SID 2001 PREVIEW

Information DISPLAY

SID

April 2001
Vol. 17, No. 4

Official Monthly Publication of the Society for Information Display

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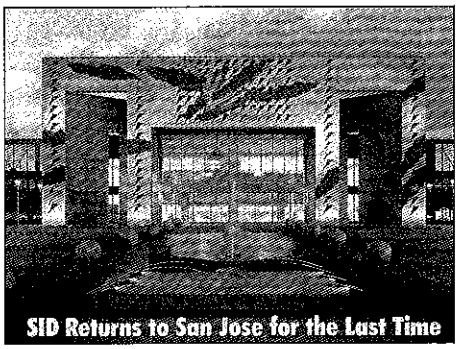
COVER: From June 3 to 8, the San Jose Convention Center will welcome the largest SID International Symposium and Exhibition ever held.



San Jose Convention and Cultural Facilities

For more on what's coming in *Information Display,* and for other news on information-display technology, check the SID Web site on the World Wide Web: **http://www.sid.org**.

Next Month in *Information Display*

SID 2001 Show Issue
- Products on Display
- Large Inexpensive Flat-Panel TVs
- Driving AMLCDs at High Speed
- Flexible Organic LEDs
- More-Efficient Notebook Backlights
- Color Conference Review

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Information DISPLAY

APRIL 2001
VOL. 17, NO. 4

editorial


Kahn International

There Are Rivers

My friend John Peter died last night, nearly a continent away. I know about it now because a friend of his, who does not know me, sent an e-mail to everyone in John's e-mail address book.

So now I'm thinking about death instead of deadlines, and the effects that individual lives can have on the world, and it seems to me that the display world has experienced the passing of some particularly notable people in the last couple of years: Sanai Mito and Kouichi Miyaji, two of the founders of the Society for Information Display (SID) Japan Chapter; Jim Hurd, founding CEO of Planar Systems; Chuji Suzuki, Executive Director of Interface Corp.; Harold A. Ketchum, founder of Thomas Electronics; color-TV innovator Sam Kaplan; and Ted Lucas, who, among his many activities in support of the founding and growth of SID, established the newsletter that grew into *Information Display* magazine.

When we are confronted over a short period of time by several deaths of people who inhabit our personal and professional worlds, it feels as though – and we often say it – an era is passing. It is not, of course. The near chaos that constitutes the life of men and women in the universe is a continuum without borders. But we have a marvelous ability to order the chaos with artificial boundaries that become real to us, and one class of boundaries are the imaginary lines that divide one era from another.

But we do more than simply divide the geography of experience into eras. We also say that the continuum of human experience is a river. But there is no single river. To what sea would such a river flow? Do all the currents of all our lives flow to the same place in neatly laminar fashion?

No. The flow of life and experience is turbulent, with conflicting directions. But we can see that individual human beings can give rise to currents, or redirect them, or collect them into larger and stronger currents. By ordering the near chaos of complex experience, men and women can and do give birth to rivers – not one river, but many, and unlike real rivers they cross each, sometimes many times, each finding its own direction.

Each of the people I've mentioned helped create orderly currents and rivers, large or small, that others could navigate. People now sail on those rivers, and go to places they could not go before.

My friend John Peter was not part of the display industry, so you probably don't know him. But he created a river. He made mistakes in his life and, with grace and great courage, transcended them. He was a committed, generous, and loving father. And he was a loyal friend who loved life and took great joy in it. That is a river worth navigating.

— KIW

We welcome your comments and suggestions. You can reach me by e-mail at kwerner@nutmegconsultants.com, by fax at 203/855-9769, or by phone at 203/853-7069. The contents of upcoming issues of *ID* are available on the *ID* page at the SID Web site (http:// www.sid.org).

