic phases existing in a broad temperature range has been developed. At any temperature within this range, as well as in the antiferroelectric phase range, several birefringence color states can be switched stepwise by application of an electric field, and therefore a LC cell placed between crossed polarizers can display several colors without the use of color filters. A very small time switching between color states (about 10  $\mu\text{sec}$ ) can be a basis for this new mode in display technology because several full-color optical states can be realized in the same material (or in the mixture of materials). These possibilities were investigated both theoretically and experimentally.

The light transmission spectra of the developed mixture (layer thickness is 4.75  $\mu\text{m}$ ) placed between two crossed polarizers at  $T = 25^\circ\text{C}$  are presented in Fig. 16. The color switches from blue to green and then to red by application of different voltage.

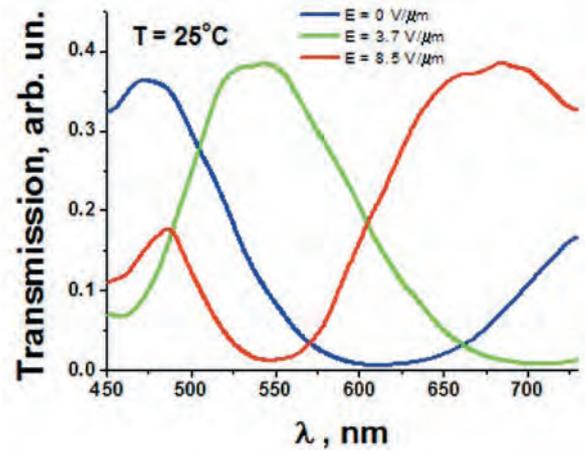


FIGURE 16 — Light transmission spectra for newly developed mixture.

## 2-D FOCON arrays and their application in displays and planar illuminators

Putilin N. Andrew  
Lebedev Institute of the  
Russian Academy of Science

**Abstract** — Focusing cones (FOCON) have been designed for fiber-optic communication systems as coupling devices. The main aim of these couplers is to match the spatial distribution of the light source or photodetector with the aperture configuration of light-guiding modes of the optical fibers. In this paper, the application of a 2-D array of FOCONs for collimating large-sized optical beams in display devices is proposed. The design of a light-efficient illumination unit for LCDs that can operate in the reflection mode as a backlight has been demonstrated. The approach proposed is based on the spatial separation of the light propagation in a FOCON array for reflected beams and light that comes from the backlight unit. The application of a FOCON array in backlight units and antiglare coatings has been demonstrated.

This paper is devoted to the application of a FOCON in optical processing and, in particular, in display design. A 2-D array of FOCONs for collimating large-sized optical beams in display devices has been applied. Figure 1 shows the basic element of such an array, the aperture of TIR operation that depends upon the index of refraction of the FOCON material, and the shape of the TIR surface. The FOCON is formed by a TIR surface and one or two output-input surfaces ( $S_i$  and  $S_o$ ). The TIR surface is designed to transform the input light distribution into an output light distribution, and perfect light concentration can be achieved for a parabolic shape.

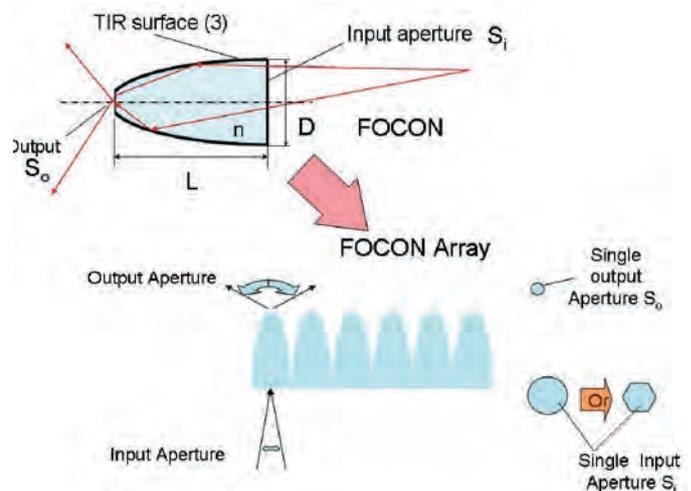


FIGURE 1 — Basic FOCON array element and the principle of its operation.

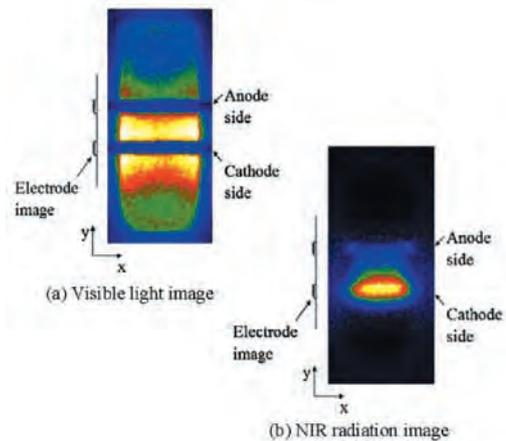
## High-efficacy plasma-display designs achieving 5 lm/W

Toshiyuki Akiyama (*SID Member*)  
Takashi Yamada  
Yasuyuki Noguchi  
Koji Shinohe  
Masatoshi Kitagawa  
Tsutae Shinoda (*SID Fellow*)

*Advanced PDP Development Center Corp.*

**Abstract** — Under high-Xe-content conditions, the luminous characteristics were evaluated for the sustaining electrode width and the sustaining pulse cycle. It was recognized that the proper designs for them in a high-Xe-content gas mixture make it possible to obtain high luminous efficacy. In this research, it was found that narrower electrodes can gain higher luminous efficacy in high-Xe-content conditions. The dependency of the luminous characteristics on the electrode width was analyzed and the differences of discharge phenomena from low-Xe-content conditions, which explain the dependency on the electrode width, were recognized. In an 8-in. test panel, 5.2 lm/W of the maximum white efficacy was obtained. The found phenomenon that narrower electrodes are more advantageous for the luminous efficacy is favorable in high-definition PDPs.

Figures 12(a) and 12(b) show a visible-light image and a NIR-radiation image of a single discharge for a pulse cycle of 10  $\mu$ sec, a pulse voltage of 280 V, an electrode width of 50  $\mu$ m, and a Ne + Xe 20% gas mixture. The visible-light image shows a relatively wide extension. The distribution of visible luminescence exceeds the area of the electrodes. On the other hand, NIR radiation is limited on the area of the electrodes. The area of the NIR radiation corresponds to the area radiating VUV radiation. These indicate that VUV radiation from a relatively small area lead to a relatively wide area of visible luminescence.



**FIGURE 12** — The visible light image and NIR radiation image of a single discharge for a pulse cycle of 10  $\mu$ sec, a pulse voltage of 280 V, an electrode width of 50  $\mu$ m, and a gas mixture of Ne + Xe 20%. The light was integrated over the entire 5  $\mu$ sec of the sustain pulse. (a) Visible-light image. (b) NIR-radiation image.

## Near-to-eye display with diffractive exit pupil expander having chevron design

Tapani Levola (*SID Member*)  
Viljakaisa Aaltonen  
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**Abstract** — Near-to-eye displays (NEDs) provide a unique way to perceive a larger image than the device itself. The user acceptance of commercially available NEDs has not been high partly because of reported physiological symptoms. Devices also tend to be thick and heavy, and therefore uncomfortable to wear. To overcome these shortcomings and to make a very usable device, a new approach was needed. By using very thin plastic light guides with diffractive structures on the surfaces, many of the known obstacles can be notably reduced. These exit pupil expanders (EPEs) enable a light and thin design for see-through NEDs. The so-called chevron EPE was designed to further improve the design and usability aspects of NEDs. The diffractive EPE has typically one incoupling grating area that delivers light into the light guide symmetrically towards the left and right eyes. By using slanted or overhanging gratings, the incoupling is very asymmetric. If the incoupling area is divided into two parts, each having opposite slanting angles, the EPE plate can be cut in half, and the left and right parts can be separated. The plates can be further tilted to a chevron shape following more closely the human face and mimicking the conventional eyeglass design. The reflection of the light from the tilted plate is directed out from the image-forming optics, and therefore the contrast is improved.

The volume production of slanted gratings on a plastic substrate enables many new features in the VRD that is based on a diffractive EPE. By splitting the incoupling grating in two oppositely slanted grating areas a chevron configuration of the EPE can be formed. This configuration mimics the conventional eye-glass design.



**FIGURE 10** — Experimental stack of two chevron EPEs for the left and right eye. Each EPE plate has six different grating areas. The chevron angle is 10°.

## 2-D/3-D displays based on switchable lenticulars

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Siebe T. de Zwart  
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Oscar H. Willemsen  
Maarten Sluijter

*Philips Research Laboratories*

**Abstract** — An attractive concept for 3-D displays is the one based on LCDs equipped with lenticular lenses. This enables autostereoscopic multiview 3-D displays without a loss in brightness. A general issue in multiview 3-D displays is their relatively low spatial resolution because the pixels are divided among the different views. To overcome this problem, we have developed switchable displays, using liquid-crystal (LC) filled switchable lenticulars. In this way, it is possible to have a high-brightness 3-D display capable of fully exploiting the native 2-D resolution of the underlying LCD. The feasibility of LC-filled switchable lenticulars was shown in several applications. For applications in which it is advantageous to be able to display 3-D and 2-D content simultaneously, a 42-in. locally switchable prototype having a matrix electrode structure was developed. These displays were realized using cylindrically shaped lenticular lenses in contact with LC. An alternative for these are lenticulars based on gradient-index (GRIN) LC lenses. Preliminary results for such switchable GRIN lenses are presented as well.

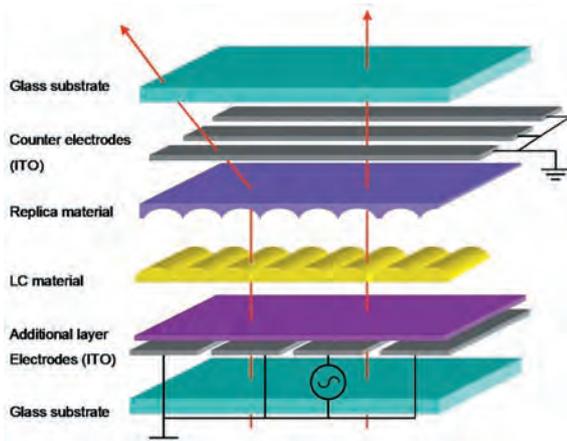


FIGURE 7 — Exploded view of LC-based locally switchable lenticular.



FIGURE 8 — Prototype (42 in.) of a locally switchable 2-D/3-D display. Shown is a 3-D window on a 2-D background.

## Diffractive backlight grating array for mobile displays

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Tapani Levola (*SID Member*)  
Pasi Laakkonen

*Nokia Research Center*

**Abstract** — The display backlight unit (BLU) is the most power-consuming sub-unit in mobile liquid-crystal displays. The state-of-the-art BLUs utilize scattering, refractive, and reflective microstructures to generate a uniform distribution of white light through the display. More effective means of transmitting light through the display color filters could be obtained by using diffraction, but previously proposed diffractive backlights do not fully utilize all the possibilities to design gratings effectively for optimal color separation and outcoupling. A new pixelated diffractive backlight grating array as an approach for overcoming these obstacles in BLU design is presented. A model array was fabricated to couple out red, green, and blue primary colors from the respective subpixel locations. The results show that it is possible to manufacture such an array and that the light couples out as intended, giving a starting point to design mobile-display modules with low light-transmission losses.

Figure 1 shows the new BLU concept in broad detail. Light from red, green, and blue LEDs is launched into the BLU from different corners of the BLU. The light is then spread out into uniform beams propagating in the backlight, by fan-out gratings. A pixel array of gratings is then used for outcoupling the light toward the LCD pixel array. With polarizing gratings, there would be no need for a polarizer between the BLU and the LCD. Also, by designing the BLU grating array to pass light through the active aperture area only, it is possible to prevent unwanted light from hitting the areas outside the active aperture of the LCD pixel.

