DISPLAY WEEK PREVIEW / HONORS AND AWARDS ISSUE

Information DISPLAY

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Hollywood Rolls Out the Red Carpet for SID

- ***SID Comes to Los Angeles***
- ***2008 Honors and Awards Winners***
- ***China's LCOS Opportunity***
- ***ITO Alternatives for Transparent Conductors***
- **Journal of the SID** ***April Preview***

Information DISPLAY

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COVER: Los Angeles will play host to the Society for Information Display International Symposium, Seminar, and Exhibition the week of May 18–23 at the Los Angeles Convention Center. If you cannot attend Display Week 2008, you can be there by visiting Information Display OnLine at www.informationdisplay.org.

CREDIT: Los Angeles Convention Bureau

Next Month in *Information Display*

Display Week 2008 Show Issue
- Products on Display
- 2008 Display of the Year Awards
- Glass Substrates for LCD TVs
- Evolution of Projection Displays
- *JSID* May Preview

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editorial

Display Week 2008: See You in LA!

By now, of course, you know that Display Week 2008 is coming to Los Angeles, the entertainment capital of the world. I could not think of a better destination for this year's gathering of the industry. While television programs and movies are not the only content applications for displays, they sure are one of the biggest. They are also the ones with which our friends and families can most easily associate. When casual friends ask me what I do for a living, I describe my work in the context of computer displays and flat-panel televisions. Saying that I design parts of LCD televisions is not such a stretch because several of my designs are used are in commercial television products today. But more importantly, it is easy to explain what I do in terms that people can readily appreciate. Such would not be the case if I had chosen to be a Medieval archaeologist or an insolvency practitioner. Maybe Medieval archaeologists have some pretty good industry events, but I think ours is much better. I could go on and on about all the great things contained in Display Week, but Managing Editor Michael Morgenthal has done that for me in his article, "Hollywood Blockbuster: Display Week 2008 Comes to Los Angeles." This great preview should give you all the motivation you need to make your plans and block off your calendar.

And what visit to LA would be complete without an awards show? This issue also features profiles of the annual 2008 SID Honors and Awards winners, a distinguished group that will be honored at a formal dinner to be held Monday night of Display Week – always one of the best events of the entire week. The winners are chosen each year from a very diverse and prestigious list of nominees. However, I won't steal the thunder by naming names, you need to read the article to find out who the winners are.

Meanwhile, as a long-time proponent of LCOS technology, I was pleased to read Dr. Yong-Jing Wang's article on the ongoing investment in LCOS in China, and the high-level visibility these efforts are receiving from Chinese President Hu Jingtao. Dr. Wang has provided us a unique and well-considered point of view on the opportunity afforded by LCOS to make mainland -China-based companies competitive in the global HDTV marketplace. If Chinese display manufacturers can achieve a unique technological and economic advantage by commercializing LCOS technology as described in Dr. Wang's article, then it may serve as a new model for business development in other parts of the world as well. I tend to believe that LCOS can achieve broader commercial success than it has thus far, but the circumstances must be very carefully considered and surely will be cost driven, since the dominance of direct-view panels has created real downward pressure on the demand for projection TV products.

This month, we also feature a very persuasive article on the use of alternate compounds such as fluorine-doped tin oxide (FTO) as a transparent conductor for PDPs and other applications. FTO can be used as a viable substitute for indium tin oxide (ITO), which is especially interesting given the various reports about the scarcity of indium and rapidly rising price of this rare material. Along with the interesting description of their particular research, authors H. Tolner, B. Feldman, *et. al.* give us some unique insight into the processes used for coating ITO on substrates, and a better understanding of the physics of transparent conductors in general.

Finally, on the cover of our February issue of *Information Display*, we featured a commercial measurement system along with the tagline "Introduction to the ICDM Display Measurement Standard." Inadvertently, we implied that the new ICDM

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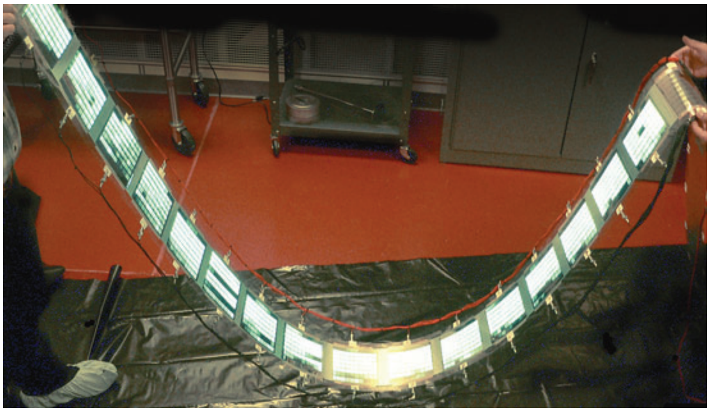
GE Demonstrates World's First "Roll-to-Roll" Manufactured OLEDs

NISKAYUNA, N.Y.- **GE Global Research** announced on March 11 the successful demonstration of the world's first roll-to-roll manufactured organic light-emitting diode (OLED) lighting devices. According to a press release issued by the company, this demonstration is a key step toward making OLEDs and other high performance organic electronics products at dramatically lower costs than what is possible today.

"Researchers have long dreamed of making OLEDs using a newspaper-printing like roll-to-roll process," said **Anil Duggal**, manager of GE's Advanced Technology Program in Organic Electronics. "Now we've shown that it is possible. Commercial applications in lighting require low manufacturing costs, and this demonstration is a major milestone on our way to developing low cost OLED lighting devices.

"Beyond OLEDs, this technology also could have broader impact in the manufacturing of other organic electronic devices such as organic photovoltaics for solar energy conversion, sensors and roll-up displays."

The demonstration of a low-cost, roll-to-roll process for OLED lighting represents the successful completion of a four-year, $13 million research collaboration among GE Global Research, **Energy Conversion Devices Inc. (ECD)** and the U.S. Commerce Department's **National Institute of Standards and Technology (NIST)**. The goal of the collaboration was to demonstrate a cost-effective system for the mass production of organic electronics products such as flexible electronic-paper displays, portable TV screens the size of posters, solar powered cells and high-efficiency lighting devices.



"This program was a major step in developing high volume roll-to-roll manufacturing for OLEDs and other organic semiconductor devices," ECD Senior Vice President **Nancy Bacon** said. "The success of this program is testimony to the effectiveness of NIST's advanced technology program model, and our 20-year history of pioneering research in roll-to-roll technology."

GE researchers provided the organic electronics technology and were responsible for developing the roll-to-roll processes, while ECD provided its roll-to-roll equipment-building expertise to build the machine that manufactures the OLED devices. The machine is being utilized for further manufacturing research at GE's Global Research Center in Niskayuna, New York.

According to GE, the development of this low cost roll-to-roll manufacturing process has the potential to eliminate the manufacturing hurdles that currently exist in preventing a more widespread adoption of high performance organic electronics technologies such as OLED lighting. The unique commercial equipment and technology needed to enable high performance-based organic electronics products does not currently exist. The few organic electronics products on the market today are made with more conventional batch processes and are relatively high cost. A roll-to-roll manufacturing infrastructure that enables high performance and low cost devices will allow a more widespread adoption of organic electronics products.

— Staff Reports

Samsung Electronics Acquires Clairvoyante's IP Assets

CUPERTINO, Calif. - **Samsung Electronics** announced on March 25 the acquisition of IP assets of Clairvoyante Inc., an IP licensing company responsible for the development of PenTile subpixel rendering display technology and associated gamut mapping algorithms. The financial terms of the agreement were not disclosed.

According to a Samsung press release, Clairvoyante's PenTile technology offers a significant reduction in power consumption for high-resolution mobile LCDs and for extending the lifetime of high-resolution mobile OLED displays, according to a Samsung press release. Samsung and Clairvoyante have worked together often in the past, most recently in October 2007, when **Samsung SDI** announced that it was using PenTile subpixel rendering technology to develop the world's first high-resolution active matrix OLED panel, a handheld wVGA (480 × 800) OLED PenTile RGB panel.

"Samsung recognized the potential of Clairvoyante's PenTile technology to improve display performance more than seven years ago when we became the first company to license the IP," said **Seung-Ho Ahn**, vice president, External Affairs & IP Group at Samsung Electronics. "This new business relationship will afford us the opportunity to guide this technology in support of a wide range of markets and applications."

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Grow Your Digital-Billboard Sales in Six Easy Steps

by Darrin Friskney

"Build it and they will come" is a classic line from the well-known movie, *Field of Dreams*. Although it refers to baseball, the saying also applies to digital billboards. It seems that wherever digital billboards are installed, the advertisers quickly follow. There is good reason for this: advertisers recognize that digital billboards can deliver timely, relevant messages to a mobile audience.

Independent outdoor operators thinking of expanding into the digital-billboard business often have questions about where to start and how to make the move to digital lucrative. There are six strategies that will help you succeed with the new digital-billboard media.

1. ***Learn How to Compete with Traditional Media.*** Digital-billboard message flexibility rivals that of newspapers, television, the Internet, and radio. With digital billboards, there is practically no lead-time needed to change the message or be creative, which allows advertisers to test copy, experiment with designs, and even run short-term promotions.

This opens up an entirely new list of potential advertisers for most billboard operators; those businesses that could not wait weeks to change their message on a vinyl board now can take advantage of digital billboards. These include:

- Department stores advertising sales events.
- Sports teams promoting specific games.
- Real-estate agents advertising specific listings.
- Restaurants promoting time-specific menu items.
- A hardware store promoting snow blowers or umbrellas when storms are forecast.
- Banks updating mortgage rates and loan products in real time.
- Radio stations promoting personalities on the air "right now."

2. ***Understand What Messages Are Important to Your Advertisers.*** There are several areas that are important to advertisers when talking about digital billboards.
   - *Digital billboards are more targeted and harder to ignore*: Americans spend more time in their cars now than ever before. This translates into less time viewing ads in other media, yet billboard rates remain high. Digital outdoor ads cannot be ignored like television or radio ads that can be skipped over by changing a channel or speeding through them on a DVR. Nor can they be filtered out with a pop-up blocker on the Internet.
   - *Digital billboards are uniquely flexible:* Dayparting is revolutionizing the billboard industry. Businesses can now use digital billboards to target customers with messages that are immediately relevant to them. No other medium can do this as quickly, graphically, and cost-effectively as the digital outdoor media.
   - *Digital billboards deliver unparalleled responsiveness:* Digital billboards can be updated remotely in minutes using software and a high-speed Internet connection, allowing advertisers the opportunity to respond quickly to a changing situation. For example, a hardware store can promote its sale on

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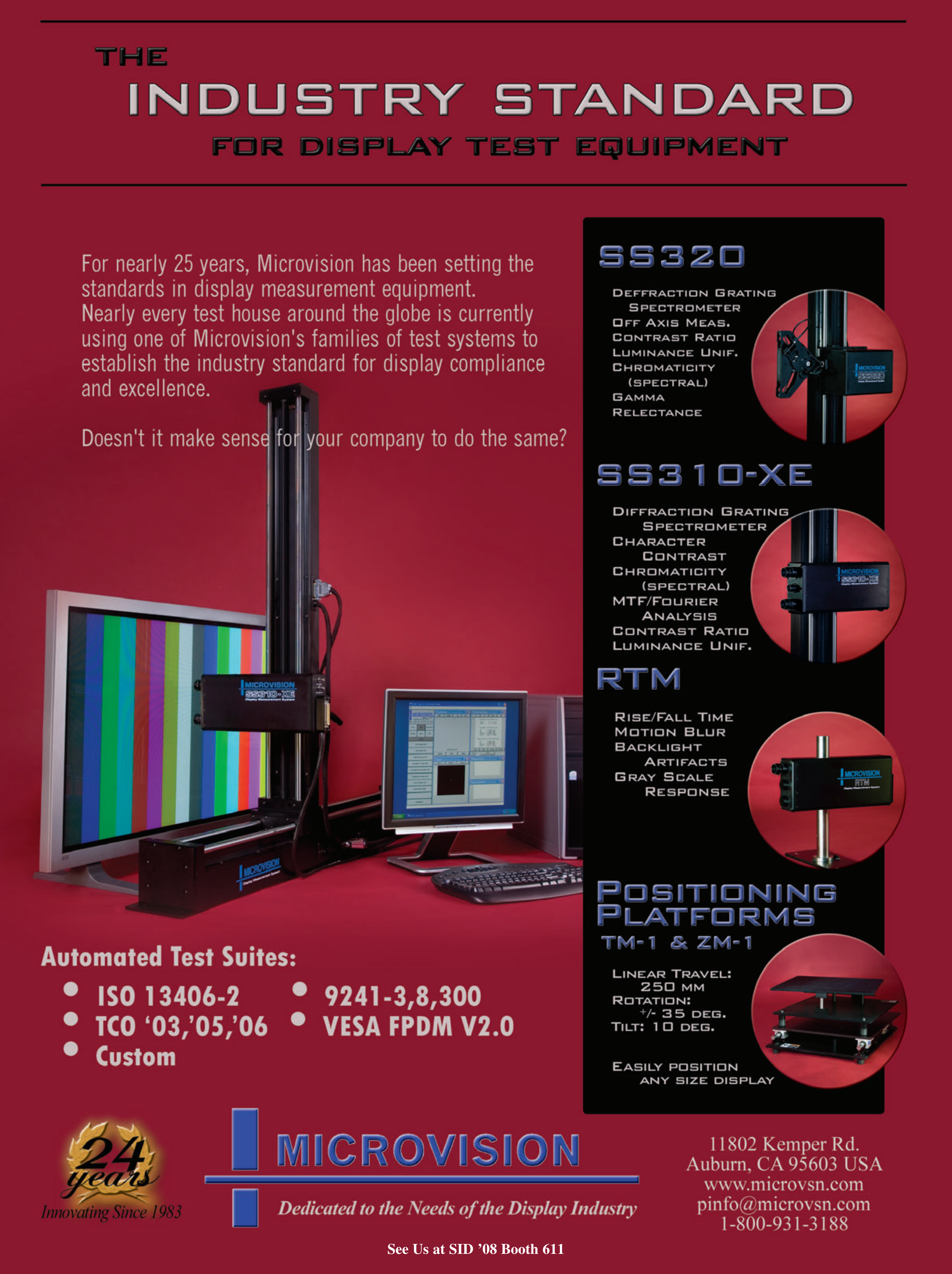
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Hollywood Blockbuster: Display Week 2008 Comes to Los Angeles

The entertainment capital of the world is rolling out the red carpet for the Society for Information Display as Display Week 2008 descends upon Los Angeles this May. Just like the Hollywood blockbuster movie, Display Week is an event that cannot be missed! Here is a sneak peak at what is on tap.

by Michael Morgenthal

THERE ARE MULTIPLE REASONS why comparing Display Week 2008: The SID International Symposium, Seminar & Exhibition to a blockbuster Hollywood movie is an apt analogy. First, Display Week, the premier annual international display event in the world, is taking place May 18–23 in Los Angeles, California, U.S.A, the movie capital of the world. In fact, it is completely logical to surmise that without the display industry, there would be no movie industry, so the synergy is palpable.