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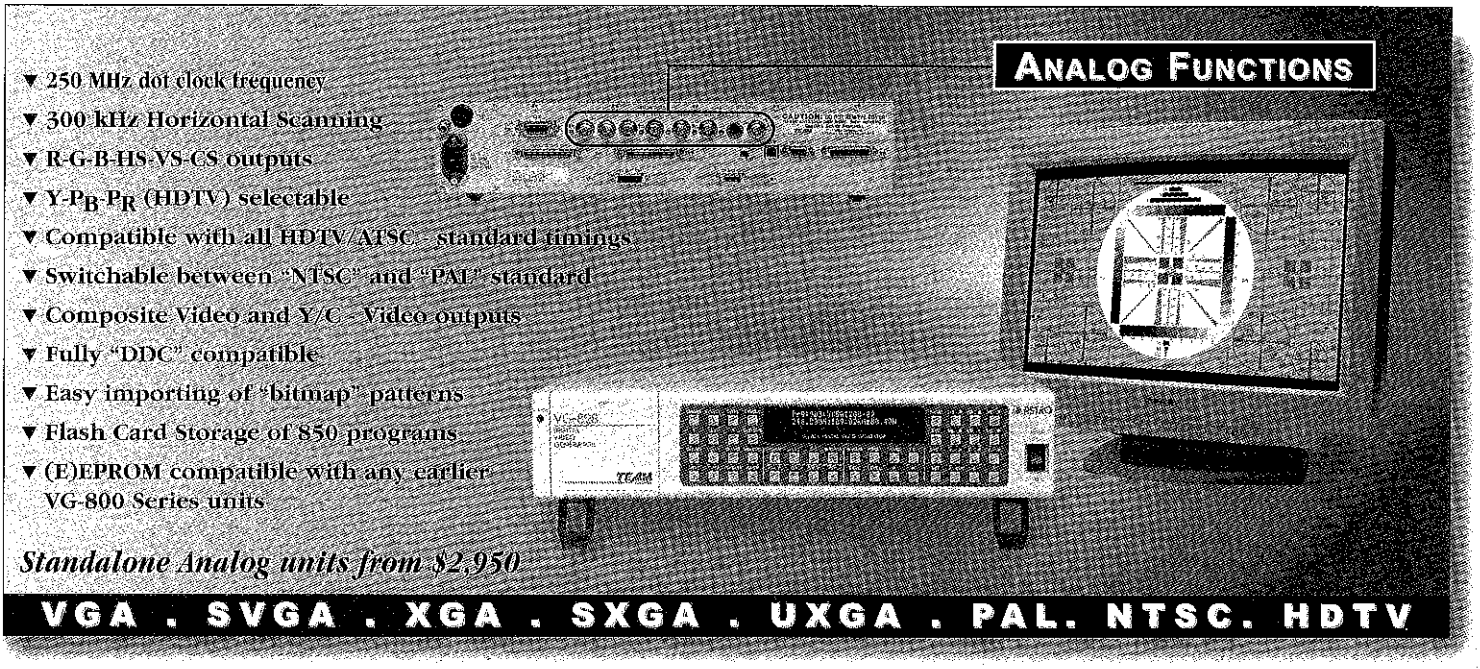