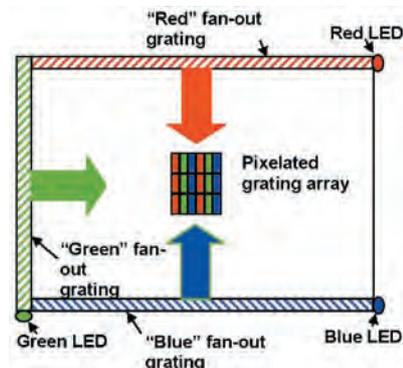


FIGURE 1 — Pixelated backlight concept, not to scale.

# Physical interpretation of the characteristics of LCDs embedded with MgO and SiO<sub>2</sub> nanoparticles

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 Y. Saeki  
 S. Kodaira  
 K. Takatoh (SID Member)  
 T. Kineri  
 H. Hoshi  
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 S. Sano

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**Abstract** — The electro-optical characteristics of TN-LCD and ECB-LCD cells, both of which were embedded with MgO and SiO<sub>2</sub> nanoparticles at a low concentration of about or below 1 wt.%, were investigated. The threshold voltage and operating voltage of these LCD cells were found to decrease by 5–16%, depending on the materials and the concentration of nanoparticles. Measurements of the physical properties of nanoparticle-embedded NLCs, such as the order parameter, clearing point, birefringence, dielectric anisotropy, elastic constants, and rotational viscosity on the nanoparticle-doped NLC sample cells, were performed. Through these measurements, it is shown that the decrease in the threshold voltage and the operating voltage may be attributed to the decrease in the order parameter by 10–30% due to the existence of these nanoparticles.

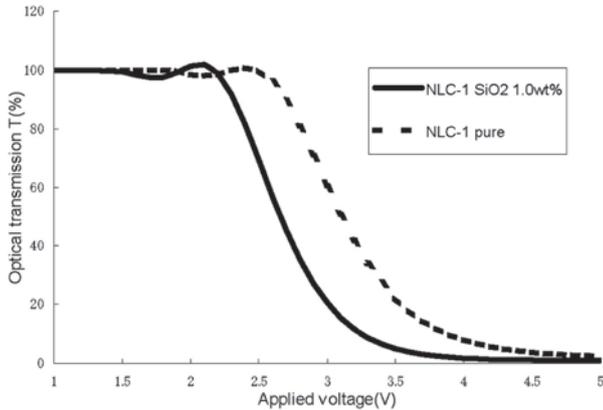


FIGURE 1 — V–T curves of TN-LCD doped with and without SiO<sub>2</sub> nanoparticles in NLC-1.

TABLE 1 — Measured values of the dielectric anisotropy, elastic constants, and viscosity on ECB cells with NLC-1 and NLC-2 embedded with and without SiO<sub>2</sub> nanoparticles.

Sample	$\Delta\epsilon$	$K_{11}$ (PN)	$K_{33}$ (PN)	$K_{eff}$ (PN)	$V_{th}$ (calculated)	$V_{th}$ (measured)	$\gamma_1$ (mPa-sec)
NLC-1 pure	5.07	13.6	13.2	14.5	1.79	1.73	278.6
NLC-1 +SiO <sub>2</sub> 1.0%	4.69	10.7	20.7	12.2	1.70	1.59	234
NLC-2 pure	7.18	11.4	16.6	10	1.39	1.33	161
NLC-2 +SiO <sub>2</sub> 1.0%	6.61	8.66	16.6	9.6	1.28	1.18	155

# Enhancement of blue-light-emission properties for OLED displays by using a polarized light-recycling structure

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 Sukekazu Aratani  
 Kaoru Yanagawa

Hitaachi, Ltd.

**Abstract** — The blue-light-emission properties of organic light-emitting-diode (OLED) displays must be enhanced to meet the requirements for color purity and luminous efficiency because few blue-light-emitting materials meet these requirements. This is particularly true for polymeric and phosphorescent light-emitting materials. To attain the required purity and efficiency, a polarized-light-recycling structure for blue light that is called a blue enhanced circular polarizer (BECP) has been developed. The principle of the structure and the fabricated prototype device is described and it is shown that the structure increases blue-light intensity and color purity, improves efficiency, provides a wide color gamut, and limits ambient-light reflection.

As shown in Fig. 2, the BECP for the proposed blue-light recycling structure consists of a polarizer, a retardation film (quarter-wave plate), and a cholesteric liquid-crystal polymer layer (CLC) with a selective reflection property in the wavelength corresponding to pure blue. The polarizer and retardation film constitute the so-called circular polarizer. The CLC has specific optical characteristics based on a helical molecular alignment.

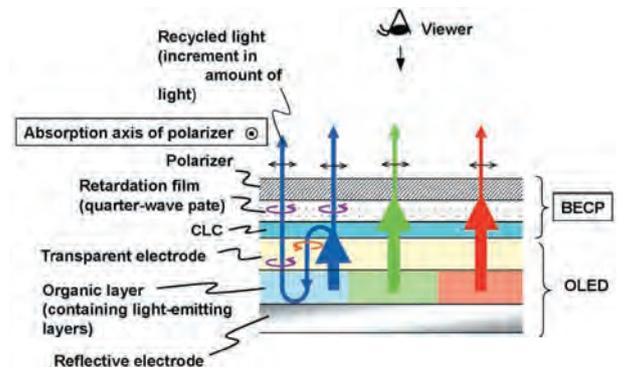


FIGURE 2 — Schematic cross section of BECP for a full-color OLED display in the case of light emission. The BECP consists of a polarizer, a retardation film (quarter-wave plate), and a cholesteric liquid-crystal polymer layer (CLC) with a selective reflection property for the wavelength range corresponding to pure blue. The BECP is arranged on all the pixels (which includes red and green ones).

## Moving-image-sticking phenomenon induced by an outside force in liquid-crystal displays

Hyung Ki Hong  
JiYoung Ahn  
HoYoung Jung  
Heume-Il Baek  
Moojong Lim  
Hyun-Ho Shin

LG Display

**Abstract** — Image deformation caused by an outside force is observed to remain for hours at high gray levels for liquid-crystal displays (LCDs) in the multi-domain (MD) vertical-alignment (VA) mode. This so-called moving-image-sticking phenomenon demonstrated a non-symmetric luminance profile for the left and right viewing direction for MDVA-mode LCDs which have original symmetric viewing-angle characteristics. The generation of a stable reverse-tilt domain by an outside force was assumed to be the cause of this phenomenon, and the stability of a reverse-tilt domain under an electric fringe field was calculated by changing the electric-fringe-field distribution which determines the LC tilt direction. The domain of a given tilt direction is calculated to change to another tilt direction induced by a fringe field at a low gray condition, but to remain unchanged at a high gray condition. This agrees with the observed trends of duration time of the moving-image-sticking phenomenon.

In this paper, the term “moving image sticking” is used to describe the phenomenon where a trace of the previous image displayed at the moment that an outside force is applied remains even after the image data is changed. An example is shown in the photograph shown in Fig. 1, where the trace of a soccer ball image is observed at the upper left region behind the soccer ball shortly after the LC panel is pressed by hand. Duration times of the moving image sticking are found to be different for the displayed moving images and LC modes.



FIGURE 1 — Photograph of the moving-image-sticking phenomenon. Position of the moving image sticking is noted by the white arrows.

## A self-reset ambient-light sensor system for low-temperature polycrystalline-silicon active-matrix displays

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**Abstract** — A new digital ambient-light sensor system has been designed and fabricated on a glass substrate using a conventional low-temperature polycrystalline-silicon (LTPS) technology. In the proposed system, analog-to-digital conversion (ADC) is performed in the time domain instead of the voltage domain and is combined with a light-detection process. The proposed system employs self-reset architecture and requires only one comparator for n-bit digital output. Because the complex analog circuitry is eliminated from the system, it can be readily integrated on the glass substrate.

The block diagram of the proposed system is shown in Fig. 1. It consists of a light sensor, a converter, an n-bit binary counter, and an n-bit output register. Several features were incorporated in our design such as a light sensor, comparator, and self-reset conversion process. In the proposed system, only one was required, simplifying the conversion process.

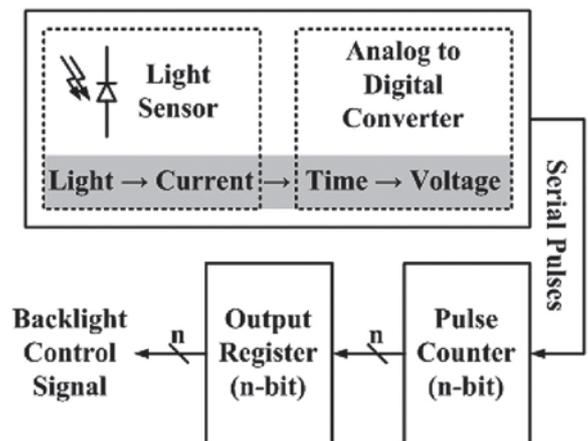


FIGURE 1 — The block diagram of the proposed ambient-light sensor system.

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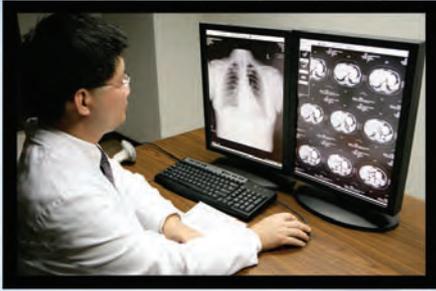
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# Directory of the Display Industry

ID's twenty-second annual directory of the display industry.

COMPILED AND EDITED BY JAY MORREALE

Part I, beginning on this page, is a listing of products and services relevant to the display industry. Part II, the company directory, begins on page 64.

## Part I: Products and Services

### ADHESIVES

□ Acheson Colloids □ Adhesives Research □ Chomerics □ CPFilms □ CRG Chemical □ Dawar Technologies □ Delo Industrial Adhesives □ Diemat □ DuPont Display □ Dymax □ EPCONSEIL □ EXFO Photonic Solutions □ **Eyesaver** □ GE Silicones □ GZO Technologies □ Intelicoat Technologies □ Master Bond □ Miyachi Unitek □ Nippon Paper □ Sekisui S-Lec American □ Sheldahl □ Sheldahl Display Products □ Soken Chemical □ Specialty Tapes □ Venture Tape

### ANTIREFLECTION COATINGS

□ Abrisa Industrial Glass □ All American □ Anders Electronics □ Arrow □ Bell Microproducts □ Berliner Glas □ Bookham □ Colorado Concept Coatings LLC □ Corning Inc. □ CPFilms □ CRG Chemical □ Dawar Technologies □ **Dontech** □ DuPont Display □ EuropTec □ **Eyesaver** □ Fraunhofer Institute of Physics □ Fujitsu Components America □ GZO Technologies □ Horizon Technology □ **Jaco Electronics** □ **JDS Uniphase** □ Man & Machine □ Metavac □ Mirvec □ Monitech Industrial Display □ Nanogram □ Nippon Paper □ Nitto Denko □ OC Oerlikon Balzers - Optics □ Optical Polymers □ Performance Coatings □ Photo Sciences □ Purdy Electronics □ Schott North America □ Sheldahl Display Products □ Sumitomo Osaka Cement Co. □ Sycamore Glass Components □ TFD □ Tredegar Performance Films □ Unaxis Optics □ Unaxis Shanghai □ White Electronic Designs □ Zeon Chemicals □ Zytronic

### ANTIREFLECTION SCREENS

□ All American □ Anders Electronics □ Arrow □ Astra Products □ Bell Microproducts □ Bookham □ CI Lumen Industries □ CYRO Industries □ **Dontech** □ EuropTec □ **Eyesaver** □ General Digital □ Horizon Technology □ **Jaco Electronics** □ Lumen Technology □ Optical Filters □ Optical Polymers □ **Parker Chomerics** - **Silver Cloud** □ **Solomon Systech** □ White Electronic Designs