Second, Display Week 2008 ends on the day that the summer blockbuster movie season begins in the U.S.– the start of the Memorial Day holiday weekend. And with its myriad segments and various technology focuses, Display Week in many ways resembles the cast and crew of the typical Hollywood blockbuster movie – with each sector and technology playing its own vital role.

So, without further ado, it is time to dim the lights, raise the curtain, and take a look at what awaits the 8000-plus attendees expected to flock to Los Angeles for Display Week 2008. For complete program and registration information, visit the official Display Week 2008 Web site at www.sid2008.org.

***Michael Morgenthal** is Managing Editor of* Information Display *Magazine; e-mail: mmorgenthal@pcm411.com*

The Plot

Any successful movie needs an engaging plot and, for 46 years, Display Week has provided the most compelling stories in the display industry. In 2008, that is no different.

The main story, as usual, will take place during the Symposium, which kicks off Tuesday, May 20. For 2008, Display Week will feature a record 73 sessions divided into 12 broad tracks of invited and contributed papers, comprising 290 oral presentations and 260 poster presentations addressing such leading-edge topics as AMLCDs, OLEDs, plasma displays, electronic paper (e-paper), projection, microdisplays, and 3-D displays, to name a few. More on the Symposium below.

There are other secondary yet no less important plot points to which attention should be paid. Perhaps most noteworthy is a special session on 3-D digital cinema that is taking place on Wednesday, May 21, featuring some of the leading professionals in this exciting, emerging display field, and covering topics that span the full 3-D movie process – from content creation (animation and live action) and editing, to post production and stereoscopic theater display. The session will kick off with a luncheon address by Andy Hendrickson, VP of Technology for Walt Disney Animation Studios, who will delve into the evolution of display technology and the various display-related challenges and opportunities specific to the entertainment industry. (For more on the 3-D cinema special session, see the March issue of *Information Display* or www.informationdisplay.org.)

Another special session will focus on display applications. Co-sponsored by technology service and product supplier Avnet, Inc., the Display Applications Special Session on Thursday, May 22, offers everything attendees need to know in order to specify and design a display for a product, from the basics of how to select an appropriate display for a product, to in-depth analysis of individual display technologies, to the chance to network with leading display innovators.

One fascinating subplot at Display Week 2008 will develop during a special panel discussion on Tuesday evening, May 20, titled "AMLCD World Domination: Does Anything Stand in the Way?" This panel will host several industry experts spanning AMLCD, plasma, OLED, and projection technologies, who will discuss the proliferation of each in the context of AMLCD's current dominant market-share position. Moderated by Roger Stewart of Sourland Mountain Associates, the panel is scheduled to include an impressive roster of speakers, including Jun Souk from Samsung, Fan Luo from AU Optronics Corp., Norbert Fruehauf from the University of Stuttgart, SID President Larry Weber, consultant Fred Kahn, Mike Hack from Universal

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Display Corp., Nobutoshi Asai from Sony Corp., and Stewart Evans from PlasticLogic.

"The lineup of this year's Display Week is extremely exciting," noted Display Week's general chair, Amal Ghosh. "With a record number of high-caliber submissions and top presenters, the 2008 program will be unparalleled to those of years past. Moreover, we will be hosting a number of events that will delve into today's latest display trends. Some of the more notable topics include a face-off on where TV is really going, the continued growth of mobile applications, and what the display industry is bringing to the table in the area of touch technologies. We will also see more on 3-D, where we have seen Hollywood reinvigorate the technology's viability with big-budgeted feature films exhibited in stereoscopic 3-D, as well as a look at next-generation 3-D display technologies."

These special features of Display Week 2008 further complement the already jam-packed line-up filled with the annual features that have made Display Week such a vital event for the industry. These include:

- ***The Exhibition*** (May 20–22): The Display Week Exhibition is the de facto nursery of the industry, where more than 250 companies ranging in size from large Fortune 500 corporations to small startups to everything in between proudly unveil their cutting-edge display-technology developments for the first time. In addition, the Exhibitors' Forum allows exhibitors a platform to present detailed information on what is being showcased in their booths.
- ***The Business and Investors Conferences*** (May 19–21). The Business Conference will take place Monday, May 19, and Tuesday, May 20, and features an exciting lineup of senior executives from leading display industry companies, such as Corning, DuPont, Qualcomm MEMS Technologies, Novaled AG, and Kopin Corp.; industry organizations such as the Optoelectronics Industry Development Association and Plasma Display Coalition; and market analysts such as DisplaySearch, McLaughlin Consulting Group, Pacific Media Associates, and MJT Associates. The Investors Conference, co-sponsored by securities and investment banking firm Cowen & Co. LLC on Tuesday, May 20, and Wednesday, May 21, offers a forum for leading public and private display companies to present to securities analysts, portfolio managers, investors, M&A specialists, and display company executives.
- ***Sunday Short Courses*** (May 18): These four-hour classes covering the fundamentals of information displays in four vital areas: Vision and Color, Display Optics, Video, and Polymer-OLED Technology.
- ***Display Technology Seminars*** (May 19): These 12 90-minute seminars cover a wide range of topics related to the display field, including transflective displays, TFT-LCDs, FPD measurements, LCD electronics, touch-screen technology, 3-D, flexible displays, AMOLEDs, and mobile displays.
- ***Applications Tutorials*** (May 21-23): These practical and interactive 90-minute tutorials focus on the application and evaluation of electronic information displays and will cover areas such as 3-D displays and content delivery, display applications for military and harsh environments, mobile multimedia displays, lithography applied for FPDS, microdisplay applications for virtual imaging, and emerging applications of electronic paper.

The Los Angeles Convention Center.

The Cast

As any Hollywood producer will readily admit, a good story is not enough to sell a movie – you need a star-studded cast to make a film a true blockbuster. At Display Week, the A-List cast is made up of the various display technologies that will be explored during the four-day Symposium. Each plays a distinct role that will be familiar to followers of Hollywood:

The Lead Role: LC Technology. The mark of any true Hollywood movie megastar is the ability to work in myriad roles that vary greatly, from the biggest action blockbuster to the most touching independent tearjerker. Clearly in today's display industry, the only technology with the range to pull this off is liquid-crystal (LC) technology. From the largest HDTVs to the smallest mobile-display devices, from electronic paper and flexible displays to 3-D and touch technology, LC is the unquestioned star of the display world, and has been for many years.

So, it should come as no surprise that LC technology once again will be the star of stars at Display Week 2008. LC's most famous role thus far has been its role in the emergence of HDTV, a technology that has reached a very mature status. One of the key areas here, according to Active-Matrix Devices subcommittee chair Takatoshi Tsujimura from Kodak, is the attempt to improve the performance of

VA-mode TFT-LCDs. Tsujimura explains that VA seems to be winning the battle with IPS because it does not require a rubbing process, but VA has a drawback in that the display can wash-out when the viewer is off-angle, meaning that contrast is lost. The major approach to overcoming this issue is to make multiple gamma curves in one pixel, which can be achieved now but is complicated and expensive. Several papers address this research to try to make it easier and more cost-effective. Session 16 is devoted exclusively to this topic, with paper 16.1 from Samsung, "82-in. Ultra-Definition LCD Using New Driving Scheme and Advanced Super PVA Technology," of particular note.

But LC is just as comfortable in other smaller, emerging roles. For example, a big topic at Display Week 2008 will be electronic paper, which has four complete sessions devoted to it from amid the 11 sessions emanating from the LC Technology subcommittee. Subcommittee chair James Anderson from 3M says that they received a tremendous number of high-quality papers this year on e-paper, with a particular focus on the attempts to develop and commercialize color for e-paper displays. Anderson cited paper 46.1 from Philips Research Laboratories, "Novel Design for Full-Color Electronic Paper," as one of the more interesting approaches to achieving color e-paper.

Another focus in the e-paper arena is the desire to reduce power even further, which at first glance would not seem to be a critical issue. After all, e-paper's bistable characteristics means that power is only used to change the image on the display, not to continually display the image. However, Anderson points out that per update, most e-paper technologies consume more power than other display technologies, so for e-paper displays that are refreshed frequently – such as electronic billboards – there is a need to reduce the power consumption even further. Paper 53.1 from Magink Display Technologies, "Recent Advances in Tiled Cholesteric Billboard Displays," delves into this area.

Touch technology has been a rising star in its own right, and paper 55.1 ("An Inner Touch-Screen-Panel-Embedded 12.1-in. a-Si:H TFT-LCDs" from Samsung) and paper 55.2 ("Integrated Active-Matrix Capacitive Sensors for Touch-Panel LTPS-TFT LCDs" from Seiko Epson Corp.) explore the use of touch with AMLCDs.

Special Guest Stars. The special guest stars are enough to push any movie over the top, and the lineup of Keynote Speakers who will kick off the Display Week 2008 Symposium will expertly fill those roles. They include:

- ***Paul (Shuang-Lang) Peng***, Senior Vice President and General Manager, Information Technology Display Business Group, ***AU Optronics Corp.***, will discuss the evolution of green products and their introduction into the TFT-LCD industry.
- ***Yoshito Shiraishi***, General Manager, E-Products and Business Development Department, TV Business Group, ***Sony Corp.***, will explore Sony's challenges in launching the world's first OLED TV, which features an astonishingly thin 3-mm thickness and unparalleled picture quality, as well as long-term OLED business opportunities in the display marketplace.
- ***Mary Lou Jepsen***, Founder, ***Pixel Qi***, will discuss the creation of One Laptop per Child (which she co-founded), its business model, and the design of the XO laptop. The display is the key in creating a low-cost low-power laptop because it is the most expensive and power-hungry component in portable consumer-electronics devices. Furthermore, it enabled a new power-management architecture and sunlight-readability capability. Jepsen will describe a future where the display will play a key role in the initial design and architecture of portable electronics devices.

Up-and-Coming Star: OLEDs. If LCD is the star of the show, in many ways OLED can be viewed as the up-and-coming star that is generating a tremendous amount of buzz. According to Denis Kondakov of Kodak, who is the chair of the OLED subcommittee, Display Week 2008 will feature one of the strongest group of OLED papers in the history of the Symposium, ranging in topic from the fundamentals of OLED technology to the manufacture of OLEDs, and everything in between.

One area that is garnering much attention in the OLED field is the continuing development and improvement in the area of white LEDs because they are much more cost efficient than building displays with three distinct types of OLED devices as subpixels. There were nearly 20 papers submitted for this subject, covering the entire spectrum of white OLED technology, from emitting materials, host and transport materials, and devices architectures for single-stack devices, to devices based on fluorescent and phosphorescent emitters, and multistack devices with two stacks having different natures. Kondakov explains that while there were significant advances made in this area, he would not describe any of the developments as a breakthrough, perhaps because this sector of OLED technology is already fairly mature, having already closely approached (or even having reached) both theoretically maximum efficiency and efficiency/lifetime appropriate for large-scale commercial applications.

There are two entire sessions devoted to white OLEDs (61 and 68), with one in each session worthy of particular attention: paper 61.3 from Samsung Advanced Institute of Technology, "3.0-in. 308-ppi WVGA AMOLED by Top-Emitting White OLED with Color Filter," and paper 68.4 from Samsung Electronics, "Microcavity Design of RGBW AMOLED for 100% Color Gamut."

Other papers of note in the OLED area include papers 3.1 and 3.2, focusing on AMOLEDs, paper 8.2 focusing on OLED microdisplays for head-mounted displays, papers 22.1 and 22.2 focusing on OLED-enabling technologies, and paper 41.4 focusing on OLED materials.

Star on the Comeback Trail.

Plasma-Display Panels (PDPs). While LCD continues to grab most of the headlines, Display Week 2008 could mark an important point in the renaissance of plasma technology. Much like a once-promising actor now making a comeback, plasma will be the subject of several important papers, according to Shigeo Mikoshiba of the University of Electro-Communications, who serves on the Emissive Displays subcommittee.

Paper 34.1 is an invited paper from Matsushita/Panasonic detailing the technology that went into the construction of the company's stunning 150-in. PDP, the world's largest FPD.

Mikoshiba also pointed to two papers from Pioneer Corp., papers 21.1 and 21.2, which focus on the company's KURO plasma technology. KURO means "black" in Japanese, and these papers delve into Pioneer's new "crystal emissive layer" (CEL), which pushes plasma displays closer than ever to true black in either the on or off state. The PDP displays deeper blacks regardless of viewing angle, while lighter areas of the screen retain their brightness. In the off-state, the screen is so dark that it is virtually invisible in a dark room. These displays are already for sale in Japan.