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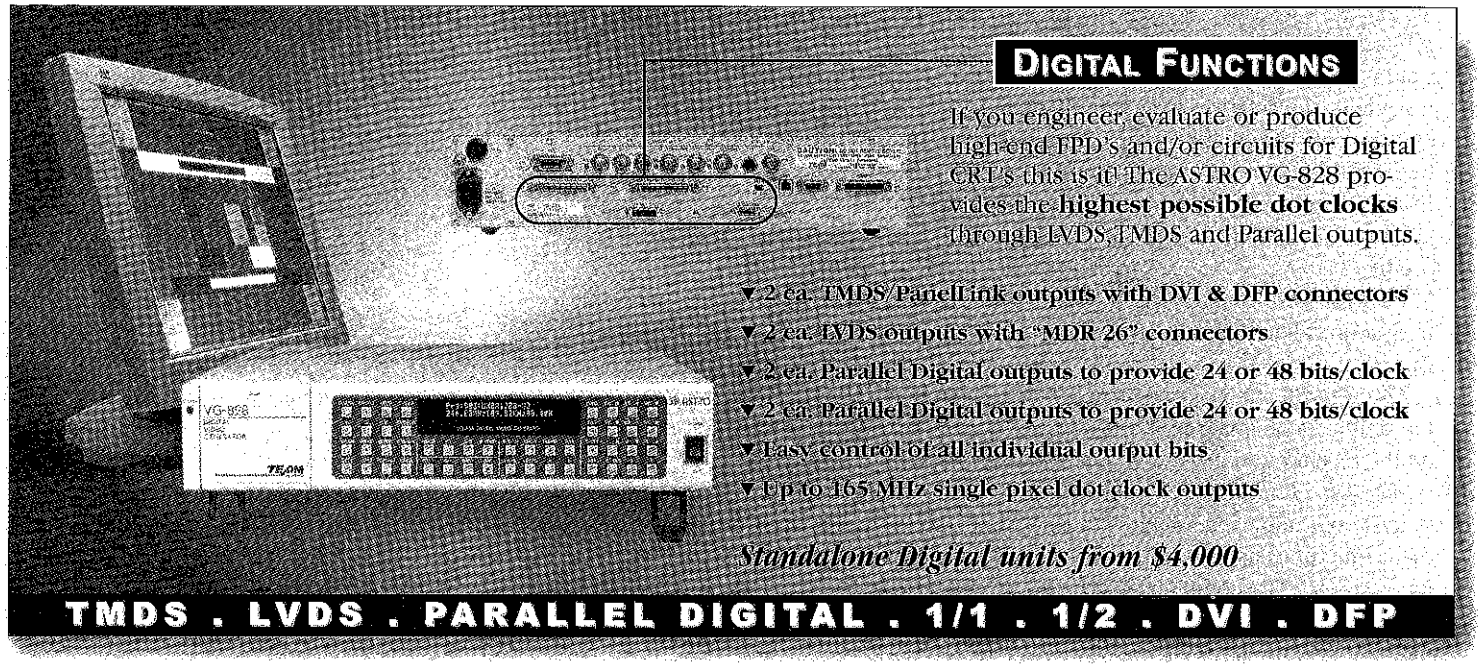

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a view from the hilltop

Wishful Thinking . . .

by Aris Silzars

Is there a point at which one can properly assert that unbridled optimism has crossed over into wishful thinking – or maybe even a denial of reality? I am beginning to feel that way about some of the next-step opportunities being proposed for the Internet and personal computers as control centers for our homes and for our lives. Here are the disconnects I am trying to reconcile.

Wishful Thinking #1. The Internet will become the means by which we do more and more of our computer-related work activities. Our files will be stored remotely, and we will access software from central sites as we need it for a small usage fee. Our computers will become more like communications appliances than today's self-contained processing and data-storage devices.

The Reality. In the last month, I have had to deal with at least a dozen virus-laden messages. Some I could recognize immediately as of suspicious origin. Several looked dubious, and I checked with the sender prior to opening them. Sure enough, in both of these cases, they were indeed carrying nasty viruses. Three other e-mails came from "trusted sources," and my virus-scanning software caught the creepy-crawlies before they could get through. Two of the three senders did not know that their computers were infected. Unfortunately, one evening, tired from a long trip home, I was looking through my latest e-mails and tried to open an attachment that came from a known source but didn't look quite right. Because of my travel schedule, I hadn't updated my virus-scanning program for about a week. I will skip the nasty details of what happened next. Let me just say that it was almost one week and $360 later before my computer was clean and safe to use again. There are still a few remnants of broken and missing software that keep my computer from running exactly as it did before – like a car that has been repaired after a significant collision. A recently published survey by ICSA states that in the last 12 months 80% of the respondents had experienced viruses/Trojans/Worms. Is that acceptable for a ubiquitous product?