### ANTISTATIC CHEMICALS AND DEVICES

□ Albemarle □ CRG Chemical □ **Dontech** □ Nanofilm □ Performance Coatings □ Sumitomo Osaka Cement Co. □ Tredegar Performance Films □ TW Clean

### ASSOCIATIONS AND PROFESSIONAL SOCIETIES

□ EPCONSEIL □ German Flat Panel Display Forum □ Human Factors and Ergonomics Society □ Society for Information Display □ U.K. Displays and Lighting Knowledge □ VESA

### BACKLIGHTS (for liquid-crystal displays)

□ All American □ Anders Electronics □ Applied Concepts □ Arrow □ Astra Products □ Bell Microproducts □ Bi-Search International □ Bright View Technologies □ Brightside □ Brimar Ltd. □ Briteview Technologies □ C3 Laser □ CI Lumen Industries □ Capstone □ Data Modul □ Dawar Technologies □ DuPont Display □ EarthLCD □ Fonon Display & Semiconductor Systems □ Fonon Technology □ Fusion Optix □ GE Plastics □ **Global Lighting Technologies** □ GZO Technologies □ Heatron □ Hong Kong ASTRI □ Horizon Technology □ IDC □ IEE □ IFM □ Interface Displays & Controls □ IntertechPira □ i-sft GmbH □ Jaco Electronics □ JKL Components □ Korry Electronics □ Landmark Technology □ LCD Lighting □ Lumen Technology □ Luminus Devices □ Lumitex □ Man & Machine □ Microsharp □ NDF □ OMT □ OSRAM Opto-Semiconductors □ Physical Optics □ Purdy Electronics □ Pure Depth □ Quadrangle Products □ Southwall Technologies □ Supertex □ Telios Tech □ 3M Optical Systems □ Thomas Electronics □ Tredegar Performance Films □ US Micro Products □ White Electronic Designs □ Wintek

### CABLES

□ All American □ Apollo Display Technologies □ Arrow □ Avocent □ Axon' Cable □ Bell Microproducts □ Communications Specialties □ Data Modul □ Dawar Technologies □ **Jaco Electronics** □ Meritek □ Monitech Industrial Display □ Nicomatic □ Peter's Co. □ Purdy Electronics □ Quadrangle Products □ Thomas Electronics

### CATHODES

□ e beam □ Kurt J. Lesker □ Thomas Electronics

### CCD IMAGERS AND CAMERAS

□ Aaeon Systems □ Albemarle □ Cyantek □ **ELDIM** □ Gamma Scientific □ Horiba Jobin Yvon □ Nanofilm □ Schott North America

### CLEANING AGENTS

□ Albemarle □ Cyantek □ Nanofilm □ PVA TePla AG

### COATING EQUIPMENT

□ Coating & Converting Resources □ Colorado Concept Coatings LLC □ MBraun □ Mirvec □ Performance Coatings

### COLOR MATCHING SYSTEMS

□ **B&W TEK** □ Fraunhofer Institute of Physics □ Genesis Microchip □ **Klein Instruments** □ **Konica Minolta** □ **Konica Minolta Photo Imaging** □ Ocean Optics □ **Optek Technology** □ Photo Research □ Radiant Imaging □ Unaxis Optics

### CONNECTORS AND SOCKETS

□ Apollo Display Technologies □ Axon' Cable □ Data Modul □ ITT Electronic Components □ JAE Electronics □ Meritek □ Nicomatic □ Purdy Electronics □ Quadrangle Products □ SMK □ Thomas Electronics

### CONSULTANTS AND ANALYSTS

□ Abbie Gregg Inc. □ Advanced Manufacturing Group □ AGC Systems □ Apollo Display Technologies □ Applied Concepts □ Applied Technology □ Breault □ Capstone □ Display Asia □ Display-Metrology & Systems □ e beam □ ECSIBEO AB □ EPCONSEIL □ Fraunhofer Institute of Physics □ G2D Technologies □ German Flat Panel Display Forum □ GZO Technologies □ Informative View □ IntertechPira □ i-sft GmbH □ ITO America □ Kent State University □ Kristel □ Logystyx □ Lumen Technology □ Meko □ Murgence □ National Quality Assurance □ nFlexion □ Optical Research Associates □ Performance Tech Associates □ Pixel Interconnect □ Alan Sobel □ Systemation Technology □ Tannas Electronics □ Thomas Electronics □ Veritas et Visus

### CONVERTERS, DIGITAL/ANALOG, ANALOG/DIGITAL

□ **Astro Systems** □ Bell Microproducts □ Cabletime □ Data Modul □ Jaco Electronics □ Kristel □ Monitech Industrial Display □ NDF □ Quadrangle Products □ Systemation Technology □ Thinklogical

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□ Anders Electronics □ **Astro Systems** □ Bell Microproducts □ Cabletime □ Capstone □ Data Modul □ Gennum □ **Jaco Electronics** □ Landmark Technology □ Monitech Industrial Display □ Quadrangle Products □ Systemation Technology □ Thinklogical

### CONVERTERS, POWER

□ Applied Concepts □ Arista □ Capstone □ Crane Aerospace □ ELDEC □ Jaco Electronics □ Landmark Technology □ NDF □ Orbit International □ Purdy Electronics □ Quadrangle Products □ Supertex □ Zippy Technology

### COUNTING EQUIPMENT

□ Kurt J. Lesker

### CRT DESIGN SERVICES

□ Brimar Ltd. □ CELCO □ e beam □ Lynch Systems □ Monitech Industrial Display □ Optical Research Associates □ Thomas Electronics

### CRT MONITORS

□ Aaeon Systems □ Arrow □ Brimar Ltd. □ e beam □ FIMI Philips □ Kristel □ Lynch Systems □ Monitech Industrial Display □ Precision Display Technologies □ Quest International □ Richardson Electronics □ Samsung Semiconductor □ Teltron Technologies □ Thomas Electronics □ **3M Touch Systems** □ Timeline

### CRT TESTING LABORATORIES

□ Brimar Ltd. □ CELCO □ e beam □ Gamma Scientific □ Monitech Industrial Display □ Photo Research □ Quest International □ Radiant Imaging □ Thomas Electronics

### DEFLECTION AMPLIFIERS

□ Brimar Ltd. □ CELCO □ CELCO Pacific □ Citronix □ Thomas Electronics

### DEFLECTION YOKES

□ Brimar Ltd. □ CELCO □ Thomas Electronics

### DEPOSITION EQUIPMENT

□ Aixtron □ ANS □ Dimatix □ DOOSANDND □ FUJIFILM Dimatix □ Kurdex □ Kurt J. Lesker □ MBraun □ OTB Display □ Sunic System □ Trovato Mfg.

### DEPOSITION SERVICES

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□ Metavac □ OC Oerlikon Balzers – Optics  
□ Sheldahl □ TFD □ Unaxis Optics  
□ Unaxis Shanghai

#### DIGITAL FILM RECORDERS

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□ Thomas Electronics

#### DIGITAL VIDEO SYSTEMS

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□ Capstone □ Communications Specialties  
□ Data Modul □ Digital View Group □ EPIX  
□ Genesis Microchip □ Gennum □ IntelliMats  
□ Thinklogical

#### DIGITIZING TABLETS/DIGITIZERS

□ Bell Microproducts □ Slencil □ Wacom

#### DISABLED DISPLAY USER AIDS

□ Aaeon Electronics □ Immersion □ Man & Machine

#### DISPLAY DRIVERS AND CONTROLLERS

□ Aaeon Electronics □ All American □ Apollo Display Technologies □ California Micro Devices □ Capstone □ Data Modul □ Dawar Technologies □ Digital View Group □ EarthLCD □ ELDIM

#### DISPLAY HOUSING, RUGGEDIZED

□ All American □ Apollo Display Technologies  
□ Arrow □ Bell Microproducts □ Capstone  
□ CELCO □ Computer Dynamics □ Data Modul □ Donteck □ DuPont Display  
□ EarthLCD □ EuropTec □ Eyesaver □ GE Plastics □ General Digital □ GM Nameplate  
□ GZO Technologies □ Hong Kong ASTRI  
□ Horizon Technology □ Industrial Displays  
□ IntelliMats □ Interface Displays & Controls  
□ Jaco Electronics □ L-3 Communications  
□ Monitech Industrial Display □ Orbit International □ Parker Chomerics – Silver Cloud □ Precision Display Technologies  
□ Purdy Electronics □ Quest International  
□ Richardson Electronics □ White Electronic Designs

#### DISPLAY SIMULATION AND MODELING SYSTEMS

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□ Pure Depth □ sim4tec GmbH □ Thinklogical

#### DISPLAY SUBSYSTEMS

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□ Algolith □ All American □ Anders Electronics  
□ Applied Concepts □ Bell Microproducts  
□ Brimar Ltd. □ Cabletime □ Capstone  
□ CELCO □ Citronix □ ColorLink □ Compass Technology □ Computer Dynamics □ Data Modul □ Dawar Technologies □ Dialog Semiconductor □ Donteck □ EarthLCD  
□ General Digital □ Gennum □ Hampshire Co.  
□ Horizon Technology □ i-Chips Technology / Daitron □ IFM □ Industrial Displays  
□ Interface Displays & Controls □ Jaco Electronics □ JDS Uniphase □ Kopin □ L-3 Communications □ Landmark Technology  
□ Man & Machine □ Nemoptic □ Orbit International □ Planar Systems □ Purdy Electronics □ Quadrangle Products □ Silicon Monitor □ Alan Sobel □ Solomon Systech  
□ Systemation Technology □ Thinklogical  
□ Thomas Electronics □ 3M Optical Systems  
□ Unaxis Optics

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□ Brimar Ltd. □ CELCO □ CI Lumen Industries  
□ Capstone □ Data Modul □ Dawar Technologies □ Digital View Group □ Donteck  
□ Dynamic Digital Depth □ EarthLCD  
□ Fraunhofer IPMS □ Fusion Optix □ General Digital □ Hitachi Electronic Devices □ Horizon

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□ Lumen Technology □ Man & Machine  
□ Miyachi Unitek □ Monitech Industrial Display  
□ Motion Research □ Orbit International  
□ Planar Systems □ Purdy Electronics  
□ Quadrangle Products □ Richardson Electronics □ Solomon Systech □ Systemation Technology □ Thinklogical □ Thomas Electronics

#### DISTORTION CORRECTION DEVICES

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#### ELECTROLUMINESCENT DISPLAYS (inorganic)

□ Brimar Ltd. □ Colorado Concept Coatings LLC □ DDP □ IEE □ IFM □ Planar Systems  
□ Schott North America □ Sheldahl Display Products □ Solomon Systech □ Supertex  
□ Telios Tech

#### ELECTRON GUNS

□ e beam □ Thomas Electronics

#### EYE AND HEAD MOVEMENT TRACKERS

□ Anders Electronics □ Brimar Ltd.  
□ CopyTele □ Fraunhofer Institute of Physics

#### FIBER-OPTIC FACEPLATES

□ Anders Electronics □ Brimar Ltd.  
□ CopyTele □ Schott North America

#### FIELD-EMITTER DISPLAYS

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#### FILTERS

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□ Bell Microproducts □ Berliner Glas □ Bright View Technologies □ California Micro Devices  
□ Colorado Concept Coatings LLC □ ColorLink  
□ CYRO Industries □ Donteck □ EuropTec  
□ Eyesaver □ H. W. Sands □ Interface Displays & Controls □ Jaco Electronics □ JDS Uniphase  
□ Korry Electronics □ Metavac □ OC Oerlikon Balzers – Optics □ Optical Filters □ Optical Polymers □ Parker Chomerics – Silver Cloud  
□ Performance Coatings □ Schott North America □ Southwall Technologies  
□ Stemmerich □ Sumitomo Osaka Cement Co. □ Sycamore Glass Components □ 3M Optical Systems □ Touch International  
□ Unaxis Optics □ Unaxis Shanghai □ Zytronix