Of course, for an actor to have a true rebirth, the focus has to be not just on current projects but future developments as well. Paper 34.2, "Development of 1 × 2-m Plasma Tube Array (PTA) Technologies Ready for Ultra-Large Film Display," is from the new company Shinoda Plasma Co., Ltd., and describes its breakthrough in the area of plasma tube array (PTA). According to Mikoshiba, this technology could allow for a wall to morph into a display when turned on by allowing the PDP to blend into its environment, and also could allow PDPs to be curvable, which to date has not occurred.

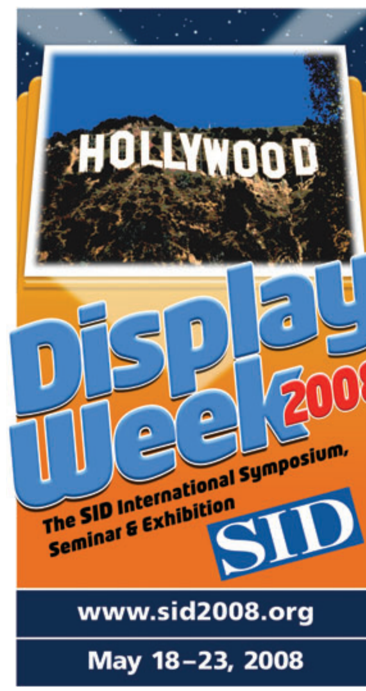
Supporting Roles. While the stars always receive top billing in any movie, often it is the supporting roles that are even more memorable. LCDs, OLEDs, and PDPs will clearly enjoy much of the focus at Display Week, but many other important display-technology sectors are just as noteworthy. These include:

Projection Displays: This is an exciting time for projection displays as many manufacturers are introducing pico-projectors, small projectors that are portable and can be embedded into mobile devices, according to Projection subcommittee chair Ed English from 3M. Session 70 will be exclusively devoted to this area, including paper 70.2 from Light Blue Optics, on a potentially revolutionary "Holographic Laser Projection Technology."

Session 63 will cover New Projection Light Sources, with talks from Explay on Red Laser Array Light Sources; Corning and Konica Minolta on Efficient and Compact Green Lasers, and Nichia Corp. on Continuous-Wave Blue-Laser Diodes. Here, the development of light sources that are low cost, durable, low power, and meet the requirements of projection systems is key.

Lastly, paper 56.1 from Sony Corp., "High Frame Rate, High Contrast Laser Grating Light Valve Projection Display," will detail the latest developments in the company's decade-long attempts at developing extremely high-resolution wide-angle projection displays. The company has previously demonstrated this technology on screens as large as 10 m high × 50 m wide.

Display Measurement: This is another category that has received more valuable papers than ever before, according to Stephen Atwood, Chair of the Display Measurement



subcommittee, thanks to the work being done in the TFT-LCD sphere. There are six separate, unique papers on motion-blur characterization and measurement, and several more on mura measurement.

Paper 4.1 will explore the work that has been done to establish a new FPD measurement standard called ICDM (for more on this, see the February issue of *Information Display* or www.informationdisplay.org). In addition, paper 4.2 from autronic-Melchers looks at reflective LCD measurements methodology, an area where many display people have been advocating for standardization. Atwood believes this paper could lay the groundwork for the establishment of just such a standard. Poster paper 92 from IRCCyN, University of Nantes, Nantes, France, addresses motion-blur estimation in LCDs in a novel way, and points to the increasing convergence between the measurement community and the applied-vision community, working toward the holy grail of electronic vision recognition that is still decades away. Paper 10.2, "Motion-Artifact Analysis on Scanning-Backlight LCD," from Southeast University School of Electronic Science and Engineering, and Philips also points to this convergence by examining the fundamentals of modulated backlight approach to eliminating motion blur.

FEDs: Field-emission displays (FEDs) re-emerged on the scene at Display Week 2007, and in 2008 there are two dedicated sessions to this display technology. Paper 7.1, "Technologies and Prospect of Fine-Pitch FED Monitor," is from Sony's FED venture business, Field Emission Technologies, Inc., and describes its prototype in this area, with a focus on the motion-blur-free line-sequential impulse drive system. Many of the other papers in this area deal with carbon nanotubes (CNTs) for use in FEDs. It is difficult to achieve uniformity of luminance and color with CNTs, according to FED subcommittee chair Masayuki Nakamoto of Shizuoka University, so much of the research is directed toward conquering this problem both within CNTs and with other nanomaterials such as nanowires.

3-D: It is also an extremely exciting time for 3-D displays, as technology finally starts to catch up to the imagination. In addition to the special session referenced above on 3-D digital cinema, there are some other noteworthy developments. Paper 25.1, "Multi-Viewer Autostereoscopic Display with Dynamically Addressable Holographic Backlight" from Light Blue Optics discusses the use of a novel laser-based holographic projection system to tackle the problems incurred by a dynamically addressable movable backlight in autostereoscopic display systems for multiple viewers simultaneously. Paper 25.4, "Beyond Flat Panels: Multi-Layered Displays with Real Depth" from PureDepth focuses on stacking multiple LCD panels on top of each other to create a 3-D display. PureDepth recently collaborated on such displays with Samsung, according to Display Systems subcommittee chair Brian Schowengerdt, so there is tremendous potential in this technology turning into a real product.

Conclusion

The synergy between the display industry and the entertainment industry has never been more evident, which makes Los Angeles the perfect setting for Display Week 2008. Like the year's biggest Hollywood blockbuster movie, Display Week 2008 will be the one event of the year that everyone will be talking about. We'll see you in Los Angeles! ■


Self-Service Check-In
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SID Honors and Awards: Uchida Leads SID's 2008 Class of Honorees

For nearly 40 years, Dr. Tatsuo Uchida has dedicated himself to the study of LCDs. His lasting impact has been in the myriad students he has mentored, including those who have participated in his innovative special program designed to train engineers already in the display field.

by Michael Morgenthal

THERE is an old cliché that states, "It's not what you know, it's who you know." But for Dr. Tatsuo Uchida, the winner of the SID 2008 Slottow–Owaki Prize for outstanding contributions to personnel training in the field of information display, that cliché is only half true, for whom he knows is a direct result of what he knows.

What Uchida knows is LCDs – he is a leading expert in the field. SID has already recognized this fact by awarding Uchida the Jan Rajchman Prize in 2004 for "his outstanding contribution to the science and technology of liquid-crystal displays, including molecular orientation and high-performance LCDs, and his leadership in the display community." That SID has chosen to honor him a second time with one of its major awards is a rarity indeed – he is only the fourth person to be so honored twice by SID. And he is believed to be the first person in Japan to be awarded a Ph.D. for work specifically associated with LCDs.

Uchida's wide range of knowledge of LCDs and his kind, instructive teaching style have attracted those eager to learn about the technology from within Japan and across the globe to come to Tohoku University in Sendai, Japan. Since 1975, he has supervised 29 Ph.D. candidates (including seven students from outside of Japan), 82 masters-degree students, and 70 bachelor-degree students. His students have gone on to excel both in academia – seven former students have become professors – and the corporate world: large display companies and research institutes abound with those who studied with Uchida, including 1 president, 1 vice president, 6 directors, and 14 managers.

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Dr. Tatsuo Uchida

These numbers do not include the 49 visiting researchers from companies around the world who have come to study with Uchida since 1997 in the special program he established at Tohoku University specifically designed for engineers already working at display companies. This program, believed to be the first of its kind when established, is now a model for engineering schools around the world. Engineers from companies such as Nitto Denko, Fuji Film, Sumitomo Chemical, and Kurare, to name just a few, have already participated in the program.

Engineers enroll in the program for 1 or 2 years in order to learn the fundamental science of liquid crystal and related optics, and to cultivate logical consideration for research and development. The first year of the program begins with 3 months of basic-training courses that cover subjects such as the exact calculation of the molecular alignment of liquid crystal under application of a voltage by elastic theory, and exact calculation of optical properties based on the birefringence including the measurement of physical parameters such as elastic coefficients, refractivity, *etc.* According to Nobuki Ibaraki of Toshiba Matsushita Display Technology Co., Ltd., in Japan, this training makes it possible for researchers to understand the fundamental theory and experiments of liquid crystal and to design high-performance LCDs.

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Otto Schade Prize: Louis D. Silverstein

(For Outstanding Service or Technical Achievements in, or contribution to, the Advancement of Functional Performance and/or Image Quality of Information Displays)

The accomplishments of Dr. Louis D. Silverstein, winner of the 2008 Otto Schade Prize in Display Performance and Image Quality, are as varied and interesting as all the colors of a rainbow or, if you prefer, the CIE chromaticity diagram. This is especially apropos for Silverstein, who is known as one of the leading experts in color science and displays in the world.

A prolific author of more than 125 journal articles, book chapters, papers, and technical reports, Silverstein has contributed to more than 25 issued patents related to display technology and display performance enhancement with an additional 8 patents currently pending and has presented a display-technology seminar relating to color and displays at Display Week for the past 17 years.

His career achievements are equally as impressive. In the early 1980s, he lead efforts at Rockwell International and Boeing to specify, measure, calibrate, and verify the visual and color-performance characteristics of the first color CRTs for mission-critical avionics applications, which ushered in new generations of avionics displays. His work from 1984 to 1990 at Sperry Corp. and Honeywell focused on pixel mosaics, addressing methods, and color optimization of AMLCDs, as well as extensive work on the visual performance of both monoscopic and stereoscopic display presentations.

In 1990, he founded VCD Sciences, Inc., a technical consulting firm with a focus in the areas of applied vision, color science, and display technology. He has since worked on a wide variety of display-related projects at more than 25 companies and government laboratories, including long-term research projects at Xerox PARC (which ultimately was spun off to form dpiX), Motorola Corporate Research Labs, NASA Ames Research Center. and Optiva. Inc. His groundbreaking work developing thin-film polarizers and retardation films for LCD optical designs established the viability of such thin-film optical components for LCDs and led to several novel LCD optical designs and applications. Of late, he has focused on novel approaches to display color synthesis and on improved methods for characterizing the performance of projection-display systems. He developed a new approach to color synthesis called hybrid spatial-temporal color synthesis that results in improved display resolution, reduced fixed-pattern noise, and an expanded color gamut over standard methods that synthesize color by either spatial patterning or field-sequential-color operation alone.

For his many contributions to the enhancement of display performance and image quality including pioneering efforts in integrating display technology and color science, SID has bestowed the 2008 Otto Schade Prize to Louis D. Silverstein.

Karl Ferdinand Braun Prize: Richard Williams

(For Outstanding Technical Achievement in Display Technology)

If it weren't for Richard "Dick" Williams, many of you would likely not be reading this magazine right now. For when Williams, then working at RCA Laboratories, discovered in 1962 that clearly visible domains formed in liquid crystal when the applied field reached about 1000 V/cm, the inevitable march toward today's flat-panel-display world in which liquid-crystal displays are virtually ubiquitous had begun.

Spurred by David Sarnoff's request for a flat-panel television display among other factors, Williams began investigating the optical behavior of nematic LC materials (primarily para-azoxyanisole at about 120°C) under an applied electric field. Williams described his results in a paper entitled "Domains in Liquid Crystals" in the *Journal of Chemical Physics* in July 1963; these later became known as "Williams Domains." In the paper, Williams explained that the formation of the domains occurs at a sharp threshold field and that as the field is increased further as a stirring action occurs, which becomes quite vigorous when the field reaches about 3000 V/cm. Williams filed a patent application, which issued as U.S. Patent 3,332,485 on May 30, 1967, describing both reflective and transmissive modes of operation. This was RCA's sole LC patent when it publicly announced the results of its secret project to develop LCD technology at a famous 1968 press conference in New York City.

For the pioneering discovery of a significant electro-optic effect in liquid-crystal materials and the recognition of its importance to flat-panel displays, SID has awarded Richard Williams with the 2008 Karl Ferdinand Braun Prize.

Jan Rajchman Prize: Shin-Tson Wu

(For Outstanding Scientific and Technical Achievement or Research in the Field of Flat-Panel Displays)

The next time that you pull out your cell phone on a sunny day and can read the display without any trouble, thank Professor Shin-Tson Wu of the University of Central Florida. In 1995, Wu invented a high-resolution single-polarizer reflective LCD using a mixed-mode twisted-nematic (MTN) cell, an invention that lay the foundation for today's transflective LCDs that are widely employed in cell phones because of their excellent sunlight readability.

Wu holds a dozen patents in transflective LCDs among his 69 issued and pending patents and is the author of four books, five book chapters, and approximately 400 articles that have accumulated more than 2700 ISI citations.

His major research accolades are myriad. In the mid-1980s, Wu discovered the origins of liquid-crystal refractive indices and developed a three-band model to describe the refractive index and birefringence dispersions of liquid crystals, which is known as "Extended Cauchy model" for anisotropic materials and has been commonly used for designing LCD devices by taking the wavelength and operating temperature effects into considerations. In the mid-1980s, Wu's team at Hughes Research Labs developed several approaches for improving the liquid-crystal response time, such as the overdrive and undershoot voltage method, the thin-cell-gap approach, and the crossed-fields method. The overdrive and undershoot voltage method has been widely implemented in LCD TVs for reducing motion blur, and the thin-cell-gap approach has been widely employed in color-sequential LCDs.

At Hughes, Wu worked on liquid-crystal light valves for projection displays, a technology that in 1991 was transferred to JVC for commercialization. JVC is still working with Wu's group at UCF to develop new fast-switching liquid-crystal materials for color-sequential displays. Wu has delivered a new LC mixture with a figure of merit (FoM) approximately 2 times higher than that of the best commercial materials. JVC is implementing this new mixture into its thin-cell LCD panels.

For wide-view transmissive LCDs, Wu's group pioneered analytical solutions to describe the polarization states at each layer and invented several new broadband and wide-view linear and circular polarizers. To recycle unused light in LCD polarizers, Wu's group invented a new polarization converter using nanoscale metallic gratings. The simulated light recycling efficiency exceeds 90%. Chi-Mei Optoelectronics is implementing the latter two designs into its next-generation LCD products.