Wishful Thinking #2. In the future, we will see more shopping and financial transactions handled over the Internet. Banking and bill paying will all be on-line.

The Reality. Our newspapers and television news almost daily report the latest attacks on commerce sites that end up with stolen credit-card numbers and on the recent rapid growth of a crime known as "identity theft."

Wishful Thinking #3. Soon the computer will become the central control point in our homes, helping us to control heating, lighting, appliances, entertainment functions, and security. We will all have keyless entry with biometric recognition. The computer will be the reliable device that helps us in our daily activities, such as ordering grocery items, reminding us to pick up the dry cleaning, and keeping track of where we need to be next.

The Reality. In my home/office, we have two relatively new computers. We also have two older models that run on Windows 3.1 and DOS. The older ones get fewer hours of use, but can you guess which ones are the most reliable? The new machines, using the most popular software, can be counted on to hang up at least once per day. Why can my computer exit my Internet hook-up three times

continued on page 44

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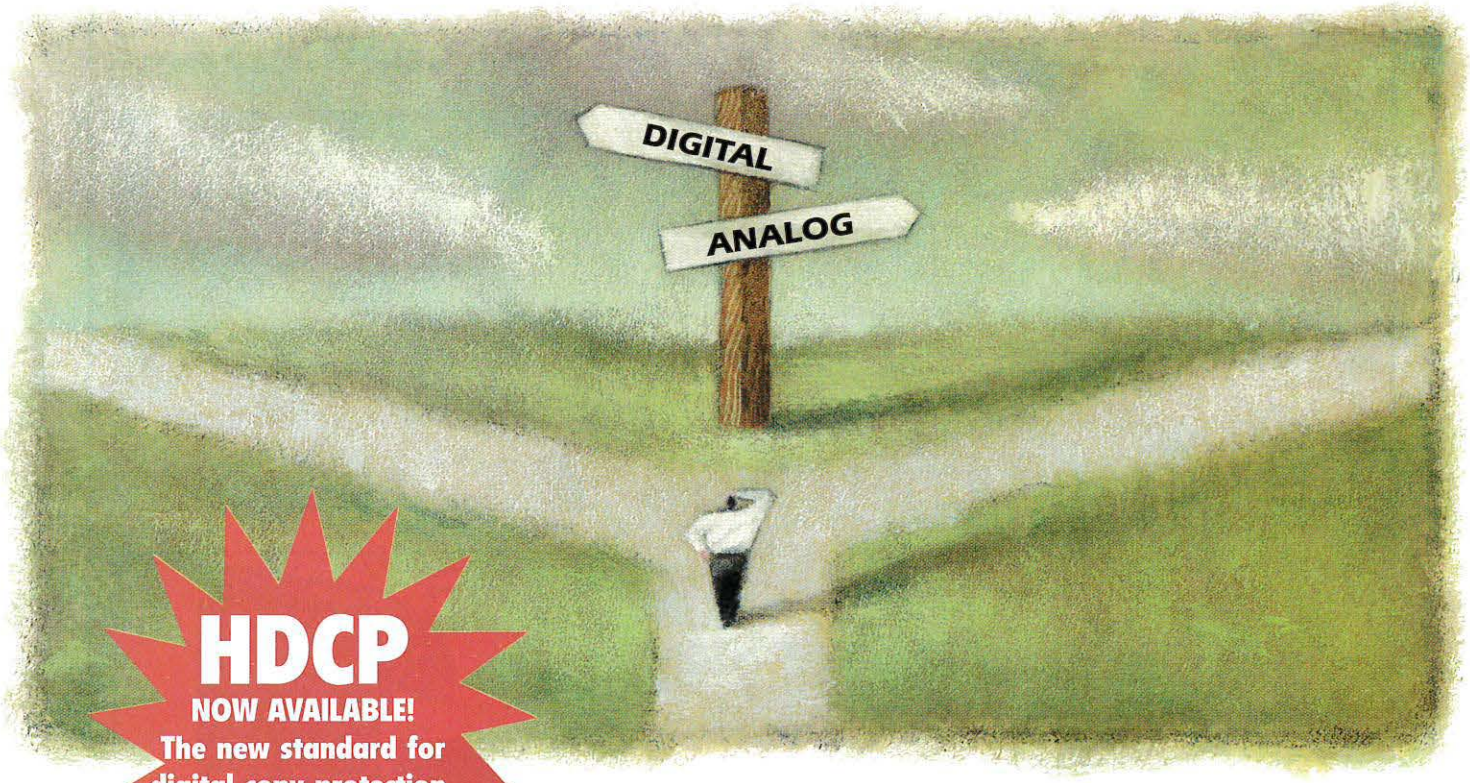