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□ Bell Microproducts □ CI Lumen Industries  
□ Colorado Concept Coatings LLC  
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□ DuPont Display □ EarthLCD □ Fonon Technology □ Fujitsu Components America  
□ German Flat Panel Display Forum □ GM Nameplate □ ITO America □ Landmark Technology □ Mirvec □ Nitto Denko □ Pixel Interconnect □ Plastic Logic □ Rofin-Sinar  
□ Sciensy □ Sheldahl Display Products  
□ Alan Sobel □ Timeline

#### FLAT-PANEL MATERIALS

□ Albemarle □ Axon' Cable □ Bell Microproducts □ Colorado Concept Coatings LLC □ Compass Technology □ Delo Industrial Adhesives □ Dialog Semiconductor  
□ Donteck □ DuPont Display □ GM Nameplate □ H. W. Sands □ ITO America  
□ Meritec □ Mirvec □ Nitto Denko □ Optical Polymers □ Pixel Interconnect □ Plastic Logic  
□ Rofin-Sinar □ Sheldahl Display Products

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□ DuPont Display □ EarthLCD □ GM

Nameplate □ ITO America □ Mirvec □ Nitto Denko □ Pixel Interconnect □ Plastic Logic

#### FLEXIBLE CIRCUITS

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□ ITO America □ Meritec □ Mirvec □ Nitto Denko □ Pixel Interconnect □ Plastic Logic  
□ Sheldahl Display Products

#### FOCUS COILS

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#### GETTERS

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□ Thomas Electronics

#### GLASS CUTTING/SCRIBING EQUIPMENT

□ Abris Industrial Glass □ Applied Photonics  
□ Colorado Concept Coatings □ Rofin-Sinar  
□ TLC International

#### GLASS FOR CRTs

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□ Brimar Ltd. □ Corning □ Donteck □ e beam  
□ Eyesaver □ Monitech Industrial Display  
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□ Abris Industrial Glass □ Astra Products  
□ Basler AG □ Berliner Glas □ Brimar Ltd.  
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□ Data Modul □ Eurotech / Applied Data Systems □ Interface Displays & Controls

#### GRAPHICS WORKSTATIONS

□ Arrow □ ColorLink □ CRLO □ Fraunhofer Institute of Physics □ Fraunhofer IPMS  
□ Monitech Industrial Display □ Motion Research  
□ The MicroOptical Corp. □ Thomas Electronics  
□ White Electronic Designs □ Zygo

#### HEAD-MOUNTED DISPLAYS

□ Arrow □ ColorLink □ CRLO □ Forth Dimension □ Fraunhofer Institute of Physics  
□ Fraunhofer IPMS □ MicroEmissive Displays  
□ Monitech Industrial Display □ Motion Research □ Schott North America □ The MicroOptical Corp. □ Thomas Electronics  
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#### ICs (video, graphics, and display)

□ California Micro Devices □ Dialog Semiconductor □ Genesis Microchip □ i-Chips Technology / Daitron □ Jaco Electronics  
□ Kawasaki Microelectronics □ Kopin □ Maxim Integrated Products □ Microsemi □ Monitech Industrial Display □ Silicon Image □ Silicon Monitor □ Solomon Systech □ Supertex

#### IMAGE COMPRESSION

□ Aaeon Systems □ Algolith □ Brightside  
□ ColorLink □ Monitech Industrial Display

#### IMAGE STORAGE

□ Brightside

#### IMAGE TUBES

□ Brimar Ltd. □ Monitech Industrial Display  
□ Teltron Technologies

#### IMAGERS AND CAMERAS

□ All American □ Alternative Vision □ Basler AG □ Brightside □ EPIX □ Horiba Jobin Yvon  
□ Schott North America □ Thinklogical

#### INVERTERS, POWER

□ Applied Concepts □ Data Modul □ Dawar Technologies □ Endicott Research Group  
□ Kristel □ Landmark Technology  
□ Microsemi □ Monitech Industrial Display  
□ Quadrangle Products □ Solomon Systech

#### JOYSTICKS

□ Data Modul □ Orbit International □ US Micro Products □ White Electronic Designs

#### KEYBOARDS

□ Arista □ Data Modul □ Fujitsu Components America □ General Digital □ GM Nameplate  
□ Interface Displays & Controls □ Man & Machine □ Orbit International □ US Micro Products □ White Electronic Designs

#### LAMPS

##### backlighting

□ Applied Concepts □ Briteview Technologies  
□ CI Lumen Industries □ Corning □ Donteck  
□ ELDIM □ Heatron □ i-sft GmbH □ JKL Components □ Landmark Technology □ LCD Lighting □ Logystyx □ Lumileds Lighting  
□ NDF □ OSRAM Opto Semiconductors  
□ Purdy Electronics □ Pure Depth □ Seoul Semiconductor □ Thomas Electronics □ 3M Optical Systems □ Wintek

##### domestic and commercial lighting

□ Abris Industrial Glass □ Corning  
□ Fraunhofer Institute of Physics  
□ Fraunhofer IPMS □ Heatron □ NDF  
□ OSRAM Opto Semiconductors

##### projection

□ OSRAM Opto Semiconductors □ Slencil

#### LIGHT-EMITTING DIODES

□ All American □ Colorado Concept Coatings LLC □ GraffTech International □ IntertechPira  
□ Lumileds Lighting □ Luminus Devices  
□ MicroEmissive Displays □ NDF □ Optek Technology □ OSRAM Opto Semiconductors  
□ Purdy Electronics □ Pure Depth  
□ Quadrangle Products □ Schott North America □ Seoul Semiconductor □ Sharp Microelectronics of the Americas

#### LIQUID-CRYSTAL DISPLAYS

□ Abris Industrial Glass □ AU Optronics  
□ CI Lumen Industries □ Colorado Concept Coatings □ Corning □ Data Modul  
□ Everbouquet International □ Forth Dimension □ Rofin-Sinar □ Schott North America □ Sciensy □ Sheldahl Display Products □ Alan Sobel □ Tianma Microelectronics □ Timeline □ Toshiba America Electronic Components

#### MAGNETIC SHIELDING

□ Abris Industrial Glass □ Ad-Vance Magnetics □ Astra Products □ Bell Microproducts □ Chomerics □ Colorado Concept Coatings LLC □ Donteck □ EuropTec  
□ Eyesaver □ GM Nameplate □ Optical Filters □ Zytronix

#### MANUFACTURING EQUIPMENT

□ Applied Photonics □ Axometrics □ Azores  
□ B&W TEK □ Basler AG □ Benchmark  
□ Capstone □ Coating & Converting

Resources □ Corning Inc. □ DOOSANDND  
 □ Dark Field Technologies □ DisplayCheck  
 □ EXFO Photonic Solutions □ Exitech □ ITO  
 America □ Jenoptik Automatisierungstechni  
 □ Klein Instruments □ Konica Minolta  
 □ Kurdex □ LC-TEC Automation AB □ Lynch  
 Systems □ Micronic Laser Systems AB  
 □ Mirwec □ Miyachi Unitek □ NDF □ New  
 Wave Research □ **New Way Air Bearings**  
 □ OTB Display □ Photomaching □ Pixel  
 Interconnect □ Preco Industries □ PVA TePla AG  
 □ Rofin-Sinar □ Scienstry □ Sensor Products  
 □ Synova □ **Tempo** □ TGI Technologies □ TLC  
 International □ Thinklogical □ Todco □ Tricor  
 Systems □ Unitek EAPRO (Miyachi Unitek)

## MARKET RESEARCHERS/PUBLISHERS

□ AGC Systems □ Breaull □ Dempa  
 Publications □ Display Asia □ EPCONSEIL  
 □ iSuppli □ Laser Photonics □ Meko  
 □ Performance Tech Associates □ Photonics  
 Spectra □ Reed Business Information □ The  
 Rankin Group □ USDC □ Veritas et Visus

## MASKS

□ Adtek Photomask □ Advance Reproductions  
 □ Corning Inc. □ Kurdex □ Lite Enterprises  
 □ Micronic Laser Systems AB □ Photo Sciences  
 □ Pure Depth □ Specialty Tapes □ Synova

## MATERIALS FOR

### electrochromic displays

□ Aaeon Systems □ Colorado Concept  
 Coatings □ Five Star Technologies  
 □ Monitech Industrial Display □ Telios Tech

### electroluminescent displays

□ Acheson Colloids □ Albemarle □ Applied  
 Technology □ Astra Products □ Brimar Ltd.  
 □ Coating Materials □ Colorado Concept  
 Coatings □ CPFilms □ CRG Chemical  
 □ CYRO Industries □ **Dontech** □ DuPont  
 Display □ Five Star Technologies □ Fraunhofer  
 IPMS □ IntertechPira □ Sheldahl □ Sheldahl  
 Display Products □ **3M Optical Systems**

### electromechanical displays

□ Coating Materials □ CYRO Industries  
 □ **Dontech** □ Fraunhofer IPMS □ Immersion  
 □ Nanofilm □ Sharp Microelectronics of the  
 Americas □ Telios Tech □ White Electronic  
 Designs

### electronic-ink displays

□ Acheson Colloids □ Advance Reproductions  
 □ Albemarle □ Applied Technology □ CPFilms  
 □ Dialog Semiconductor □ Digital View Group  
 □ DuPont Display □ Five Star Technologies  
 □ Kent Displays □ Plastic Logic □ Sartomer  
 □ Sheldahl □ SiPix Imaging □ **Solomon  
 Systech**

### light pens

□ CPFilms □ Schott North America □ **Stencil**

### light-emitting diode displays

□ Abris Industrial Glass □ Albemarle □ Astra  
 Products □ Brightside □ Coating Materials  
 □ CYRO Industries □ **Dontech** □ Five Star  
 Technologies □ GrafTech International  
 □ Heatron □ IntertechPira □ Labsphere  
 □ MicroEmissive Displays □ Nanogram  
 □ **Optek Technology** □ Phosphor Technology  
 □ **Seoul Semiconductor**

### organic light-emitting diode displays

□ Advance Reproductions □ Albemarle  
 □ Applied Technology □ ASF Future  
 Business GmbH □ Brimar Ltd. □ Cambridge  
 Display Technology □ Coating Materials  
 □ CPFilms □ CYRO Industries □ Data Modul  
 □ Dialog Semiconductor □ DuPont Display  
 □ e-RAY Optoelectronics □ Five Star  
 Technologies □ Fraunhofer IPMS □ Heatron  
 □ IntertechPira □ Kurt J. Lesker □ Labsphere  
 □ Main Tape □ Meritec □ Nanogram

□ OLED-T □ Powertip Technology □ Schott  
 North America □ Sensient Imaging Technologies  
 □ **Solomon Systech** □ Tredegar Performance  
 Films □ UDC

### plasma displays

□ Abris Industrial Glass □ Applied Technology  
 □ Arrow □ Astra Products □ Bi-Search  
 International □ Bright View Technologies  
 □ Coating Materials □ CYRO Industries  
 □ Data Modul □ **Dontech** □ DuPont Display  
 □ EuropTec □ **Eyesaver** □ Genesis Microchip  
 □ Gennum □ GrafTech International □ **Jaco  
 Electronics** □ Miyachi Unitek □ Nanofilm  
 □ Nanogram □ Phosphor Technology  
 □ Plasmaco □ Rofin-Sinar □ Sartomer  
 □ Sheldahl Display Products □ Soken Chemical  
 □ Southwall Technologies □ **3M Optical Systems**  
 □ Tredegar Performance Films □ Viox □ Zeon  
 Chemicals

### spacers

□ Dana Enterprises Intl. □ H. W. Sands  
 □ Soken Chemical

### thin films

□ Colorado Concept Coatings LLC □ Fonon  
 Technology □ Mirwec □ PVA TePla AG  
 □ Rofin-Sinar □ Sheldahl Display Products

### touch screens

□ Data Modul □ EarthLCD □ Five Star  
 Technologies □ Fujitsu Components America  
 □ Sheldahl Display Products □ Touch  
 International □ eGalax\_eMPIA Technology