Since 2001, Wu has been the PREP Professor of Optics at the University of Central Florida in Orlando. In recognition of his exceptional contribution to liquid-crystal-display science and technology, especially display device physics, electro-optic effects, and materials, SID has awarded Shin-Tson Wu with the 2008 Jan Rajchman Prize.

For those that choose to stay on for a second year of study, an advanced training course is offered at the beginning of the second year, covering polarization analysis using the extended Jones' matrix and Poincaré Sphere. This training makes it possible for researchers to understand the accurate analysis of polarization, compensation of the optical retardation of liquid crystals for wide viewing angle, and less dispersion of wavelength dependence, for example, Ibaraki explains.

Following completion of the course work, there are 9 months of project research, the subject of which is decided in cooperation with the researcher's company and Uchida. The results of this research are applied to patents, presented at conferences, and submitted to journals. Thus far, the research has resulted in 8 journal papers and 43 presentations at conferences worldwide.

Programs such as these offer an alternative path for engineers interested in continuing their studies but who cannot afford the 3-year commitment often required for Ph.D.-level research. And Uchida's program was the first of its kind.

"The 3-year period for a Ph.D. is a deterrent to all but those most determined to do research. Most often, only a minority of people who will enter industry are prepared to take this amount of time before starting their careers," explains Anthony C. Lowe of Lambert Consultancy in the U.K. and a past-president of SID. "What Uchida achieved was to enable those working in the industry to gain real research experience over a much shorter period and then take their new skills back into industry. So he enabled many more industrial scientists and engineers to enhance their skills than would otherwise have been the case. The impact was better trained and educated engineers available to industry. Uchida had the idea and he personally pushed it through. I imagine this took a great deal of dedication and determination."

In part, Uchida was able to establish this program due to his long history with Tohoku University, which dates back to 1966 when he began his undergraduate studies in the Department of Electronics. He received his masters degree from the university in 1972 and his Ph.D. from Tohoku in 1975. He

The 2008 award winners will be honored at the SID Honors & Awards Banquet, which will take place Monday, May 19 at the Wilshire Grand Hotel in Los Angeles. Tickets cost $50 and must be purchased in advance – they will not be available on site. Visit www.sid2008.org for more information.

joined the faculty in 1975 as a research associate and then in 1982 became an associate professor and then a full professor in 1989. In 2005, he was named vice-dean of the graduate school of engineering and, in 2006, became the dean of the graduate school of engineering.

Uchida began his research in LCDs when he began his masters studies in 1970. According to Ibaraki, he started his work by examining the synthesis and purification of liquid-crystal material. Since then, he has performed broad research on LCDs in areas such as molecular alignment of liquid crystal on the surfaces based on physical chemistry, chromaticity, and driving technology.

Throughout his career, Uchida has been active in SID. He has been an integral member of the program committees for the SID Symposium and the International Display Research Conference (IDRC). He helped found the International Display Workshops (IDW) in 1994 and remains active in this annual display conference in Japan, serving as the general chair for IDW 2004. He has delivered myriad presentations at conferences both in Japan and abroad and is a widely respected and published author.

Therefore, for his remarkable contribution to bringing up students and company researchers in the display field, especially liquid-crystal displays, SID bestows the 2008 Slottow–Owaki prize to Professor Tatsuo Uchida. ■

2008 SID Fellow Awards

Each year, the Society elevates distinguished SID members to Fellows of the Society. The 2008 Fellows are

- ***Dr. Vladimir Chigrinov***
  "For his many contributions to the understanding of the physics and electro-optic effects in liquid crystals, including photo-alignment and the modeling of LC modes to enable optimization for flat-panel-display applications."
- ***Dr. Ingrid Heynderickx***
  "For her significant contributions to the study and measurement of display image quality and for her outstanding educational efforts in training young scientists around the world."
- ***Dr. Chishio Hosokawa***
  "For his outstanding scientific contributions to the development and commercialization of organic light-emitting-diode (OLED) materials technology.
- ***Dr. Junji Kido***
  "For his many contributions to the science and technology of OLEDs including high-efficiency materials, white-light-emitting and long-life devices."
- ***Dr. Seung Hee Lee***
  "For his invention, product development, and commercialization of fringe-field-switching (FFS) liquid-crystal-display devices."
- ***Mr. Richard McCartney***
  "For his many significant contributions to the application of active-matrix LCD technology to avionics, television, and mobile displays encompassing methods for viewing-angle control and LCD electronics."

2008 SID Special Recognition Awards

Each year, the Society recognizes individuals for specific outstanding achievements. The 2008 Special Recognition Award winners are

- ***Mr. Kimio Amemiya***
  "For his outstanding contributions to the research and development of high-performance plasma displays using single-crystal MgO powder with its unique priming electron emission effect."
- ***Dr. Alan Jacobsen***
  "For his outstanding contribution to human-centered design within the aviation industry including the introduction of LCDs on commercial-airplane flight decks by developing safety-enhancing display formats and flight-deck prototyping systems."
- ***Dr. Sungkyoo Lim***
  "For his outstanding service to SID including the role as Secretary General of Asia Displays 1988, the International Display Manufacturing Conference, the International Conference on Display LEDs, and the Crystal Valley Conference and Exhibition."
- ***Dr. Hiroyuki Mori***
  "For his outstanding contributions to the improvement of optical simulation technology used to develop optical compensation films for LCDs."
- ***Dr. Kiyoshi Yoneda***
  "For his pioneering contributions to the commercialization of low-temperature poly-Si-based active-matrix OLEDs."

China's LCOS Opportunity

With the backing of the Chinese government, manufacturers are focusing on the development of LCOS TVs because of its relatively open technology platform and potential cost savings. This article details what the Chinese need to do in order to succeed.

by Yong-Jing Wang, Handing Zhao, and James Lupino

THE EVOLUTION of the liquid-crystal–on–silicon (LCOS) industry over the past 10 years has been much like taking a roller-coaster ride. When it was introduced, LCOS technology was believed to be very promising for low-cost high-definition big-screen TVs. Around the year 2000, when the dot-com bubble burst, there had been a few dozen companies involved in the development of LCOS technology, either at the component or systems level, including major consumer-electronics giants such as Sony, Philips, JVC, and Intel, as well as many companies.

The first two attempts to commercialize LCOS rear-projection TVs (RPTV) were made by Displaytech/Samsung and Thomson (marketed as the RCA brand in the U.S.) around this time. Considering the undeveloped state of the HDTV market and the immature technology at that time, their lack of success was not a surprise. Subsequently, Philips, JVC, and Sony all commercialized LCOS RPTV after several years of development.

However, facing the dual competitive pressures coming from flat-panel-display technologies, *i.e.*, liquid-crystal-display (LCD) and plasma-display-panel (PDP) technologies, and Texas Instruments' DLP technology, Philips pulled the plug on its LCOS division at the end of 2004. JVC and Sony finally pushed their LCOS RPTV to the mainstream consumer market and received very high appraisals with respect to display performance. Nevertheless, due to brutal competition from LCD TVs, the market share of LCOS RPTV has not reached industry expectations. Microdisplay Corp., a single-panel LCOS developer, was forced to close its doors in July 2007.

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China Prioritizes LCOS

Despite all these unfavorable factors, LCOS projection systems still attract significant attention due to their excellent display performance and potential low price. This is especially true in China, where the optical-component manufacturing infrastructure is strong and the domestic market is huge and unique. Under continued promotion by the government, the development of LCOS technology in China is still substantial, as evidenced on April 4, 2007, when Chinese President Hu Jingtao visited Sino-Brillian Display Technology Corp., a joint venture incorporated in April 2006 between IT Optics Group, Ltd., China, and Syntax-Brillian, USA. President Hu visited the company's manufacturing line of LCOS light engines and discussed the market, technology, and mass production of LCOS TVs. He displayed a firm understanding of the overall HDTV industry and related technologies, which is understandable because China is a leading TV manufacturer, and, therefore, the display industry hence is crucial to the country's economy.

President Hu made several points in his talk:

- The technology and manufacture of LCDs are dominated by Japan, South Korea, and Taiwan.
- Mainland China does not possess key intellectual property (IP) in the LCD sector.
- LCOS is a relatively open technology platform. Its required investment is also much lower than that for LCDs. Therefore, Chinese companies should pay more attention to LCOS technology.

Fig. 1: LCOS components manufactured by Chinese companies.

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- The state will support the development of LCOS technology, such as light engines and microdisplay chips.
- Chinese companies should focus on the development of the supply chain, expedite the development of LCOS TV, and mass-produce LCOS TVs for its massive consumer market.

Three months later, on August 20, a summit of the Chinese LCOS industry was held in Nanyan, Heinan, China. At the summit, Lou Qingjian, Vice-Minister of the Ministry of the Information Industry of China (MII), stated: "MII will continually develop the full industry supply chain of LCOS, from components to systems. MII will utilize the industry's strength from all directions to build up new display-industry groups, enforce the cooperation between big projects, and help relative departments and companies to mass-produce LCOS TVs." Figures 1–3 show the LCOS components, light engine, and RPTV manufactured by Chinese companies.

Of course, the recommended direction of President Hu is from a viewpoint of how to independently develop China's own technology and hence transfer China from a manufacturing-based country to a technology-based country. LCOS is only one example he used. The remaining tasks for the engineers and scientists in the Chinese LCOS industry are to evaluate the technology, market, and development status in China, and to come up with a solution and roadmap for China's HDTV industry. In our opinion, the development of LCOS in China is dependent on the following four factors.

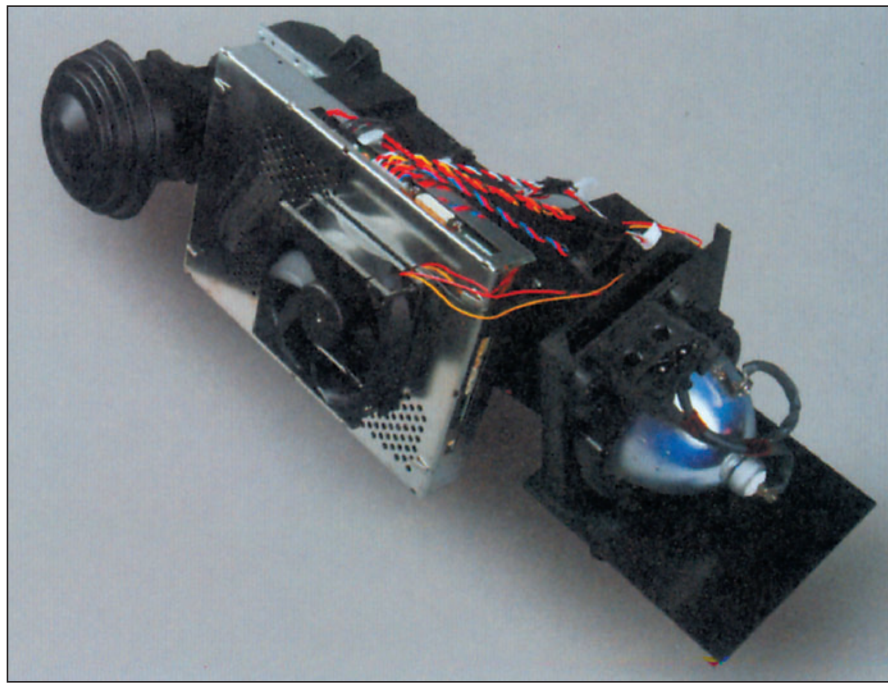

Fig. 2: *LCOS projection light engine manufactured by a Chinese company.*

1. *Can one technology be developed and marketed in only one or a limited number of countries?* In this globalized world, this question is not trivial. LCOS has reached a saturation stage worldwide – it will continually exist in the high-end TV and projector markets. LCDs will continue to dominate the market for most consumer applications. Can LCOS be developed only in China and capture the local consumer market? To answer this question, one must consider if it is possible for one technology or product to be developed only for one country. The history of technology proves that the answer is a resounding yes. One clear example is that of the Video Compact Disk (VCD). VCD, as a video media technology, has a significant overlap with video cassette recorders (VCR) in image performance and market. Therefore, its market has never been developed outside China, where the VCR had already dominated the market. However, for historic reasons, the VCR and VCD entered the Chinese market at about the same time. Due to the advantages of VCDs in price and media size, VCDs captured the Chinese market. The continued efforts on VCDs not only rewarded Chinese companies with a multi-billion-dollar market in VCDs, but they also helped build up the industry infrastructure for DVDs in China. After DVDs entered the world market, Chinese companies quickly took over the leading position of DVD manufacturing from Japanese companies. Consumers throughout the world enjoy DVD movies on players made in China for less than $50 instead of Sony- or Philips-branded players costing several-hundred dollars. Most consumers do not realize that this is possible due to the independent development of VCDs in China.
2. *Is the Chinese manufacturing infrastructure unique and large enough to support the independent development of LCOS TV in China?* Of course it is large enough. LCD and PDP technologies are dominated by Japan, Korea, and Taiwan. The cost of the panel for these technolo-

> ***LCOS is a relatively open technology platform. Its required investment is also much lower than that for LCDs. Therefore, Chinese companies should pay more attention to LCOS technology.***

Fig. 3: *LCOS rear-projection TV manufactured by a Chinese company.*

gies represents more than 80% of the systems cost. The same is true for DLP technology. This makes it virtually impossible for Chinese companies manufacturing and distributing end-user products featuring these technologies to be profitable. This situation will not change anytime soon; therefore, Chinese companies should seek a totally different approach to participate in the HDTV industry. This approach may very well be LCOS technology.

3. *Can the price of LCOS TVs be significantly lower than that of LCD TVs with an equivalent screen size?* Most imaging experts agree that the three-panel LCOS projection TVs produce the best picture quality. The limiting factors for LCOS TVs are their size/thickness compared with LCD TV and cost compared with DLP projection TVs. Of course, if the cost of LCOS TVs is significantly lower than LCD TVs, thickness may not even be an issue. Manufacturing the light engine and TV system in China will dramatically lower the cost for the optical components of the light engine and the system. The microdisplay panel, however, is still the limiting factor. Reducing the cost of microdisplays is an important issue, which can only be solved by moving the manufacture of microdisplays locally into China.
4. *Will the improvement in brightness and reduction of price of LEDs or laser light sources be fast enough to support projection TVs?* The new light-source technologies will dramatically increase the lifetime of the lamp, which is still an issue for traditional projection lamps.