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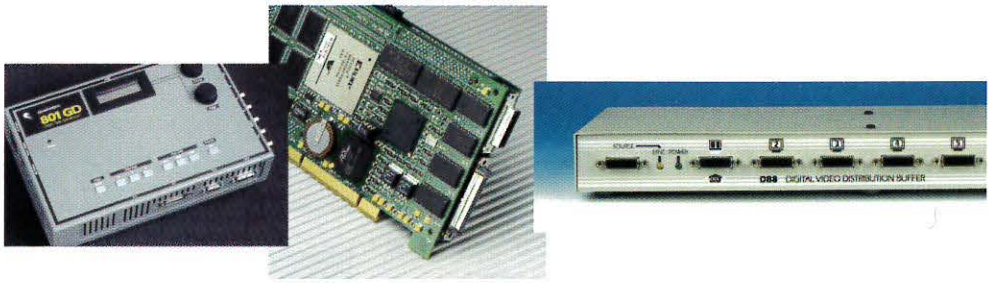

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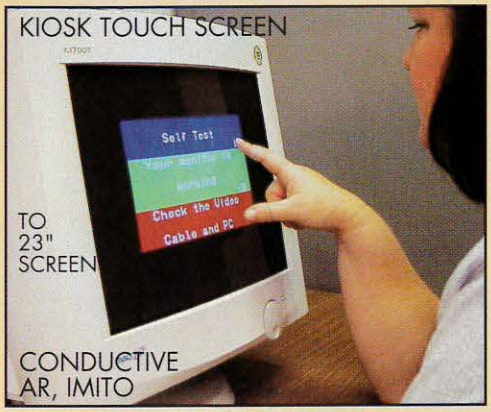