### MATERIALS HANDLING

□ **Benchmark** □ DuPont Display □ Laser  
 Photonics □ Lynch Systems □ Photomaching  
 □ Precision Technology Group □ Pure Depth  
 □ **Tempo** □ Todco

### MEDICAL DISPLAYS

□ Aaeon Electronics □ Aaeon Systems  
 □ Abris Industrial Glass □ All American  
 □ Anders Electronics □ Apollo Display  
 Technologies □ Arista □ Arrow □ Avocent  
 □ Bell Microproducts □ ColorLink  
 □ Communications Specialties □ Corning  
 □ Data Modul □ DuPont Display □ EarthLCD  
 □ **Endicott Research Group** □ EuropTec  
 □ Eurotech / Applied Data Systems  
 □ Fraunhofer Institute of Physics □ Fraunhofer  
 IPMS □ Fusion Optix □ General Digital  
 □ Gennum □ GM Nameplate □ Horizon  
 Technology □ Industrial Displays □ Jaco  
 Electronics □ Kristel □ L-3 Communications  
 □ Lumitex □ Matrix Orbital □ NDF □ Planar  
 Systems □ Purdy Electronics □ Quest  
 International □ Richardson Electronics □ Sharp  
 Microelectronics of the Americas □ Sheldahl  
 Display Products □ **Solomon Systech** □ Telios  
 Tech □ Teltron Technologies □ US Micro  
 Products □ Wintek

### MEMS

□ **Benchmark** □ Colorado Concept Coatings  
 LLC □ Corning Inc. □ Fraunhofer IPMS  
 □ Microvision Labs □ Schott North America  
 □ Synova □ **Texas Instruments, DLP Div.**

### MICE AND OTHER POINTING DEVICES

□ Fujitsu Components America □ **Stencil**

### MICROCHANNEL PLATES

□ Physical Optics

### MICRODISPLAY IMAGERS

□ ColorLink □ Corning Inc. □ CRLO □ Forth  
 Dimension □ MicroEmissive Displays □ OC  
 Oerlikon Balzers – Optics □ Unaxis Shanghai

### MONITOR MOUNTING DEVICES

□ Capstone □ Chief Manufacturing  
 □ Ergotron □ General Digital □ Innovative  
 Office Products □ Quest International

### OLEDs

□ Albemarle □ Anders Electronics □ Colorado  
 Concept Coatings □ Data Modul □ eMagin  
 □ Fraunhofer IPMS □ H. W. Sands  
 □ IntertechPira □ MicroEmissive Displays  
 □ Mirwec □ OSRAM Opto Semiconductors  
 □ Powertip Technology □ PVA TePla AG  
 □ Schott North America □ Sheldahl Display  
 Products □ sim4tec GmbH □ Synova

### OLED DEVICES

□ All American □ Anders Electronics □ Bright  
 View Technologies □ Cambridge Display  
 Technology □ CRG Chemical □ Dialog  
 Semiconductor □ DuPont Display □ eMagin  
 □ Fraunhofer IPMS □ H. W. Sands  
 □ IntertechPira □ Kurt J. Lesker □ MBraun  
 □ MicroEmissive Displays □ Novald AG  
 □ **Optek Technology** □ Photo Sciences  
 □ Powertip Technology □ sim4tec □ Toshiba  
 America Electronic Components □ US  
 Micro Products □ UDC □ Vision Display  
 System □ Wintek

### OPTICAL COATINGS

□ Abris Industrial Glass □ Adhesives Research  
 □ Anders Electronics □ Applied Technology  
 □ Arrow □ Astra Products □ Bi-Search  
 International □ Bookham □ Capstone  
 □ Colorado Concept Coatings □ Corning  
 □ CPFilms □ CRG Chemical □ Dana  
 Enterprises Intl. □ **Dontech** □ DuPont Display  
 □ EuropTec □ **Eyesaver** □ Fraunhofer  
 Institute of Physics □ Fujitsu Components  
 America □ Fusion Optix □ GE Plastics  
 □ GZO Technologies □ Intelcoat Technologies  
 □ Jaco Electronics □ **JDS Uniphase** □ Kent  
 State University □ LOFO High Tech Film  
 □ Labsphere □ Master Bond □ Metavac  
 □ Mirwec □ Nanofilm □ Nanogram □ OC  
 Oerlikon Balzers – Optics □ Ocean Optics  
 □ **Optek Technology** □ Optical Polymers  
 □ Performance Coatings □ Performance  
 Tech Associates □ Photo Sciences □ Purdy  
 Electronics □ Schott North America □ Sheldahl  
 □ Sheldahl Display Products □ Sycamore  
 Glass Components □ TFD □ **3M Optical  
 Systems** □ Tredegar Performance Films  
 □ Unaxis Optics □ Unaxis Shanghai □ White  
 Electronic Designs □ Zeon Chemicals  
 □ Zytronic

### OPTICAL COMPONENTS

□ Abris Industrial Glass □ Astra Products  
 □ Bookham □ Bright View Technologies  
 □ CELCO □ Colorado Concept Coatings  
 □ ColorLink □ Corning □ DDP □ **Dontech**  
 □ eMagin □ Exitech □ Fonon Technology  
 □ Fraunhofer Institute of Physics □ Fresnel  
 Technologies □ Fusion Optix □ Gamma  
 Scientific □ Hinds Instruments □ Horiba Jobin  
 Yvon □ **JDS Uniphase** □ Lumen Technology  
 □ Luminix □ Metavac □ Moxtek □ NDF  
 □ OC Oerlikon Balzers – Optics □ OMT  
 □ **Optek Technology** □ OSRAM Opto  
 Semiconductors □ **Parker Chomerics – Silver  
 Cloud** □ Photo Sciences □ Physical Optics  
 □ Purdy Electronics □ Stemmerich  
 □ Sycamore Glass Components □ Thinklogical  
 □ **3M Optical Systems** □ Unaxis Optics  
 □ Unaxis Shanghai □ Zeon Chemicals □ Zygo

### OPTICAL DESIGN SERVICES

□ Abris Industrial Glass □ AVO Photonics  
 □ **Benchmark** □ Capstone □ DDP □ **Dontech**  
 □ EuropTec □ Fraunhofer Institute of Physics  
 □ Fresnel Technologies □ Fusion Optix  
 □ GZO Technologies □ Heatron □ LAMBDA  
 Research □ Lumen Technology □ Microsharp  
 □ Physical Optics □ Purdy Electronics  
 □ Radiant Imaging □ Unaxis Optics □ Zygo

### PC-BASED TEST EQUIPMENT

□ Axometrics □ **Benchmark** □ Capstone  
 □ Dark Field Technologies □ DisplayCheck  
 □ Gamma Scientific □ **Klein Instruments**

□ Pixel Interconnect □ Radiant Imaging  
 □ Tricor Systems □ Zygo

### PHOSPHORS (inorganic)

□ Brimar Ltd. □ e beam □ H. W. Sands  
 □ IntertechPira □ Nanogram □ NDF  
 □ Phosphor Technology □ Thomas Electronics

### PHOTOLITHOGRAPHY CHEMICALS

□ Albemarle □ Azores □ Cyantek □ Pure Depth

### PHOTOLITHOGRAPHY EQUIPMENT

□ Horiba Jobin Yvon □ Micronic Laser  
 Systems AB □ Pure Depth □ PVA TePla AG

### PHOTOLITHOGRAPHY SERVICES

□ Adtek Photomask □ Advance Reproductions  
 □ Photo Sciences □ Pure Depth □ Sheldahl  
 Display Products □ Unaxis Optics

### PHOTOMASKS

□ Arrow □ Bi-Search International □ Bright  
 View Technologies □ DuPont Display  
 □ GrafTech International □ Jaco Electronics  
 □ Miyachi Unitek □ Plasmaco

### PLASMA DISPLAYS

□ Data Modul □ Rofin-Sinar

### PLASTIC MOLDING EQUIPMENT

□ GM Nameplate □ **Tempo**

### PLASTIC MOLDINGS

□ Fresnel Technologies □ **Stencil**

### POLARIZERS

□ Abris Industrial Glass □ Bi-Search  
 International □ Bookham □ Brimar Ltd.  
 □ Chomerics □ ColorLink □ Dana  
 Enterprises Intl. □ **Dontech** □ DuPont Display  
 □ EuropTec □ **Eyesaver** □ Jaco Electronics  
 □ Moxtek □ Nanogram □ Nitto Denko  
 □ Optical Filters □ Pixel Interconnect  
 □ Pure Depth □ Tredegar Performance Films  
 □ Unaxis Optics □ Zytronic

### POLYMER FILMS

□ Chomerics □ CPFilms □ CYRO Industries  
 □ **Dontech** □ DuPont Display □ EuropTec  
 □ Fusion Optix □ GE Plastics □ GiantPlus  
 Technology □ Jaco Electronics □ Kent State  
 University □ Microsharp □ Nanofilm  
 □ Nanogram □ Nitto Denko □ Photo  
 Sciences □ Pure Depth □ Rofin-Sinar  
 □ Sheldahl Display Products □ Tredegar  
 Performance Films □ Wavefront Technology  
 □ Zeon Chemicals

### POWER SUPPLIES, HIGH VOLTAGE

□ Applied Concepts □ Arrow □ Brimar Ltd.  
 □ CELCO □ Crane Aerospace □ ELDEC  
 □ **Endicott Research Group** □ Jaco  
 Electronics □ Keithley Instruments □ MKS  
 Instruments □ Monitech Industrial Display  
 □ NDF □ Supertex □ Thomas Electronics

### PRINTERS (for display fabs)

□ APS America □ Dimatix □ FUJIFILM Dimatix

### PRINTERS, INK-JET

□ FUJIFILM Dimatix □ Xenia Technology

### PROJECTION DISPLAYS

#### DLP/DMD and LCoS

□ Algorith □ **Benchmark** □ Bright View  
 Technologies □ Brightside □ Colorado  
 Concept Coatings □ Corning □ CRLO  
 □ Forth Dimension □ Fraunhofer Institute of  
 Physics □ Gennum □ GrafTech International  
 □ OC Oerlikon Balzers – Optics □ OMT  
 □ Schott North America □ Silicon Monitor  
 □ Syntax Groups □ Telios Tech □ **3M  
 Optical Systems** □ Unaxis Shanghai

### liquid-crystal displays

□ Aaeon Systems □ Advance Reproductions

□ Albemarle □ All American □ Anders Electronics □ Apollo Display Technologies □ Applied Technology □ Arima Display □ Arista □ Arrow □ Astra Products □ AU Optronics □ Basler AG □ Bell Microproducts □ Bi-Search International □ Brightside □ Brimar Ltd. □ CI Lumen Industries □ Coating Materials □ Colorado Concept Coatings □ Computer Dynamics □ Corning Displays □ Corning □ CPFilms □ CRLO □ CYRO Industries □ Data Modul □ Dialog Semiconductor □ **Dontech** □ DuPont Display □ EarthLCD □ ECSIBEO AB □ Emerging Display Technologies □ Everbouquet International □ Five Star Technologies □ Fonon Technology □ Forth Dimension □ GE Plastics □ Genesis Microchip □ Gennum □ GiantPlus Technology □ GrafTech International □ Hitachi Electronic Devices □ Horizon Technology □ IDC □ IEE □ IFM □ i-sft GmbH □ Jaco Electronics □ Jiya LCD □ Kent State University □ Kopin □ Korry Electronics □ Kristel □ Kyocera □ Lumen Technology □ LXD □ Main Tape Co. □ Matrix Orbital □ Meritec □ Microtips Technology □ Monitech Industrial Display □ Motion Research □ Nanofilm □ Nanogram □ NDF □ NKK Switches □ Nemoptix □ Nippon Paper □ Optrex America □ Pixel Interconnect □ Planar Systems □ Powertip Technology □ Purdy Electronics □ Pure Depth □ Quadrangle Products □ Quest International □ Rofin-Sinar □ Samsung Semiconductor □ Sartomer □ Scienstry □ Sharp Microelectronics of the Americas □ Sheldahl □ Sheldahl Display Products □ Silicon Monitor □ Soken Chemical □ **Solomon Systech** □ Sunic System □ Tannas Electronics □ Telios Tech □ **3M Optical Systems** □ Tianma Microelectronics □ Timeline □ Toshiba America Electronic Components □ Tredegar Performance Films □ US Micro Products □ Unitek EAPRO (Miyachi Unitek) □ Vision Display System □ White Electronic Designs □ Wintek □ Zeon Chemicals