As projection system developers and close observers of the display market for a long time, our suggestion to the Chinese government and companies are:

1. Emphasize the vertical integration of the industry supply chain, for the time being, *i.e.*, to develop the technology for LCOS microdisplay chips. The only successful players in LCOS – Sony and JVC – both adopted the vertical-integration mode. One developer or several closely related companies should have the capability to manufacture most of the components in an LCOS system, including LCOS chips, key optical components, light engines, and the final system. This is the only way to maximize profits and to enable the business to sustain profitability under brutal price pressure.
2. Make the application of LCOS versatile. To manage the development risk, the LCOS developers should make their products adaptable to more applications. For example, developers should also offer solutions for the high-end front projectors for big venues or digital-movie theaters. This is a strength of LCOS technology where flat-panel displays can never compete. LCOS projectors have been widely accepted as the technology with the best display performance. Its only competitor in this application is three-panel DLP projectors. LCOS projectors have the advantages on cost and super-high definition, such as 4K (4096 × 2160) or higher-resolution projectors.
3. Pay attention to micro-projectors (*i.e.*, pico-projectors), ultraportable projectors, *etc.* Micro-projectors are beginning to be integrated with cellular phones, PDAs, and other portable consumer devices. This is also a new application where flat-panel displays cannot compete, and its potential market volume could be even greater than that of RPTVs. Of course, three-panel LCOS systems are limited in size, so single-panel LCOS systems may be the only option within the pico-projector market, especially those non-conventional single-panel structures.

> “ ***Reducing the cost of microdisplays is an important issue, which can only be solved by moving the manufacture of microdisplays locally into China.*** ”

Conclusion

Virtually all LCOS companies have worked with mainland Chinese companies in one way or another, except Sony and JVC who may have their own captive manufacturing plants in China. For those companies working on LCOS chips, light engines, systems, and other key components, our suggestion is that China may be the only chance for LCOS to enter the mass consumer market. All related companies should treasure this opportunity and play an active role in this progress. The corporate strategy should be flexible and have the perspective to adapt to this changing environment. If companies do not adapt, they will surely not survive. ■

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Transparent Conductive Oxides for Display Applications

The search for a cost-effective replacement for indium tin oxide (ITO) for flat-panel displays continues. This article describes a practical solution of high-accuracy patterning of fluorine-doped tin oxide (FTO), making FTO an attractive replacement for ITO for PDPs.

by Harm Tolner, Bernard Feldman, Douglas McLean, and Chris Cording

TRANSPARENT CONDUCTING OXIDES (TCOs) are widely used in solar cells, as front electrodes in flat-panel displays (FPDs), electromagnetic shielding windows, touch-sensitive control panels, low-emissivity windows in refrigerators, cold heat mirrors, *etc.* (Fig. 1). Tin-doped indium oxide (ITO) is the standard transparent conductor (TC) used for practically all flat-panel displays (FPDs) manufactured today. However, indium is a relatively rare and expensive element to extract from the earth; consequently, there is mounting pressure to find a less costly replacement.

The market for ITO has recently been analyzed by Displaybank, as shown in Fig. 2. Replacement criteria for ITO differ for the

Fig. 1: *Applications of TCOs.*[1]

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two most common FPD technologies: liquid-crystal displays (LCDs) and plasma-display panels (PDPs). Because the TC of the active TFT plate is deposited after the deposition of the transistors for LCDs, high-temperature conditions are not permissible. Therefore, sputtering of the TC is the primary means of deposition. Several approaches to replace ITO for the active plate of LCDs are described by Miniam[2] and Osono *et.al.,*[3] but thus far, no industrially acceptable solution has been found.

For PDPs, on the other hand, the TC is deposited directly on a glass surface before the other processing steps. Therefore, a high-temperature process can be used as long as it does not exceed the annealing temperature of the substrate glass. Chemical vapor deposition (CVD) at high temperature (~600°C) can allow the deposition of the TC on glass as the glass is made (see Fig. 3).

Typically, the cost of an ITO layer, deposited by sputtering, constitutes more than 80% of the TCO-layer cost in a PDP and is of the same order of magnitude as the cost of the PDP glass plates. This will likely increase within a few years because there will be a shortage of indium, endangering the stable supply of ITO. This is not a positive prospect for FPD makers, who have seen market forces drive down flat-panel-TV prices by about 30% per year. The manufacturers need to realize cost savings to match these price reductions, and a likely candidate is to reduce the cost of the TCO material and the cost of the TCO deposition process.

For PDPs, the replacement of ITO by tin oxide (SnO_2) is an obvious candidate. Thanks to the new proprietary wet-chemical process described in this article, tin oxide now can be patterned accurately in the form of discharge electrodes. Fluorine-doped tin oxide (FTO) has an especially low resistance, comparable to that of ITO, and can be deposited on the glass production float-line using a CVD process (Fig. 4). By using deposition onto the glass after solidification at 600°C, the cost of annealing, needed to achieve a low resistance, is also reduced. This process is described in detail by Dong-Ki Min and Sae-Young Kim[1] and T. Ishida *et al.*[4] and has been demonstrated with good success. Tin oxide has been overlooked because it could not be patterned easily by photolithography, unlike ITO.

This article describes a practical solution of high-accuracy patterning of FTO, making FTO an attractive replacement for ITO for PDPs as well as other applications using a transparent conductor on a glass surface, such as touch screens and solar panels.

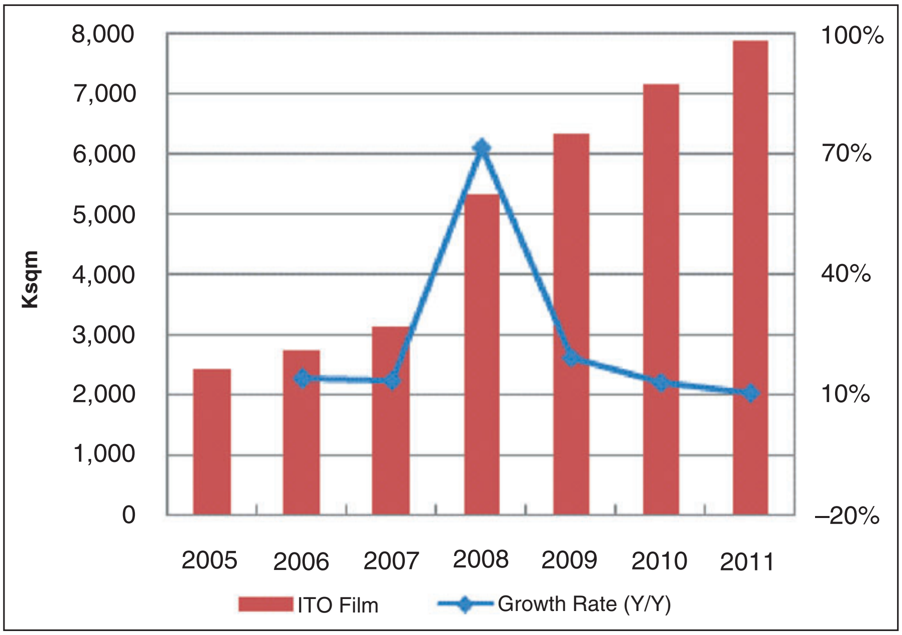

Fig. 2: Global ITO film production capacity. (Source: Displaybank, In-depth Analysis: Touch-Screen Panel Industry Trends and Business Strategies.)

Fundamentals of TCOs

While conductivity and transparency are usually mutually exclusive properties, this apparently is not the case for TCOs. So what is the secret behind this unique property of TCOs?

The high visual transparency of TCOs is the result of the high value of the electronic bandgap E_g (see Fig. 5). For TCO, it is higher than 3.0 eV, corresponding to the energy of a 400-nm blue photon. So, visible photons (having an energy between 2 and 3 eV) cannot excite electrons from the valence band (VB) to the conduction band (CB), and hence are transmitted through it.

On the other hand, electrons from the donor level to the CB (for an n-type TCO) or holes

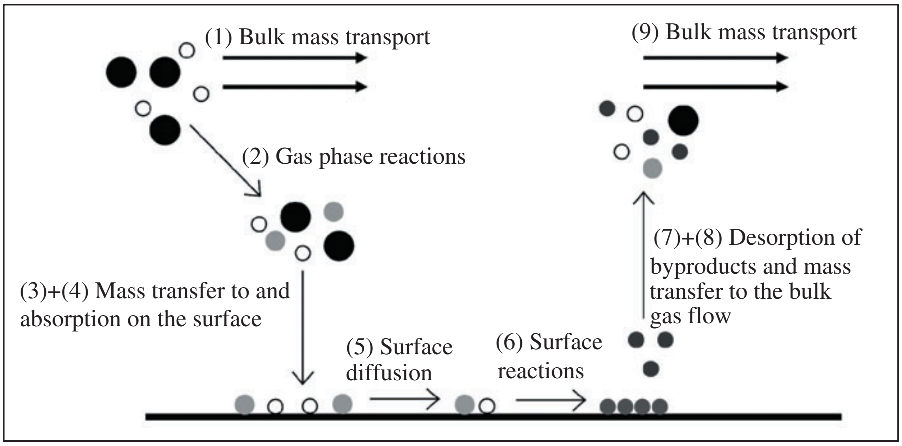

Fig. 3: Schematic representation of the basic steps in a chemical vapor deposition process.[5]

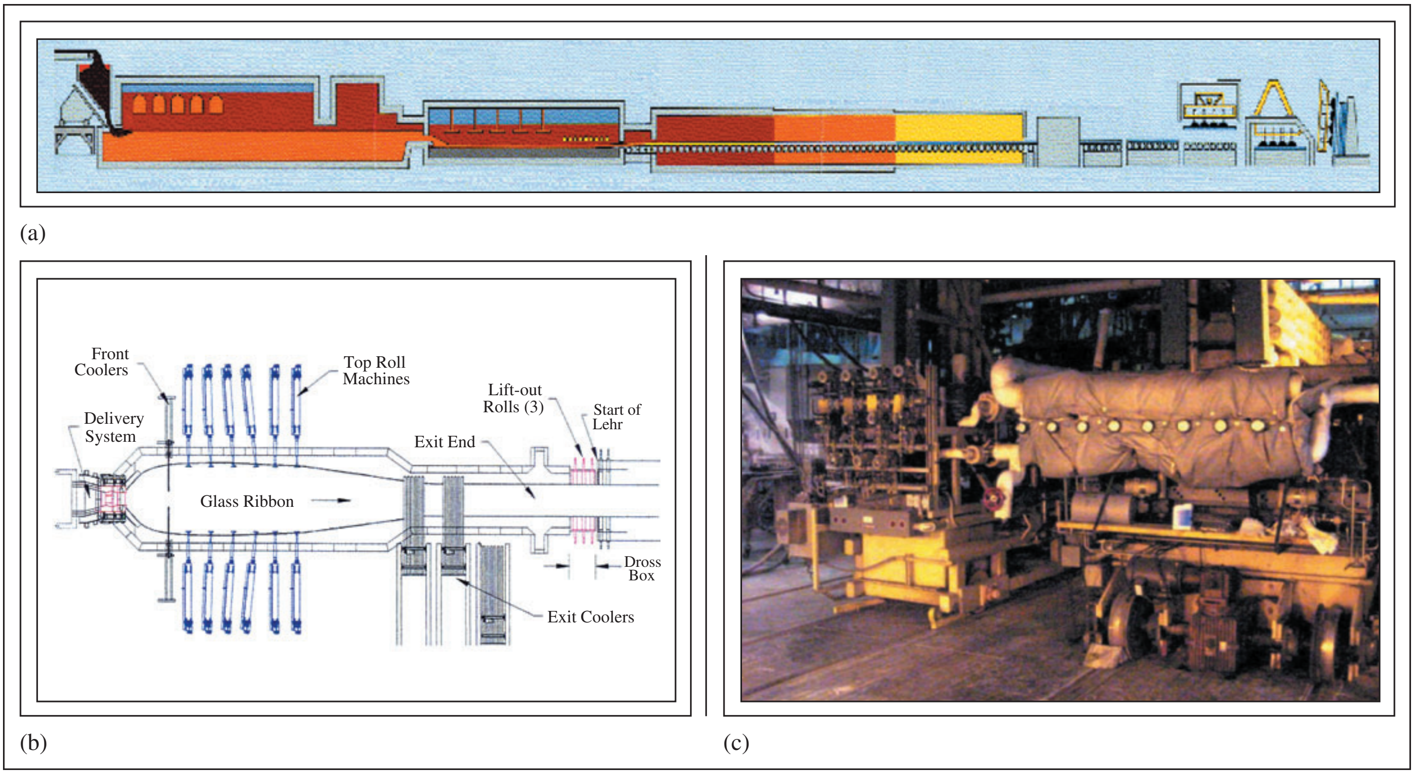

Fig. 4: *(a) Glass float-line overview; (b) detailed view of the front part; and (c) CVD reactor on the float-line. http://www.icmm.csic.es/ingesnet/presentaciones2006/Surface%20Treat%20Glass%20(J%20Marco).pdf.*

from the acceptor level to VB (for p-type TCO), generate appreciable conductivity.

In the case of fluorine-doped tin oxide (FTO), the fluorine is responsible for the creation of a donor level. For tin oxide (SnO_2) the bandgap is 3.6–4.0 eV.

UV light, with an energy higher than the bandgap energy $E_{g,}$ is fully absorbed by the TCO, while visible light is transmitted. The donor level demonstrates high conductivity.

For most applications, n-type TCOs are used because they exhibit the highest conductivity at a transparency of 80% or more. In a semiconductor, the hole mobility is much lower than the electron mobility, explaining the much higher conductivity of n-type TCOs, such as FTO and antimony-doped tin oxide (ATO).

FTO Characteristics

- FTO is deposited on the float glass line as the glass is made; a low-cost process compared to that for sputtered ITO.
- High-temperature deposition on the float-line (~600°C) eliminates any organic contamination so that post-deposition firing of the coated glass is not required by PDPs.
- High-temperature CVD guarantees superior film adhesion by virtue of the chemical modification of the surface.
- The hardness of FTO on the Mohs scale is 6.5; glass is 6 and ITO is ~5. If FTO film is scratched with a razor blade, steel will be wiped onto the FTO film. A harder-than-glass film permits direct electrical contact and eliminates film scratches during processing, thus enhancing product yield.
- The resistivity of FTO barely changes when fired on a PDP front plate at 570–580°C, contrary to the case for ITO. For example, whereas the resistivity of 30-Ω/sq. ITO film increases up to 90–100 Ω/sq. after firing, together with the transparent dielectric layer of a PDP at 580°C, the corresponding change for FTO is < 10%. Thus, a 100-Ω/sq. FTO film can replace a 30-Ω/sq. ITO film with similar resistance after the application of the dielectric overglaze for PDPs.
- The net visual transmittance for glass and film is 86% for FTO *vs*. 84% for the thicker ITO coating.
- Because the etching is performed at room temperature with much lower HCl concentrations than used in current ITO etching, there is no mist problem.

Patterning of FTO by Wet Chemical Etching

Typically, the gap control in a PDP has to be accurate within 3% (3-sigma) of the TCO gap size, so an edge definition of ±1 μm is required. Figure 6 shows the result of the new etching process applied on FTO. The etching time is less than 1 minute at room temperature and the process uses benign and dilute low-cost chemicals and is readily automated.

In Fig. 6, the 6- and 12-μm etched lines and spaces (bottom) are compared with the original photoresist pattern (top). If the resist edge and the etched structure are superimposed, there is better than 0.1-μm agreement. This is a consequence of the special penetration control in our etch process explained below in some detail.

The undercut is only ~0.9 µm for a 1.5-µm-thick S1818 photoresist (Rohm & Haas). When a thick dry film resist (DFR) is used (*e.g.*, TOK), then the undercut is about 3.0 µm.

Characteristics of the New Tin Oxide Etching Process[9]

The etching of FTO introduces a new complication not present when using ITO. Most metal oxides, including ITO, can be reduced to the metal by using hydrogen ions in strong acid solutions. FTO cannot be reduced in this way.

However, if zinc particles are added to the acid, then FTO can be etched because of electron transfer from the zinc to FTO. In this well-known process, the FTO surface is negatively charged by the electrons from the zinc; it then attracts H_3O^+ ions and reduces them to H atoms, which diffuse into the lattice and reduce Sn^{4+} to metallic tin, breaking up (etching) the FTO.

This electrochemical process can also be described as the action of multiple short-circuited 1.34-V batteries, each with negative Zn and positive FTO poles in acid electrolyte. The overlapping etch zones of the multiple batteries guarantee a complete etch of uncovered FTO.

In this normal FTO etching process just outlined, the H atoms that diffuse under the resist areas, however, can cause a drastic and uneven undercut, resulting in an edge definition that is completely unacceptable by the display industry.

In our new process,[6] this atomic-hydrogen diffusion is controlled by adding metal ions (Fe^{2+}, for example) to the electrolyte so that metal is deposited on the FTO along with the production of H atoms. Buildup of the deposited metal continues the battery action but slows the diffusion of H atoms into the lattice (penetration control), thereby controlling undercut.

The battery action proceeds at the same time as the direct action of Zn with hydrogen ions to produce diatomic hydrogen gas, although this reaction has no etching effect. Zn overvoltage slows the direct reaction to the point where it does not out-compete the battery action.

When the FTO lattice has completely broken up, the remaining metal (Sn) and reduced penetration control metal (which does not dissolve in the electrolyte) is removed in a

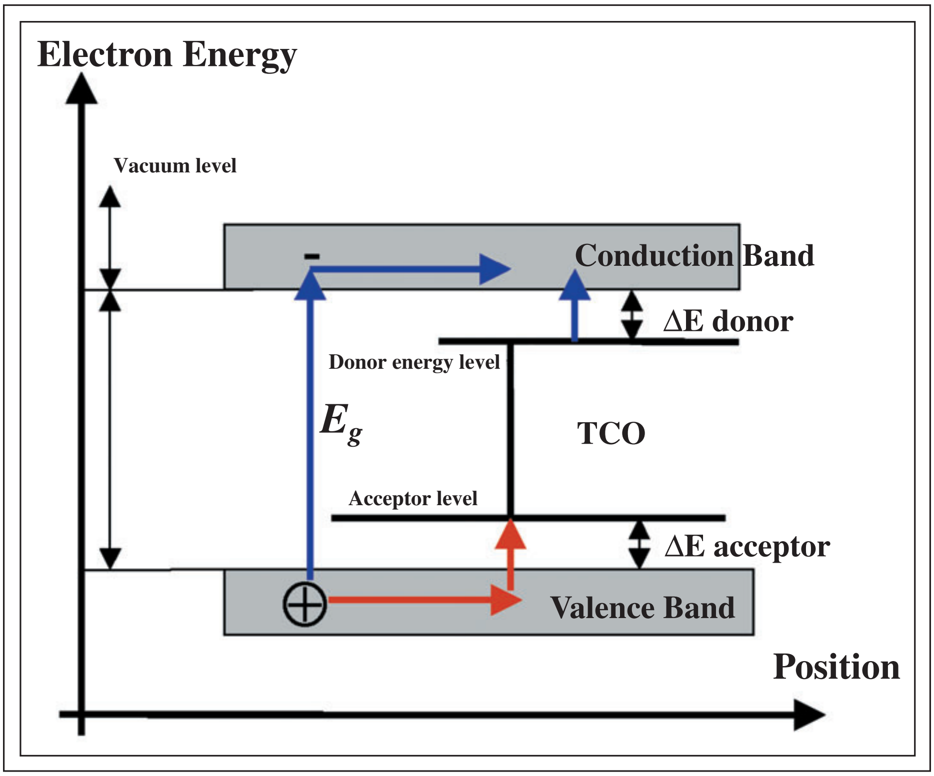

Fig. 5: *Energy levels involved in a TCO. For fluorine-doped tin oxide (FTO), the fluorine is responsible for the creation of a donor level. For tin oxide (SnO_2), the bandgap is 3.6–4.0 eV.*

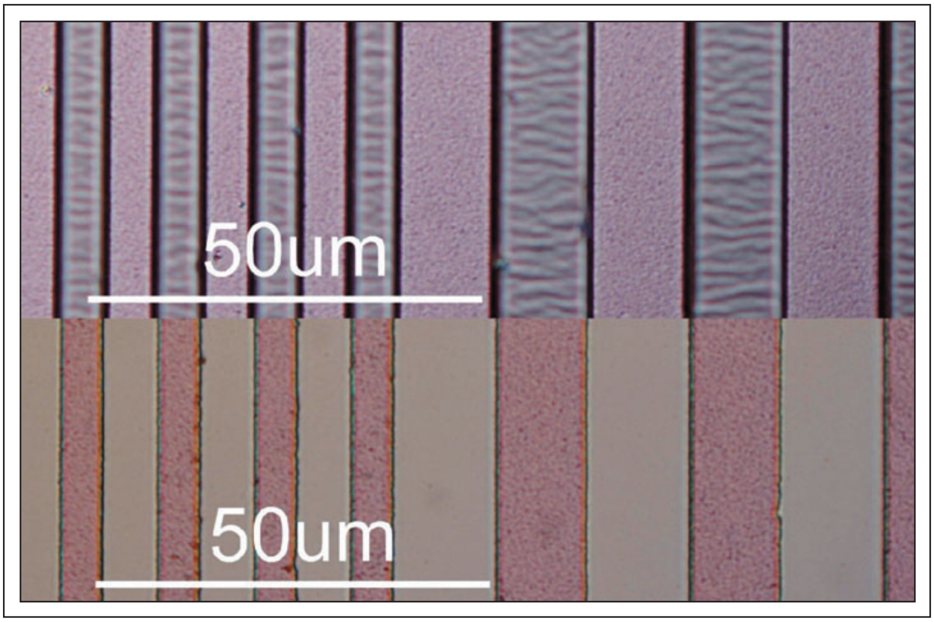

Fig. 6: *FTO pattern (bottom) after wet chemical etching of 6- and 12-µm-wide lines and spaces, compared with the resist pattern (top). The resist used is a 1.5-µm-thick S1818 photoresist from Rohm & Haas.*

subsequent operation (using acidified Fe^{3+} for example) to complete the etch.

In the new process, the only change is the use of a zinc acid slurry instead of the usual acid etch. The etching time is not increased. For an example of the automation of the etching machine, go to www.feldmantechnology.com.[7]

Although we have cited advantages of FTO *vs.* ITO, it is important to note that we have demonstrated the same properties for the etching of ITO by our new process with penetration control as an alternative to the harsh liquid-chemical etch currently employed commercially.

FTO Use in High-Definition and High-Efficiency Plasma Displays

In a plasma display, VUV light is generated in a neon–xenon plasma by triggering a discharge across a narrow gap of about 80 μm in the TCO electrodes (see Fig. 7).

The phosphor on the opposite plate converts the 147- and 173-nm radiation into visible light, and this in turn is transmitted toward the viewer through the transparent electrodes.

In order to reduce the PDP power consumption, the efficiency must be increased. This is possible by using a much higher xenon pressure than the standard 10% xenon. Unfortunately, this also increases the firing voltage, partially reducing the gain in efficiency. The solution is to reduce the TCO gap. As shown by Oversluizen *et al.*,[9] 40% or more xenon can then be used and an efficacy of 5 lm/W can be achieved.

Until recently, this operational mode could not be used because of the increase in addressing jitter. However, the invention of new types of MgO coating, such as the crystal emissive MgO layer (CEL) developed by Pioneer, has changed all of this. The new etching process will enable us to use 60 μm or even smaller gaps, with an accuracy better than 3%, enabling high manufacturing yields.

Therefore, the new etching technology opens the door widely for PDP power reduction in true high-definition 1080-line PDPs for both FTO and standard ITO.

Conclusion

This article describes a practical solution for high-accuracy patterning of metal oxides, especially fluorine-doped tin oxide (FTO), which cannot be patterned accurately by any other means. Thus, FTO is a suitable replacement for ITO, especially for PDPs. The etching method can be applied to FTO coatings applied off the glass float line, but the big cost savings occur when the FTO is applied in-line as the glass is made.

At the present time, to the best of our knowledge, FTO is available in-line only on soda-lime glass over an SiO_2 barrier. This application has been shown to work for PDPs that use striped electrodes as shown in Fig. 7.

However, to be able to compete with LCDs, a 2-D-electrode pattern more complicated than stripes (*e.g.*, T-shaped electrodes) is required to obtain high-definition PDP performance. Unfortunately, the glass is distorted and the required accuracy of the 2-D electrode pattern is lost when the dielectric overglaze is fired at ~570ºC.

What is required for full utilization of our process for PDPs is either the development of a lead-free overglaze that fires clear at <520ºC or the deposition of FTO on the high-strain-point glass currently in use for PDP fabrication. Hopefully, this article will inspire one of these developments

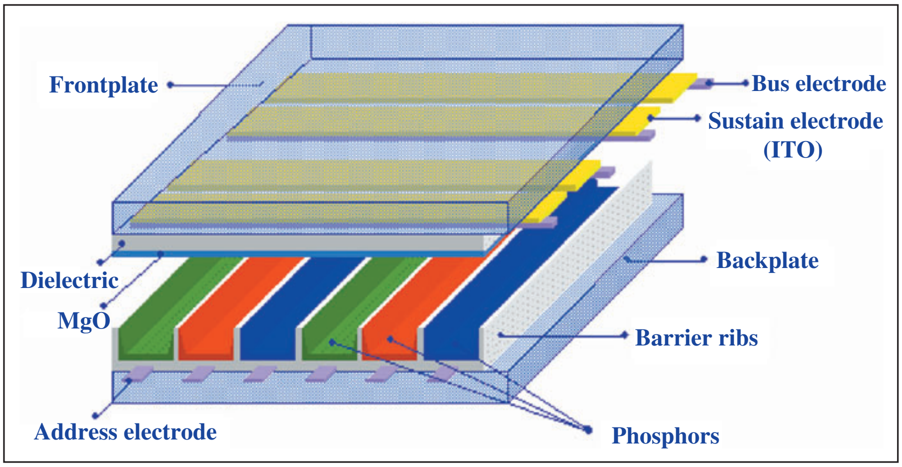

Fig. 7: The PDP cell design.[8] The front plate and back plate are shown separated in this picture (exploded view). The narrow gap (~ 80 μm) between the transparent scan and sustain electrodes determines the discharge voltage.

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Edited by Aris Silzars

Investigation of distributed Bragg reflector growth conditions for high-brightness AlGaInP light-emitting diodes

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Abstract — The effect of growth conditions of a distributed Bragg reflector (DBR) structure on the performance of AlGaInP light-emitting diodes (LEDs) has been investigated. Increasing the growth temperature and the flow rate of AsH_3 as well as lowering the growth pressure resulted in improved reflectivity and root-mean-square (RMS) roughness of the high-aluminum-content multiple pairs of the DBR structure. An increase in the growth temperature may improve the mobility of atoms on the surface for the positioning of the right atomic site and to reduce oxygen incorporation. An increase in the flow rate of AsH_3 can suppress the arsenic vacancy formation at higher V/III ratios. Furthermore, reduction in growth pressure can suppress the convection flow on the epitaxial growth surface. To verify the influence of DBR growth conditions on the successive growth of LED structures, the growth of full LED structures having two different DBR growth conditions was performed, and AlGaInP red LEDs using full LED structures were fabricated. It was found that higher growth temperature and AsH_3 flow rate with lower growth pressure for the DBR structure produced improved output power of the AlGaInP LEDs, which can be attributed to the high reflectivity and low RMS roughness of the DBR structure.