#### projection CRTs

□ Algolith □ Brimar Ltd. □ e beam □ Gennum □ Hitachi Electronic Devices □ Monitech Industrial Display □ Telios Tech □ Teltron Technologies □ Thomas Electronics

#### PROJECTION SCREENS

**rear**  
 □ Abris Industrial Glass □ Astra Products □ Bright View Technologies □ **Dontech** □ Fusion Optix □ Microsharp □ Physical Optics □ **3M Optical Systems** □ Zytronic

#### RADIOMETERS

□ Display Asia □ EXFO Photonic Solutions □ Gamma Scientific □ **Westboro Photonics** □ **Konica Minolta** □ **Konica Minolta Photo Imaging** □ Labsphere □ **Optronic Labs** □ Photo Research □ Radiant Imaging □ UDT Instruments

#### REPAIR AND MAINTENANCE of high-voltage power supplies

□ Brimar Ltd. □ Crane Aerospace □ ELDEC □ Jaco Electronics □ MKS Instruments □ NDF

#### SCANNERS (document and film)

□ CELCO □ NDF □ Optical Polymers

#### SCOREBOARDS/STADIUM DISPLAYS

□ Avocent □ IFM

#### SCRIBERS

□ Applied Photonics □ Exitech □ Fonon Technology □ New Wave Research □ Photomaching □ Rofin-Sinar □ Sycamore Glass Components

#### SEALANTS

□ Delo Industrial Adhesives □ Diemat □ GE Plastics □ GE Silicones □ Master Bond □ Venture Tape

#### SIMULATOR DISPLAYS

□ Arrow □ Brimar Ltd. □ Interface Displays & Controls □ Jaco Electronics □ Kristel □ Lumen Technology □ **Solomon Systech** □ Tannas Electronics □ Telios Tech □ Teltron Technologies □ Thomas Electronics

#### SINGLE CRYSTAL

□ Kopin

#### SOFTWARE FOR DISPLAYS graphics systems software

□ Aaeon Electronics □ CELCO □ Data Modul □ Display Asia □ Dynamic Digital Depth □ Portrait Displays

#### image processing software

□ Algolith □ Brightside □ Capstone □ Dynamic Digital Depth □ EPIX □ Genesis Microchip □ Gennum □ Portrait Displays □ Tricolor Systems

#### optical analysis software

□ autronic-Melchers □ Breault □ Display-Check □ Gamma Scientific □ **Klein Instruments** □ Optical Research Associates □ Sanayi System Co. □ sim4tec □ Tricolor Systems □ Zemax

#### signal processing software

□ Capstone □ Fraunhofer IPMS □ Motion Research

#### SPEECH INPUT/OUTPUT DEVICES

□ **Microvision**

#### TEST AND MEASUREMENT EQUIPMENT automated test equipment

□ Aerotech □ autronic-Melchers □ Axometrics □ Basler AG □ **Benchmark** □ Cambridge Display Technology □ Capstone □ **Chroma ATE** □ Dark Field Technologies □ Display-Metrology & Systems □ DisplayCheck □ Dr. Schenk of America □ **ELDIM** □ Gamma Scientific □ GZO Technologies □ Hinds Instruments □ Horiba Jobin Yvon □ Instec □ **Westboro Photonics** □ Integral Vision □ ISRA Surface Vision □ J. A. Woollam Co. □ Keithley Instruments □ KLA-Tencor □ **Klein Instruments** □ Micromanipulator Co. □ Micronics Japan □ **Microvision** □ Otsuka Electronics □ Photo Research □ Pixel Interconnect □ Quantum Data □ Radiant Imaging □ Sensor Products □ TGI □ Tricolor Systems □ UDT Instruments □ **Westar** □ Zygo

#### colorimeters

□ autronic-Melchers □ **B&W TEK** □ Display-Metrology & Systems □ **ELDIM** □ Gamma Scientific □ **Westboro Photonics** □ Integral Vision □ Interface Displays & Controls □ **Klein Instruments** □ **Konica Minolta** □ **Konica Minolta Photo Imaging** □ **Microvision** □ Photo Research □ Radiant Imaging

#### convergence gauges

□ Klein Instruments □ **Konica Minolta Photo Imaging**

#### gonioreflectometers

□ autronic-Melchers □ Display-Metrology & Systems □ **ELDIM** □ Fraunhofer Institute of Physics □ Gamma Scientific □ Horiba Jobin Yvon □ **Westboro Photonics** □ Microsharp □ Microvision Labs □ Radiant Imaging

#### hot stages

□ Instec □ Integral Vision □ Micromanipulator Co.

#### microscopes

□ CELCO □ ColorLink □ Dana Enterprises Intl. □ Instec □ **Klein Instruments** □ Micromanipulator Co. □ Pixel Interconnect □ Zygo

#### photometers

□ autronic-Melchers □ **B&W TEK** □ Display-Metrology & Systems □ **ELDIM** □ Gamma Scientific □ **Westboro Photonics** □ Integral Vision □ **Klein Instruments** □ **Konica Minolta** □ **Konica Minolta Photo Imaging** □ Labsphere □ **Lumetrix** □ Microsharp □ **Microvision** □ NDF □ **Optronic Labs** □ Photo Research □ Radiant Imaging □ Richardson Electronics □ Tricolor Systems □ UDT Instruments

#### spectrometers

□ **Astro Systems** □ autronic-Melchers □ **B&W TEK** □ **Chroma ATE** □ Display-Metrology & Systems □ **ELDIM** □ Fraunhofer IPMS □ Gamma Scientific □ Horiba Jobin Yvon □ **Westboro Photonics** □ Integral Vision □ **Klein Instruments** □ **Konica Minolta Photo Imaging** □ Labsphere □ **Microvision** □ MKS Instruments □ Ocean Optics □ Otsuka Electronics □ Photo Research □ Pixel Interconnect □ Pure Depth □ Quantum Data □ Radiant Imaging □ Unigraf OY □ **Westar**

#### video generators

□ **Astro Systems** □ autronic-Melchers □ **Chroma ATE** □ **ELDIM** □ **Klein Instruments** □ **Microvision** □ Pixel Interconnect □ Pure Depth □ Quantum Data □ Unigraf OY □ **Westar**

#### video oscilloscopes

□ Abris Industrial Glass □ Applied Technology □ Astra Products □ Basler AG □ Berliner Glas □ Bookham □ CPFilms □ CYRO Industries □ DuPont Display □ EuropTec □ **Eyesaver** □ Fusion Optix □ J. A. Woollam Co. □ **JDS Uniphase** □ Kent State University □ Metavac □ Nanofilm □ OC Oerlikon Balzers – Optics □ Ocean Optics □ Photo Sciences □ Physical Optics □ Pure Depth □ Sekisui S-Lec American □ Sheldahl □ Southwall Technologies □ Sumitomo Osaka Cement Co. □ Sycamore Glass Components □ **TFD** □ **3M Optical Systems** □ Tredegar Performance Films □ Unaxis Optics □ Unaxis Shanghai □ Zeon Chemicals

#### THIN FILMS

□ Abris Industrial Glass □ Acheson Colloids □ Adhesives Research □ Advance Reproductions □ Applied Technology □ Astra Products □ Basler AG □ Berliner Glas □ Bookham □ Coating Materials □ Colorado Concept Coatings □ CPFilms □ CRG Chemical □ CYRO Industries □ **Dontech** □ DuPont Display □ EuropTec □ **Eyesaver** □ Fonon Technology □ Fusion Optix □ Horiba Jobin Yvon □ J. A. Woollam Co. □ **JDS Uniphase** □ Kent State University □ Kurdex □ Kurt J. Lesker □ Main Tape Co. □ Metavac □ Mirwec □ Nanofilm □ Nanogram □ OC Oerlikon Balzers – Optics □ Ocean Optics □ **Parker Chomerics** – Silver Cloud □ Photo Sciences □ Physical Optics □ Pure Depth □ PVA TePla AG □ Rofin-Sinar □ Sartomer □ Schott North America □ Sekisui S-Lec American □ Sheldahl □ Sheldahl Display Products □ **Solomon Systech** □ Southwall Technologies □ Specialty Tapes □ Sumitomo Osaka Cement Co. □ Sycamore Glass Components □ **TFD** □ **3M Optical Systems** □ Tredegar Performance Films □ Unaxis Optics □ Unaxis Shanghai □ Zeon Chemicals

#### 3-D DISPLAY SYSTEMS

□ Aaeon Systems □ CI Lumen Industries □ ColorLink □ DuPont Display □ Dynamic Digital Depth □ **ELDIM** □ IEE □ Microsharp □ Physical Optics □ Planar Systems □ Pure Depth □ Seereal Technologies GmbH □ Sharp Microelectronics of the Americas □ Telios Tech □ Toshiba America Electronic Components

#### TOUCH DISPLAYS

□ Aaeon Electronics □ Abris Industrial Glass □ All American □ Anders Electronics □ Arista □ Arrow □ Basler AG □ Bell Microproducts □ Capstone □ CI Lumen Industries □ Computer Dynamics □ Data Modul □ Dawar Technologies □ **Dontech** □ Digital View Group □ DuPont Display □ EarthLCD □ eGalax\_eMPIA Technology □ **Elo TouchSystems** □ Eurotech / Applied Data Systems □ **Eyesaver** □ Fujitsu Components America □ GM Nameplate □ Hampshire Co. □ Hong Kong ASTRI □ Horizon Technology □ IEE □ Immersion □ Industrial Displays □ Interface Displays & Controls □ IR Touch Systems □ Jaco Electronics □ Kristel □ Kyocera □ L-3 Communications □ Lumen Technology □ NKK Switches □ Orbit International □ Planar Systems □ Purdy Electronics □ Pure Depth □ Quest International □ RPO □ Schott North America □ Sheldahl Display Products □ **Solomon Systech** □ Telios Tech □ 3M Touch Systems □ **Touch International** □ US Micro Products □ White Electronic Designs

#### TOUCH SCREENS

□ Aaeon Systems □ Abris Industrial Glass □ Acheson Colloids □ All American □ Apollo Display Technologies □ Applied Technology □ Arista □ Arrow □ Astra Products □ Basler AG □ Bell Microproducts □ Bi-Search International □ Capstone □ Coating Materials □ Computer Dynamics □ Corning □ CPFilms □ CRG Chemical □ CYRO Industries □ Data Modul □ Dawar Technologies □ **Dontech** □ DuPont Display □ EarthLCD □ eGalax\_eMPIA Technology □ **Elo TouchSystems** □ EuropTec □ **Eyesaver** □ Fujitsu Components America □ GE Silicones □ General Digital □ GM Nameplate □ **GUNZE USA** □ GZO Technologies □ H. W. Sands □ Hampshire Co. □ Horizon Technology □ Industrial Displays □ Intelicoat Technologies □ Interface Displays & Controls □ IR Touch Systems □ Jaco Electronics □ L-3 Communications □ Liyitec Inc. □ Lumen Technology □ Main Tape Co. □ Microtips Technology □ Nanofilm □ Nippon Paper □ Purdy Electronics □ Pure Depth □ Quadrangle Products □ Quest International □ Richardson Electronics □ RPO □ Schott North America □ Sheldahl □ Sheldahl Display Products □ SMK □ **Solomon Systech** □ Telios Tech □ **TFD** □ The Berquist Co. □ **3M Optical Systems** □ 3M Touch Systems □ Toshiba America Electronic Components □ **Touch International** □ US Micro Products □ Wacom □ White Electronic Designs □ Wintek □ Zytronic

#### TOUCH TABLETS

□ Aaeon Systems □ Abris Industrial Glass □ Bell Microproducts □ DuPont Display □ GM Nameplate □ Hampshire Co. □ Lumen Technology □ RPO □ Schott North America □ Sheldahl Display Products □ Telios Tech □ 3M Touch Systems

#### TOUCHSCREEN STYLUS

□ OSRAM Opto Semiconductors □ **Slencil**

#### TRACKBALLS

□ Orbit International

#### VACUUM EQUIPMENT

□ Instec □ Kurdex □ Kurt J. Lesker □ MBraun □ MKS Instruments □ OTB Display □ **SAES Getters** □ VAT

#### VACUUM FLUORESCENT DISPLAYS

□ EarthLCD □ IEE □ Matrix Orbital □ Optical Polymers □ Telios Tech □ Trovato Mfg.