To improve the DBR growth conditions, we enumerated as many factors as possible: (i) differential pressure between run and vent line, (ii) growth temperature, (iii) V/III ratio, (iv) growth pressure, and (v) growth rate. For a differential pressure between run and vent line, the vent flow was regulated to minimize the pressure difference between run and vent line. In the preliminary experiment, two LED structures were grown under different DBR growth rates of 1 and 2 µm/hour, respectively. We found that the device performance was not different when changing the growth rate of the DBR structure from 1 to 2 µm/hour. Therefore, the growth temperature, AsH_3 flow, and growth pressure were selected as experimental parameters.

TABLE 1 — Experimental growth conditions of a DBR set by DOE (Design of Experiment).

No	Temperature (°C)	AsH_3 flow (sccm)	Pressure (mbar)
DBR1	670	100	50
DBR2	730	400	50
DBR3	730	400	100
DBR4	670	400	50
DBR5	730	100	100
DBR6	730	100	50
DBR7	670	400	100
DBR8	670	100	100

Brightness management in a direct LED backlight for LCD TVs

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Ivan Moreno
Shih-Hsun Chung
Wei-Ting Chien
Chih-To Hsieh
Tsung-Hsun Yang

National Central University

Abstract — A method of calculating the luminance and luminance uniformity of a bottom LED backlight is proposed and demonstrated. Both the power consumption and brightness uniformity as a function of screen brightness, screen size, backlight thickness, transmittance of the LCD panel, reflective cavity efficiency, gain, cone angle of the enhancement films, LED array configuration, average luminous flux, radiation pattern, and input power of individual LEDs. Moreover, a 42-in. LCD TV using this backlight design approach was fabricated. The bottom backlight incorporates an array of RGGB 4-in-1 multi-chip LEDs within a highly reflective box behind a diffuser and a dual brightness-enhancement film. The brightness uniformity can be predicted within an accuracy of 94% and the luminance level within an accuracy of 96%.

A direct or bottom RGB LED backlight is a key concept in large-area LCDs because it does not use a light guide, is flat, and is easy to assemble. Simply, an array of LEDs is placed in a cavity directly behind the LCD panel. Moreover, a bottom backlight enables local dimming and scanning of LEDs in time with the video displayed on the screen. This feature can increase the color contrast and reduce both the movement blurring and power consumption.

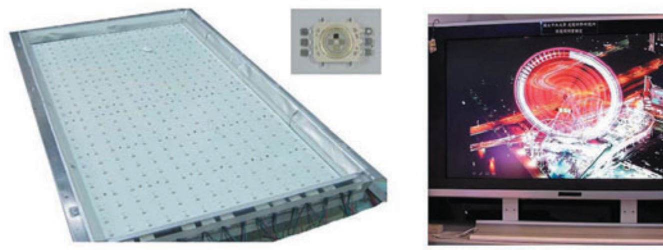

FIGURE 6 — (Left) Constructed LED backlight. (Inset) a RGGB 4-in-1 multi-chip LED. (Right) The LED-based 42-in. LCD TV displaying images.

Simulated light extraction from a light-emitting diode integrated with a microlens array

Jun-Hee Hong
Si-Hyun Park

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Abstract — Light extraction from InGaN-based light-emitting diodes (LEDs) on which microlens arrays were integrated using ray-tracing methods was simulated. Enhancement of the total light extraction and beam shaping in the forward direction of the output of microlens-integrated LEDs compared to conventional LEDs were observed. The diameter, curvature radius, and density of the microlens arrays on the LEDs were varied and the optimal conditions for external efficiency was determined.

We considered the case in which several lenses were integrated onto one LED, as shown in Fig. 4. In this case, we calculated the light-extraction efficiency according to the variation in the radius of curvature of the lenses and the variation in the pitch of the lens array. The choice of these parameters in our simulations was reasonable because the variation in the curvature radius of the lenses or number of lenses on the LED can illustrate various aspects of their effects on light extraction from LEDs.

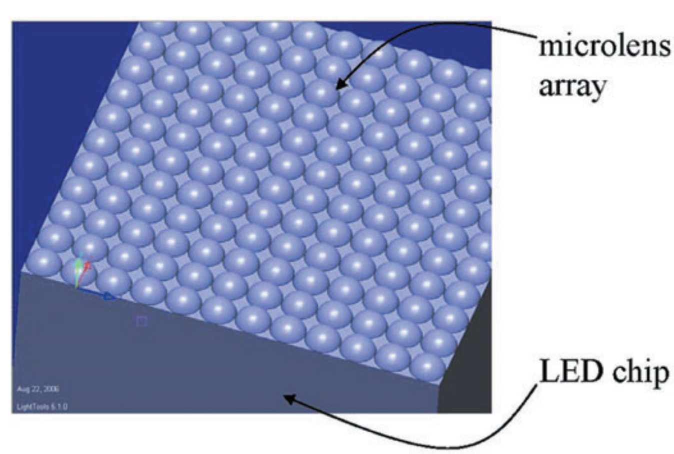

FIGURE 4 — Schematic diagram of a LED with an integrated microlens array. We calculated the light-extraction efficiency for differences in the radius of the curvature of the lenses and the numbers of lenses.

Surface-treatment effects of a sapphire substrate by He^{+-}, Ar^{+-}, and Xe^{+}-ion implantations for GaN epitaxial layers

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Dongjin Byun

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Abstract — The structural, electrical, and optical properties of GaN epilayers grown on various ion-implanted sapphire(0001) substrates by MOCVD were investigated. GaN or AlN buffer layers and pre-treatment were indispensably introduced before GaN-epilayer growth. The ion-implanted substrate's surface had decreased internal free energies during the growth of the ion-implanted sapphire(0001) substrates. The crystal and optical properties of the GaN epilayers grown in ion-implanted sapphire(0001) substrates were improved. Also, an excessively roughened and modified surface caused by ions degraded the GaN epilayers. Not only the ionic radius but also the chemical species of implanted sapphire(0001) substrates improved the properties of the GaN epilayers grown by MOCVD. It is obvious that the ion-implanted pre-treatment of sapphire(0001) substrates can be an alternative pre-treatment procedure for GaN deposition and has the potential to improve the properties of the GaN epilayers on sapphire(0001) substrates.

GaN-based materials and related nitride compounds have many attractive chemical and physical properties for use in high-temperature and high-power electronics, as well as blue and ultraviolet light-emitting diodes (LEDs) and laser diodes (LDs). Also, the wurtzite GaN structure has several advantages, including a direct bandgap of 3.4 eV at room temperature for high efficiency in optoelectronic devices, high radiation hardness, and complete solubility among the binary compounds and forms a continuous solid solution with InN and AlN, which have the same wurtzite structure and direct band gap of 1.9 and 6.2 eV, respectively.

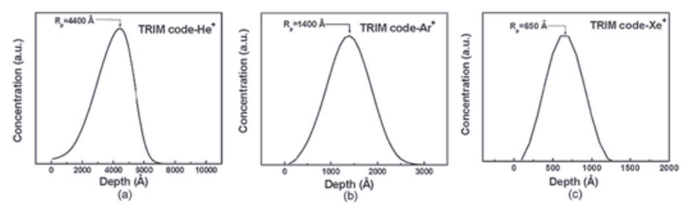

FIGURE 1 — Depth distribution of (a) He^{+-}, (b) Ar^{+-}, and (c) Xe^{+}-ion implantation in sapphire(0001) substrates.

Characterization of a SAG-InGaN/AlGaN LED by mixed-source HVPE with a multi-sliding boat system

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Abstract — The selective area growth (SAG) of a InGaN/AlGaN light-emitting diode (LED) is performed by using mixed-source hydride vapor-phase epitaxy (HVPE) with a multi-sliding boat system. The SAG-InGaN/AlGaN LED consists of a Si-doped AlGaN cladding layer, an InGaN active layer, a Mg-doped AlGaN cladding layer, and a Mg-doped GaN capping layer. The carrier concentration of the *n*-type $Al_xGa_{1-x}N$ ($x \sim 16\%$) cladding layer depends on the amount of poly-Si placed in the Al–Ga source. The carrier concentration is varied from 2.0×10^{16} to 1.1×10^{17} cm^{-3}. Electroluminescence (EL) characteristics show an emission peak wavelength at 426 nm with a full width at half-maximum (FWHM) of approximately 0.47 eV at 20 mA. It was found that the mixed-source HVPE method with a multi-sliding boat system is a candidate growth method for III-nitride LEDs.

Wide-bandgap III-nitride semiconductors are one of the most promising materials for the application of short-wavelength light emitters. III-nitride-based heterostructures have also received much attention by optical devices, such as light-emitting diodes (LEDs) and laser diodes (LDs) operating in the blue and green regions. These performances are based on multilayer epitaxial structures grown by metal-organic chemical vapor deposition (MOCVD) or molecular-beam epitaxy (MBE) methods. HVPE allows the growth of low-defect-density material that incorporates a high proportion of aluminum (Al) in the AlGaN layers without severely degrading the crystal quality.

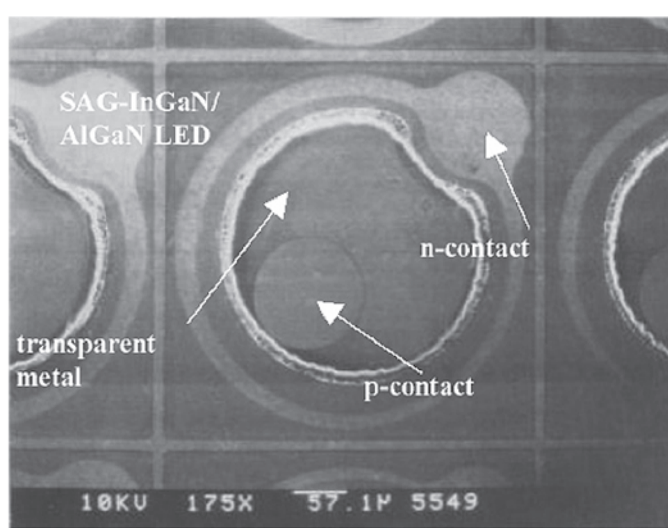

FIGURE 5 — Top view of the SAG-InGaN/AlGaN LED grown by mixed-source HVPE with a multi-sliding boat system.

Design of a prism light-guide plate for an LCD backlight module

Chen-Jung Li
Yi-Chin Fang
Wei-Tang Chu
Ming-Chia Cheng

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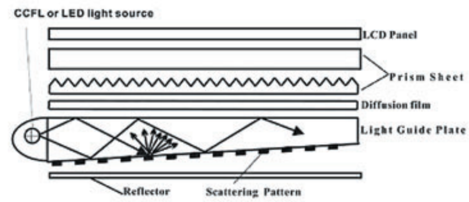
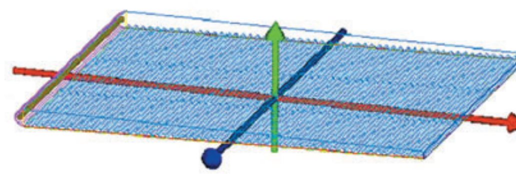
Abstract — This paper describes the development of a design method for a prism pattern for an LCD light-guide plate to improve the uniformity of its exiting light. First, the prism surface of the light-guide plate is divided into several equal regions. With the aid of ASAP simulation, this method uses the mean light flux of all regions as a reference value to adjust the distribution density of the prism pattern for each region. Curve fitting is then performed to provide a smoothly changing distribution density for further improvement of the exiting light uniformity. ASAP results demonstrate that the illuminance uniformity for a 2.5-in. light-guide plate is substantially improved from 45% to 90.9% by using this design method.

To reduce the number of prism sheets [(*i.e.,* to reduce the cost of the backlight module (BLM)], a light-guide plate with prisms (*i.e.,* V-shaped grooves) on its surface(s) was invented, such that the prism surface possesses the function of condensing light, as shown in Fig. 1(b). Therefore, the prism LGP provides higher brightness than the scattering-dot LGP for the LCD BLM, and thus this type of the LGP is considered in this paper.



(a)



(b)

FIGURE 1 — LCD backlight module and light-guide plate: (a) The schematic diagram for an LCD backlight module with a side-type LGP; (b) a wedge-shaped light-guide plate with a prism pattern.

High-efficacy drive of spatial positive-column-discharge PDP with delayed D pulses

Tomokazu Shiga
Taiko Sato
Narue Kobayashi
Shigeo Mikoshiba
Hideyuki Asai
Naoya Kikuchi

The University of Electro-Communications

Abstract — A thick-film ceramic-sheet PDP provides a long sustain discharge gap of 0.45 mm, enabling the use of positive column discharges. The discharges are established in the middle of the discharge space and are completely free from touching the surface of substrates. This allows for the reduction in diffusion losses of the charged particles. To further improve the efficacy, delayed D pulses are applied to the address electrodes during the sustain period. Although the pulses only draw a little current, they perturb the electric field, reducing the peak discharge current and hence resulting in higher efficacy and luminance. The efficacy and luminance increase by 35% and 38%, respectively, with the delayed D pulses. These pulses are incorporated into the contiguous-subfield erase-addressing drive scheme for TV application. A short gap of 70 μm between the sustain and data electrodes generates a fast-rising discharge and allows a high-speed addressing of 0.25 μsec. This provides 18 contiguous subfields for the full-HD single-scan mode, with 70% light emission duty. A luminous efficacy of 6.0 lm/W can been attained using Ne + 30% Xe 47 kPa, a sustain voltage of 320 V, and a sustain frequency of 3.3 kHz, when the luminance is 157 cd/m^2. Alternatively, the panel can achieve 4.2 lm/W and 1260 cd/m^2 by increasing the sustain frequency to 33 kHz.

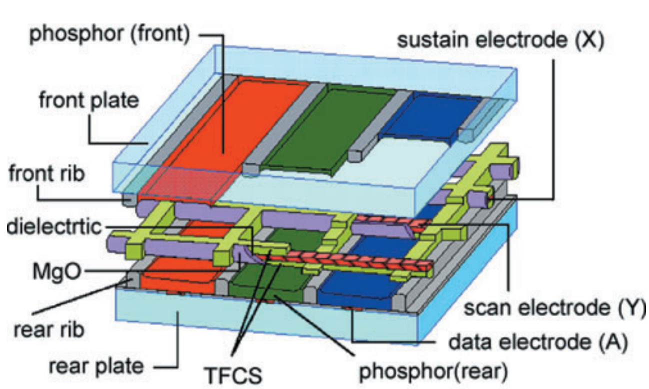


FIGURE 1 — Structure of thick-film ceramic sheet (TFCS) PDP.

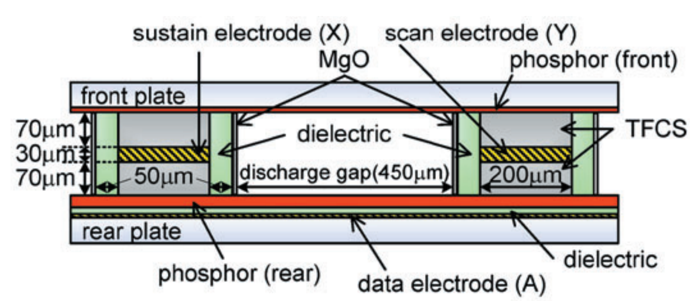


FIGURE 2 — Cross-sectional view of TFCS PDP along the data electrode.

Coatings of indium tin oxide nanoparticles on various flexible polymer substrates: Influence of surface topography and oscillatory bending on electrical properties

Tobias Königer
Helmut Münstedt

Abstract — Coatings of indium tin oxide (ITO) nanoparticles on different flexible polymer substrates were investigated with respect to the achievable sheet resistance and their electrical behavior under oscillatory bending. As substrate materials, polyethyleneterephthalate (PET), polyethylenenaphthalate (PEN), polyetheretherketone (PEEK), and polyimide (PI) were chosen, the surface resistances on the different polymer substrates were compared as a function of annealing temperature and surface topography. The surface topography, which has a strong influence on the surface resistance, was characterized by means of a white-light confocal (WL-CF) microscope. On the PET substrate, which exhibits the smoothest surface, the coating of ITO nanoparticles shows the lowest sheet resistance of 2 kΩ/□ for a layer thickness of 3 μm and an annealing temperature of 200°C. Furthermore, the electrical behavior of coatings of ITO nanoparticles under oscillatory bending was investigated using a special device. These coatings show a cyclic change of the conductivity which can be explained by an alternating compression and extension of crack flanks under the applied stress. Due to the growing number of cracks with increasing number of cycles, a decrease of the conductivity is observed in the bent state as well as in the balanced state.

The transmittance of visible light was investigated using UV/VIS spectroscopy to characterize the influence of the layer thickness on the transmittance of ITO-nanoparticle coatings. In Fig. 6, the transmittance of a 100-μm-thick PET film coated with 3- and 4-μm-thick layers of annealed ITO nanoparticles is plotted as a function of wavelength and compared to uncoated PET films and commercially available ITO-sputtered PET films.

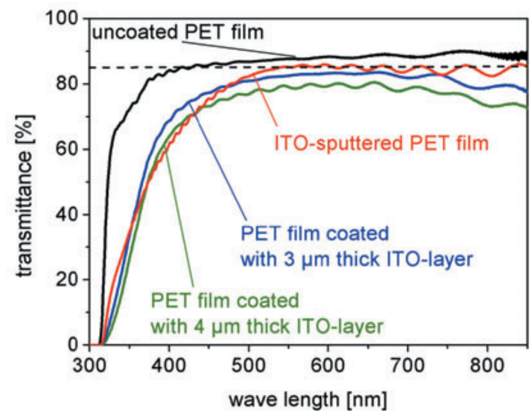


FIGURE 6 — Transmittance of visible light through uncoated PET films and PET films coated with annealed ITO nanoparticles.

Non-polar-oriented InGaN light-emitting diodes for liquid-crystal-display backlighting

Hisashi Masui
Hisashi Yamada
Kenji Iso
James S. Speck
Shuji Nakamura
Steven P. DenBaars

University of California

Abstract — This article addresses spontaneously polarized light emission from GaN-based light-emitting diodes (LEDs) fabricated on electrically non-polar crystallographic orientations and application of spontaneously polarized emission for backlighting of liquid-crystal displays (LCDs). The first half of the article describes polarized light emission from GaN-based LEDs and its role in solid-state lighting technology. The second half reports on our experimental work to explore the potential of non-polar LEDs for LCD backlighting applications. Optical transmission of non-polar LED emission was characterized through a liquid-crystal layer. Extinction ratios of 0.21 were measured between zero and an applied bias voltage to the liquid-crystal cells. These extinction ratios are not particularly high yet; nevertheless, the experiment has demonstrated the potential of such non-polar LEDs for LCD backlighting.

LED samples used in the present experiments were fabricated by using the metal organic chemical-vapor deposition method on an *m*-plane-oriented GaN substrate. LED structures consisted of a multiple QW stack of InGaN/GaN that was sandwiched by *n*-type GaN and *p*-type GaN/AlGaN layers. A conventional mesa structure (active area ~300 × 300 μm^2) was fabricated on an LED wafer to make electrical contacts. Indium tin oxide was used as a *p*-type contacting layer. A schematic of the LED is drawn in Fig. 4.

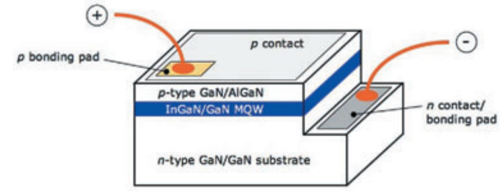


FIGURE 4 — An LED die with a common mesa structure. A stack of the multiple quantum-wells (MQW) is grown on an *n*-type GaN layer and is followed by *p*-type AlGaN and *p*-type GaN layers. A dry-etching technique is used to make the mesa structure on the grown LED wafer (~350 μm thick). Metal contacts and bonding pads are deposited via vacuum techniques. The LED wafer with metal contacts is cut into discrete LED dies, and gold wires are attached to the pads.

Temperature dependence of residual DC voltage and its evaluation parameter related to liquid-crystal and alignment-layer materials

Masanobu Mizusaki
Tetsuya Miyashita
Tatsuo Uchida
Yuichiro Yamada
Yutaka Ishii
Shigeaki Mizushima

Tokohu University

Abstract — The temperature dependence of residual DC voltage was studied based on the adsorption and desorption of ions in the liquid-crystal (LC) layer to and from the interface between the LC and alignment layers during the application of an external DC offset voltage. The relaxation process of the adsorbed ions during the open-circuit state was also studied after applying the DC offset voltage. Those processes were found to follow the Arrhenius rule, and a new evaluation parameter related to the temperature is proposed for the design of the LC and alignment-layer materials.

There are several problems with the reliability of the latest LCDs. One of the serious problems is the generation of residual DC voltage (V_{rDC}), which leads to the generation of image sticking or a residual image. V_{rDC} is the DC offset voltage generated inside a LC cell after applying an external DC offset voltage, and relates to the existence of ions in the LC layer as an impurity. It is generally known that the degree of ionization changes with a shift in temperature. In most cases, the concentration of the ion increases with increasing temperature. The fact indicates that V_{rDC} also changes with shifting temperature.

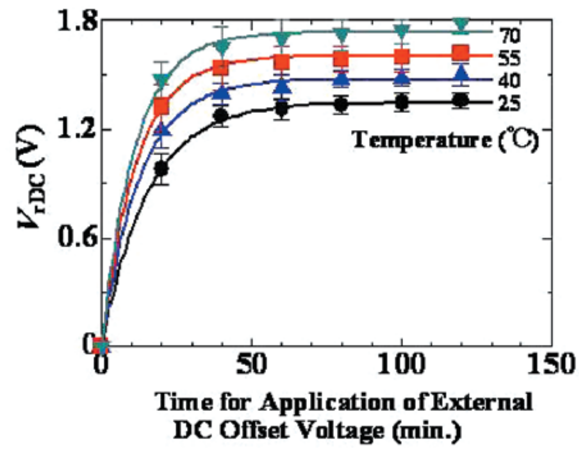


FIGURE 1 — V_{rDC} as a function of time for external DC offset voltage at various temperatures.

editorial

continued from page 2

standard is in some specific way linked to the instrumentation shown. This is not correct. In fact, as committee chair Joe Miseli pointed out in his article in the same issue, the ICDM is being developed to be as platform-independent as possible. While the methods described in the ICDM will be very detailed, they will not be tied to a specific manufacturer's system; in fact, many suppliers today already have equipment suitable for use with the ICDM methods, or are gearing up their new offerings toward the ICDM. This is a worldwide effort with representation at all levels of the display industry. A significant number of measurement-equipment suppliers are represented on the committee and many are also advertisers here in the pages of *Information Display*. The system shown on the cover was meant simply to convey a theme, and we regret any misunderstanding this may have caused.

I wish everyone safe travels to LA and look forward to seeing you at Display Week 2008.

– Stephen P. Atwood

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industry news

Samsung Electronics Acquires Clairvoyante

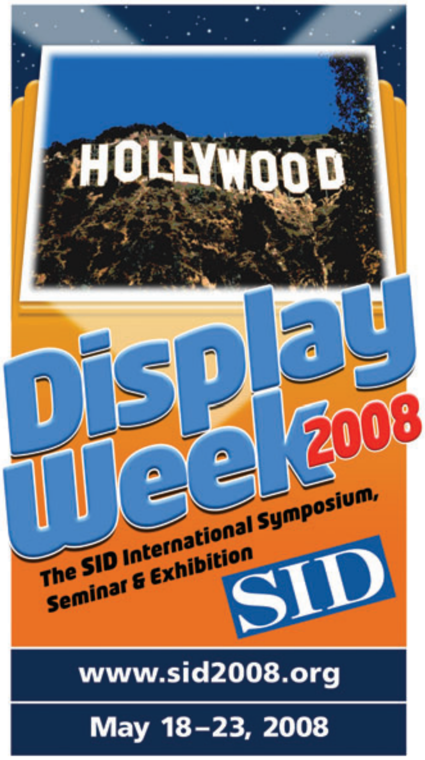
(continued from page 3)

"The acquisition of Clairvoyante's IP assets by Samsung ensures the long term development of PenTile technology to support growing demand for high resolution devices," said **Joel Pollack**, CEO of Clairvoyante Inc. "The transaction also validates the ability of PenTile technology to enable best-in-class displays with greater performance and functionality for emerging designs."

After the acquisition of IP assets, Clairvoyante will be dissolved. A new entity, Nouvoyance, has been formed. It will be led by **Candice Brown Elliott**, a founder of Clairvoyante, and staffed with the Clairvoyante engineers. Together with Samsung, Nouvoyance will carry forward the future development of PenTile technology.

"We are pleased that Nouvoyance will be able to continue display technology development to realize the dreams of low-power, high-resolution display applications," said Elliott, who will be CEO of Nouvoyance.

— Staff Reports



continued from page 4

winter storm approaches. Advertisers can even test messages for timing and impact, and then immediately tweak their billboards for maximum return on investment.

- *Digital outdoor is an efficient investment:* Digital outdoor is a more efficient investment on several fronts: production costs are significantly less than those for updating vinyl billboards, dayparting can be achieved at a lesser cost than is available through the broadcast media, and the average cost to reach each viewer is extremely competitive with other mass media.

3. ***Be prepared to justify sharing board time with multiple advertisers.*** Billboard advertisers are not familar with sharing advertising space; however, in every other mass advertising medium, advertisers are sharing "space" with other advertisers. Since digital billboards have the same flexibility and immediacy as these other mass advertising media, they should be thought of in the same way.

4. ***Determine a reasonable rate to charge for advertisements on your digital billboard.*** Because digital-billboard ads have more in common with timely, relevant media, such as television, radio, the Internet, and newspapers, than with vinyl billboards, they should be sold using the same measurement tools. This includes quoting a cost-per-thousand (CPM) impressions rate, a standard measurement used by print and broadcast media. This will assure that your billboards are priced competitively. Depending on traffic patterns, most digital billboards have a CPM of $2.00–$5.00.

5. ***Determine your potential ROI.*** Most billboard operators have locations they consider to be A+ locations. These locations typically command the highest rates and have advertiser waiting lists. Although these are prime spots for digital billboards, daily traffic counts as low as 15,000 can yield substantial profits. To determine your potential ROI, first determine how many daily impressions your billboard will generate, multiply by 28 days in each month, and then divide by the CPM factor of 1000. Finally, multiply by your CPM rate. This is what you can charge each advertiser every 28 days. Because each digital billboard can feature 6–8 advertisers at a time, it's easy to see how quickly revenues can add up.

6. ***Hire and train the right sales team.*** Just as digital billboards more closely resemble cable, TV, and radio than they do conventional vinyl boards, the best-suited sales force for this new medium may have a broadcast or print-media background or are at least be flexible enough to accommodate a new way of selling.
   Ensure that your sales associates:
   - Fully understand and communicate the benefits of dayparting;
   - Can manage the scheduling and trafficking of ads to ensure that dayparted messages are displayed at the right time;
   - Understand how to handle large detailed workloads that accompany a six-advertiser-or-more rotation; and
   - Leverage contacts in industries not currently represented in your customer list.

Additional details on all these topics plus more tips are available free in "7 Strategies to Simplify Digital Outdoor Sales and Increase Your Revenue" at http://www.watchfiredigitaloutdoor.com/strategies2.

***Darrin Friskney** is Director of Watchfire Digital Outdoor. He can be reached via e-mail at Darrin.Friskney@watchfiresigns.com or by calling 866/949-9282.*

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 Aris Silzars at 425/898-9117 or email: silzars@attglobal.net.

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