#### VIDEO AMPLIFIERS

□ Brimar Ltd. □ CELCO □ CELCO Pacific □ Thomas Electronics

# industry directory

## VIDEO AND DISPLAY STANDARDS

□ AGC Systems □ Avocent □ Genesis Microchip □ IntelliMats □ Pure Depth □ VESA

## VIDEO CUBES

□ Gennum

## VIDEO INTERFACES

□ Arrow □ Astro Systems □ Avocent □ Bell Microproducts □ Cabletime □ Capstone □ Communications Specialties □ Data Modul □ Digital View Group □ eGalax\_eMPIA Technology □ Genesis Microchip □ IntelliMats □ Systemation Technology □ Thinklogical □ VESA □ Westar

## VIDEO WALLS

□ Astra Products □ Gennum □ Landmark Technology □ Unigraf OY

## VIEWING SCREENS

□ Abrisa Industrial Glass □ Astra Products □ IntelliMats □ Optical Polymers □ Physical Optics □ Telios Tech □ 3M Optical Systems

## VIRTUAL IMAGING

□ Brimar Ltd. □ Fraunhofer IPMS □ Sensor Products

## VIRTUAL-REALITY DISPLAYS

□ Brimar Ltd. □ Dynamic Digital Depth □ Forth Dimension □ Fraunhofer IPMS

## WIRE

□ Avocent □ Data Modul □ Peter's Co. □ Purdy Electronics □ Quadrangle Products □ Thomas Electronics

## X-RAY IMAGE STORAGE SCREENS

□ Aaeon Systems □ Data Modul □ Phosphor Technology □ Physical Optics

## X-RAY IMAGING

□ Aaeon Systems □ Data Modul □ Phosphor Technology □ Physical Optics □ Schott North America

system products including operator panels, robust panel PCs, medical PCs, embedded controllers, Industrial chassis, firewall products, and related accessories.

Sean Park, Marcom Specialist  
714/671-1800, fax -1802  
e-mail: info@aaeon.com  
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480/446-8000, fax -8001  
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805/421-5411, fax -8604  
e-mail: dpuchbauer@abrisa.com  
www.abrisa.com

ACHESON COLLOIDS, 1600 Washington Ave., Port Huron, MI 48060  
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Greg Gaitens, Sls. Mgr.  
1-800/255-1908, fax 810/984-1446  
www.achesonindustries.com

AD-VANCE MAGNETICS, INC., 625 Monroe St., P.O. Box 69, Rochester, IN 46975  
Worldwide supplier of custom-fabricated magnetic shields, magnetic shields for CRTs, photomultiplier shields, shielded enclosures, computer-monitor shields, and magnetic-shielding alloy sheet and foil (0.002-0.062 thick).

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574/223-3158, fax -2524  
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www.advancemag.com

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717/235-7979, fax 717/227-8275  
e-mail: mlawson@arglobal.com  
www.adhesivesresearch.com

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Peter Erhart, Gen. Mgr.  
514/737-7030, fax -9893  
e-mail: perhart@adteckphotomask.com  
www.adteckphotomask.com

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e-mail: stevea@advancerepro.com  
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ADVANCED MANUFACTURING GROUP, 9880 S. Pioneer, Santa Fe Springs, CA 90670  
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562/949-6088, fax -4431  
e-mail: sales@advancedmanufacturinggroup.com  
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412/963-7470, fax -7459  
e-mail: sales@aerotech.com  
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Aldo Cugini, President  
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e-mail: acugini@agcsystems.com  
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## Part II: Companies

Listings are in strict alphabetical order. Punctuation, spaces, and the initial definite article "The" are ignored. Numbers (3-D, 3M, 01), symbols (&), and abbreviations (Co., Corp., Inc., Ltd.) are listed as though fully spelled out.

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e-mail: sales@aaeon.com  
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B. K. Chua  
+82-031-612-5000, fax +82-031-666-5532  
e-mail: sales@ansinc.co.kr  
www.ansinc.co.kr

APOLLO DISPLAY TECHNOLOGIES, LLC, 85 Remington Blvd., Ronkonkoma, NY 11779  
Distributors and manufacturers of controllers, value-added enhancements, and kit solutions for passive-matrix color/monochrome and character/graphics LCDs as well as active-matrix TFT-LCDs. Also available a wide range of display integration solutions for industrial control, machine automation, medical, POS/kiosk displays, LAN and WLAN networking, and digital signage.

Richard McKay, Managing Dir.  
631/580-4360, fax -4370  
e-mail: sales@apolloDisplays.com  
www.apolloDisplays.com

APPLIED CONCEPTS, INC., 397 State Rt. 281, P.O. Box 1175, Tully, NY 13159

Designers, manufacturers, and marketers of specialty power-conversion technologies and services to improve performance in all areas related to LCD (FPD) system integration, including dc-to-ac inverters and turnkey-engineered LED backlighting solutions using I-Drive™ LED converters.

Suzanne Thomas, LED Project Mgr./Strategic Relationship Mgr.  
315/696-6676, fax -9923  
e-mail: sales@acipower.com  
www.acipower.com

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480/998-2333, fax -2201  
e-mail: gfeng@appliedphotonics.com  
www.appliedphotonics.com

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e-mail: mbogin@astraproducts.com  
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e-mail: cris@astro-systems.com  
www.astro-systems.com

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Manufacturers of a line of instruments for measuring all of the polarization properties of the optical films and elements used in displays, including LCD components and LCOS.  
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256/489-0051, fax 256/704-6002  
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telephone/fax 734/995-8414  
e-mail: as1285@columbia.edu

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*Manufacturers of acrylic pressure-sensitive adhesives for optical films and protection films. Also, Acrylic micropowders for light diffusion.*

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e-mail: kasuga@sokenchem.com  
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e-mail: sales@solomon-systech.com  
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e-mail: jhlee@sunic.co.kr  
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# industry directory

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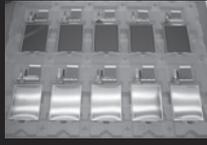
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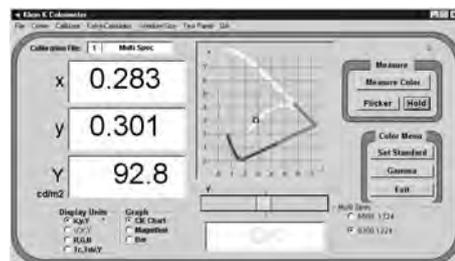
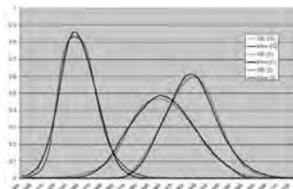
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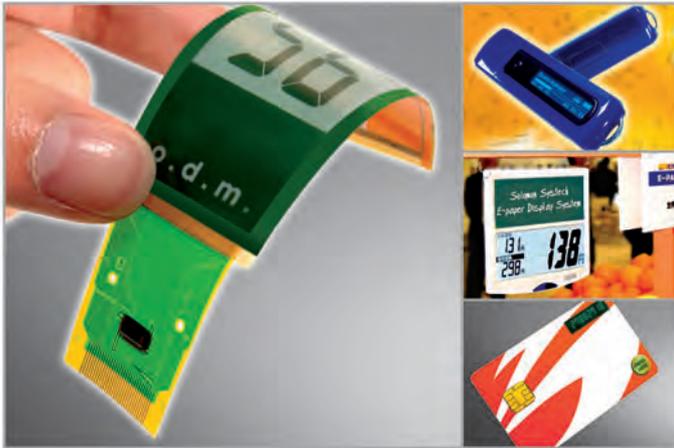
**Single chip bistable driver for both cholesteric and electrophoretic displays**

**Raymond Ho**  
*Solomon Systech Limited*

Bistable display is a non-traditional display method. It is a display device illuminated by reflecting ambient light. The image is retained on the display even after the panel power supply has been removed. Bistable display offers paper-like readability, with features such as high contrast, a wide viewing angle, reflective, and readable under sunlight. It is ultra thin and lightweight. Some bistable displays can even be twisted out of shape. Moreover, the system power can be saved by bistability characteristics, since the image remains on display even without power.

Specialized bistable display driver controller SSD1623 developed by Solomon Systech makes these advanced bistable display technologies become a reality. This highly integrated driver consists of MCU interface for command and image data input, display RAM to buffer image data, high voltage driving outputs. To minimize system cost and space, the driver has built-in DC/DC converter to supply high voltage to drive the display. The driver can be applied to different bistable display technologies such as cholesteric and electrophoretic displays since it can generate different driving waveform flexibly according to the requirement of these displays.

Because of the niche characteristics of bistable display: thin, flexible and bistable, with the highly compact and competitive design of SSD1623, bistable display is enabled in applications such as memory devices, IC cards, electronic shelf labels, mobile phones, and timepieces etc.



**Dynamic backlight control saves backlight power consumption by up to 50% for portable devices**

**Jacky Chan**  
*Solomon Systech Limited*

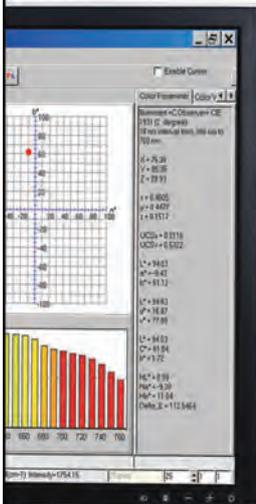
The dynamic backlight control technology by Solomon Systech is designed to reduce backlight power consumption while maintaining image fidelity and quality. Reducing power consumption is one of the most important tasks for battery-operated portable devices nowadays as small physical size and being lightweight are the general norm. And the backlight is always the most power consuming part in the application. Solomon Systech's driver ICs SSD2118B, SSD2225 with the dynamic backlight control can reduce up to 50% backlight power consumption and bring added value to portable device manufacture without sacrificing the display quality of the end products.

SSD2118B is a highly integrated single chip driver for portable 16-million color Audio Video TFT (AV TFT) displays in landscape QVGA resolution (320x240). It integrates source driver, gate driver and external power chip into a single chip solution. SSD2225 is a high speed interface version of SSD2220, which supports TFT LCD with wQVGA resolution (240x432). For the input pin side, the integrated Mobile Industry Processor Interface (MIPI) on SSD2225 enables high data rate transfer with low EMI and minimized pin count for connection, while at the output pin side to LCD panel, the SSD2225 is made compatible to SSD2220 such that they can share the same LCD panel design.



By deploying Solomon Systech's dynamic backlight control technology, the power consumption of the backlight can be reduced by up to 50% while maintaining the image quality. (a) Without dynamic backlight control; (b) With dynamic backlight control.

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## USDC Changes Name to FlexTech Alliance

(continued from page 3)

The FlexTech Alliance will leverage the strong relationships USDC has already forged with industry, the academic community, investment banks and venture capital firms, along with federal agencies including the U.S. Army Research Laboratory and the National Institute of Standards and Technology (NIST), which funded early federal initiatives in printed electronics. The FlexTech Alliance will also continue to work closely with the Flexible Display Center (FDC) at Arizona State University and the Center for Advanced Microelectronics Manufacturing (CAMM) at Binghamton University in upstate New York—both of which have substantial activity in this dynamic industry.

— Staff Reports

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# Display Week 2009: The SID International Symposium, Seminar & Exhibition

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San Antonio, Texas, USA  
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[www.sid2009.org](http://www.sid2009.org)

## editorial

continued from page 2

Also, along the lines of improving luminous efficiency in LCDs, Dr. Adi Abileah from Planar Systems graciously agreed to write an overview on the technology of light-management films used in LCD backlights, which is very helpful in understanding the systems being exhibited and the challenges to making them more efficient. We're very pleased Adi was able to do this so we could present it to you in this same issue.

This year, we decided to give organic-light-emitting-diode (OLED) displays their own category, a decision validated by the reporting of our very experienced correspondent Craig Cruickshank of cintelliq, who opened his review by stating: "History may well judge 2008 to have been a pivotal year for the evolution of OLED technology commercialization ... with key advances in materials, device architecture, optical performance, and manufacturing processes all coming to the fore this year, along with a serious attempt to prove that broad commercialization is finally close at hand." It is no wonder he feels that way; whereas Sony's 11-in. OLED TV was the main OLED story of Display Week 2007 (with its commercial release earning it the SID/Information Display Display of the Year Gold Award in 2008), Display Week 2008 featured myriad OLED developments that were the result of the tremendous efforts of OLED manufacturers to bring this technology to market as soon as possible. Perhaps most noteworthy among these was the 31-in. 1920 x 1080 OLED-display prototype from Samsung SDI. Could this be an LCD-displacing technology? Well, maybe not quite yet, but Craig certainly is convinced the future for OLED technology is bright – please pardon the pun.

We often forget that these stunning displays really are made from a large number of very specialized and critical components as well as a good sprinkling of know-how on the part of the designers. David Eccles, a well respected industry consultant and most recently past Regional VP of the Americas for SID, examines the vast array of component offerings and boils it down for us into some essential parts in his review. Dave's article immediately recognized the emphasis on improving light efficiency to reduce cost, the never-ending goal of better performance, and also the perennial mission of reducing cost as an almost perfect storm of new milestones for component improvements. From optical

films, to backlight systems, to graphics controllers and to even the familiar CCFL inverters, significant improvements were easy to spot. No doubt, Dave's highlights will be getting a lot of industry attention over the upcoming year.

Before I wrap up and let you read on, I want to recognize a member of our staff who works tirelessly to make every issue of *ID* the best it can be. Many of you know Jay Morreale and all the work he does for *ID* and the *Journal of SID*. You may not be aware that Jay also maintains and updates the annual Industry Directory. The Directory has grown significantly in the past few years and is now featured online through the *ID* Web site ([www.informationdisplay.org](http://www.informationdisplay.org)) as well as published annually in this magazine. Jay meticulously reviews every entry, contacts the companies for updates and changes to their business, and ensures that every entry is as up to date as possible. He now does this year round to keep the Web version relevant and accurate as well. You can imagine this is a tedious job, a bit like editing the Manhattan phone book, and probably not all that exciting

to describe to friends at cocktail parties, but for all of us, it is a tremendously valuable end product. Thank you Jay for your hard work and great results.

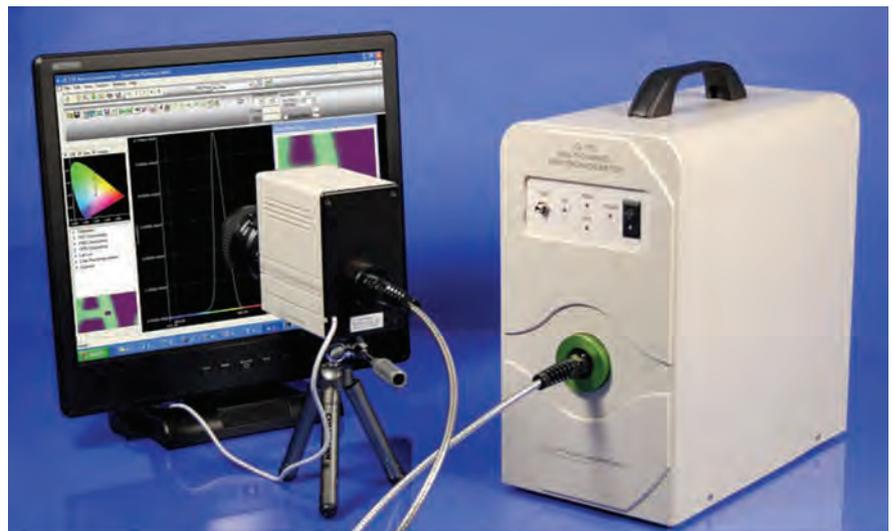
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## president's corner

*continued from page 4*

that the use of LED backlights will reduce the usage of mercury by 120 grams each year from their manufactured LCDs.

Other companies are taking other approaches toward improved environmental footprints. For example, the optical stack for LCDs is a major target of innovation, as demonstrated by 3M and others in the light-control-film arena. Backlights containing mercury can be replaced not only by LEDs, but by OLEDs or by field emission by carbon nanotubes. Companies such as 3M and others continue to innovate film technologies that capture and direct light in an AMLCD, making its use more efficient. Companies such as Corning are showing that it is possible to remove heavy metals from display glass, preventing the leaching of toxic metals into the environment once a display enters the waste stream. Sharp and others are investing in photovoltaic capacity as well as LCD capacity, sharing process technologies across the manufacturing space. The companies beginning to drive innovations in this space are remarkable, and more are joining every year.

The key item across all these initiatives is sustainability. Reducing environmental impact and energy consumption should not automatically mean that prices go up, or that people are asked to make due with less. A much better situation is to use clever design and advanced technology to generate equivalent or better performance while reducing energy costs and environmental impact. In this way, the consumer gets what they need in terms of performance and price, governments and the energy industry get what they want in terms of power efficiency and reduced greenhouse gas emission, and the company gets new markets for their electronic-display products. Being able to generate more while starting with less is the sign of a sustainable set of products, which will become increasingly important in a crowded, energy-hungry world.

The rationale of "going green" as a charitable act is rapidly becoming unnecessary. Developing and producing products that from an environmental perspective are sustainable and low impact is just good business. So, for those companies with major efforts in these areas, I salute your foresight. For those that are not yet taking this area seriously, I'll point out that you are falling behind your competitors.

Paul Drzaic  
President, Society for Information Display

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## SID 2009 honors and awards nominations

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

## SID honors and awards nominations

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

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

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

E-mail the complete nomination – including all the above material by **October 10, 2008** – to [cnelsonk@comcast.net](mailto:cnelsonk@comcast.net) or [sidawards@sid.org](mailto:sidawards@sid.org) or by regular mail to:  
Christopher N. King, Honors and Awards Chairman, Society for Information Display,  
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1. Name, Present Occupation, Business and Home Address, Phone and Fax Numbers, and SID Grade (Member or Fellow) of Nominee.
2. Award being recommended:  
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Karl Ferdinand Braun Prize  
Otto Schade Prize  
Slottow–Owaki Prize  
Lewis & Beatrice Winner Award  
Fellow\*  
Special Recognition Award  
\*Nominations for election to the Grade of Fellow must be supported in writing by at least five SID members.
3. Proposed Citation. This should not exceed 30 words.
4. Name, Address, Telephone Number, and SID Membership Grade of Nominator.
5. Education and Professional History of Candidate. Include college and/or university degrees, positions and responsibilities of each professional employment.
6. Professional Awards and Other Professional Society Affiliations and Grades of Membership.
7. Specific statement by the nominator concerning the most significant achievement or achievements or outstanding technical leadership that qualifies the candidate for the award. This is the most important consideration for the Honors and Awards committee, and it should be specific (citing references when necessary) and concise.
8. Supportive material. Cite evidence of technical achievements and creativity, such as patents and publications, or other evidence of success and peer recognition. Cite material that specifically supports the citation and statement in (7) above. (Note: the nominee may be asked by the nominator to supply information for his candidacy where this may be useful to establish or complete the list of qualifications).
9. Endorsements. Fellow nominations must be supported by the endorsements indicated in (2) above. Supportive letters of endorser will strengthen the nominations for any award.

stipend sponsored by Thompson, Inc., Sharp Corporation, and Philips Consumer Electronics, respectively.

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

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

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

nomination, please keep these criteria with their weights in mind.

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

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

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

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

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

**All 2009 award nominations are to be submitted by October 10, 2008.** E-mail your nominations directly to [cnelsonk@comcast.net](mailto:cnelsonk@comcast.net) or [sidawards@sid.org](mailto:sidawards@sid.org). If that is not possible, then please send your hardcopy nomination by regular mail.

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

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

Thank you for your nomination in advance.

– Christopher N. King  
SID Honors & Awards Committee

In addition to the International Conferences and Meetings to the right, SID is also sponsoring the following Regional and Topical Meetings:

**13 MARCH 08**

**SID-ME Mid-Europe Chapter  
Spring Meeting 2008**

**MARCH 13–14, 2008**

**Jena, Germany**

Topical sessions include:

- Microdisplay Applications
- Light Sources
- Optics: Design & Fabrication
- OLED Microdisplays

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**23 SEPTEMBER 08**

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**SEPTEMBER 23–24, 2008**

**San Diego, California, USA**

Topics include:

- Mobile-phone product design
- Other handheld mobile system designers
- Small display makers
- Driver chips for mobile displays
- Display component makers including backlights, optical enhancement films, polarizers, and drivers
- Wireless service providers
- Power management
- Graphics and display system architecture
- Materials and components for mobile displays

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**16 OCTOBER 08**

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**OCTOBER 16–17, 2008**

**Dearborn, Michigan, USA**

Topical sessions include:

- FPD technologies for vehicle applications
- Optical components
- Human factors and metrology

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**For information on SID Conferences, contact:**

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**18 MAY 08**

**SID 2008 International Symposium,  
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MAY 18–23, 2008  
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- Display Applications Session (new)
- Technical Sessions
- Poster Session
- Author Interviews
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- Technical Seminars
- Applications Tutorials
- Product and Technology Exhibition
- Exhibitor Forum
- Evening Panel

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**13 OCTOBER 08**

**Asia Display 2008 (AD 2008)**

**International Display  
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(IDMC 2008)**

**International Meeting on  
Information Display (IMDC 2008)**

OCTOBER 13–17, 2008  
Ilsan, Korea

Topical Sessions Include:

- Active-Matrix Devices
- LC Technologies and Other Non-Emissive Displays
- Plasma Displays
- OLED Displays
- EL Displays, LEDs, and Phosphors
- Flexible Displays/Plastic Electronics
- FEDs and Ultra-Slim CRTs
- Projection Displays
- Display Electronics, Systems, and Applications
- Applied Vision/Human Factors/3-D Displays
- Display Materials and Components
- Display Manufacturing and Measurement Equipment
- Novel and Future Displays

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**3 NOVEMBER 08**

**International Display Research  
Conference (IDRC)**

NOVEMBER 3–6, 2008  
Orlando, Florida, U.S.A.

Topical sessions include:

- LCDs and other non-emissive displays
- CRTs/FEDs/PDPs
- LEDs/OLEDs/ELDs
- E-Paper/Flexible Displays
- Microdisplays
- Projection Displays
- Electronics and Applied Vision
- Systems, Applications
- Markets

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**10 NOVEMBER 08**

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(CIC '08)**

NOVEMBER 10–14, 2008  
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An international multi-disciplinary forum for dialogue on:

- Scientific disciplines
- Color image synthesis/analysis/processing
- Engineering disciplines
- Applications

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**3 DECEMBER 08**

**International Display Workshops  
(IDW '08)**

DECEMBER 3–5, 2008  
Niigata, Japan

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- LC science, technologies & displays
- CRTs, PDPs, FEDs, OLEDs, 3Ds
- Large-area displays
- Display materials, components & manufacturing equipment
- Applied vision & human factors
- EL displays, LEDs & phosphors
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