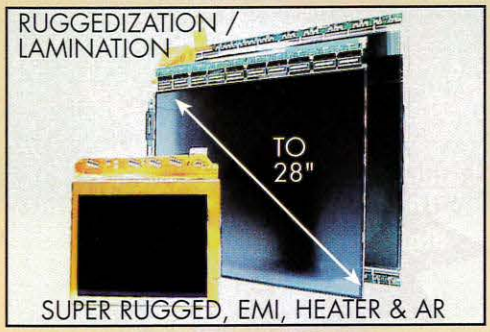

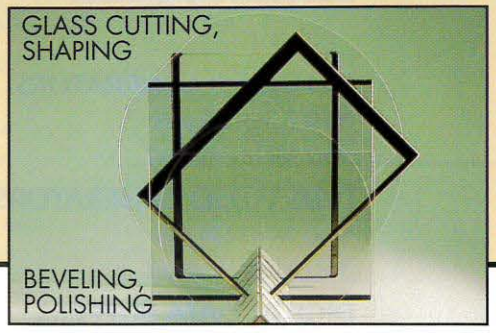

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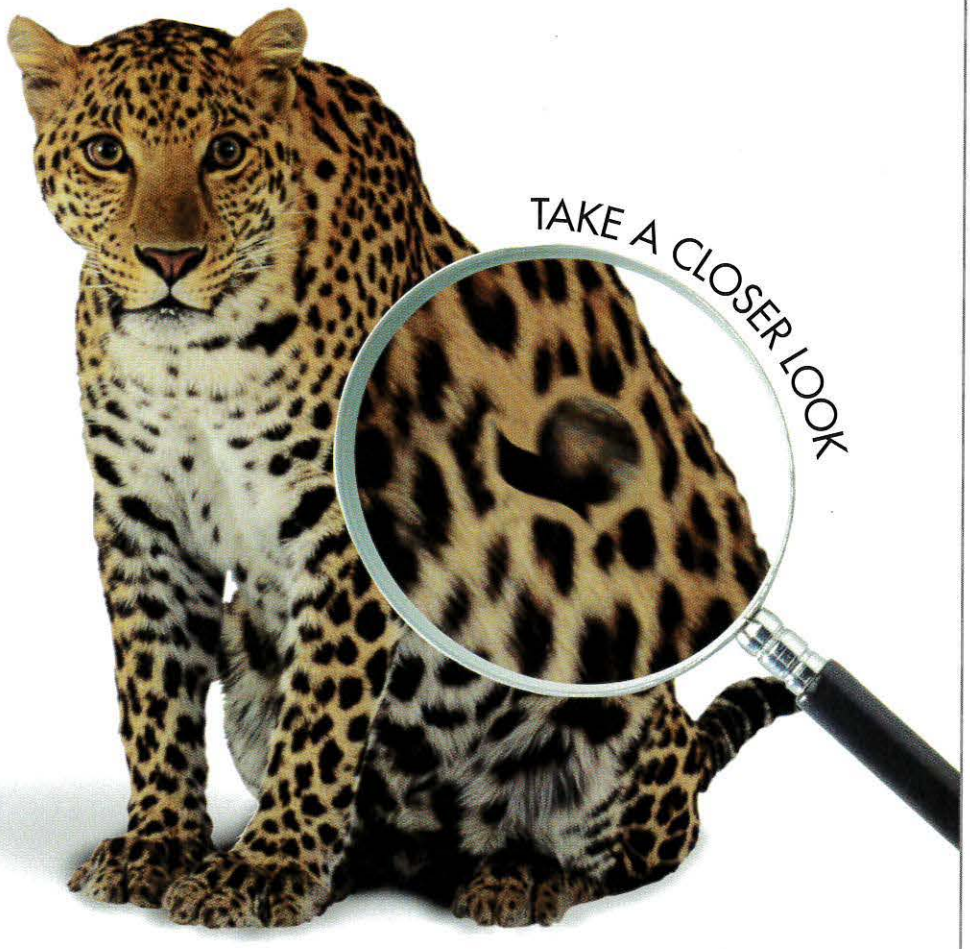

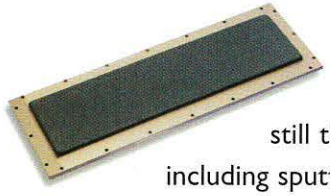

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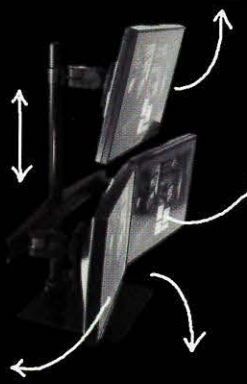

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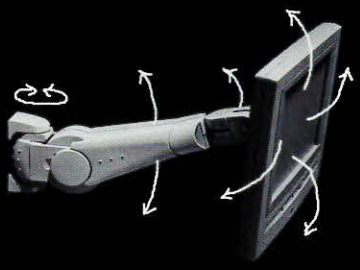
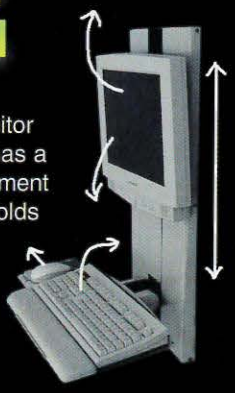


400 Series: Provides horizontal and vertical adjustment, full tilt/rotate capability.



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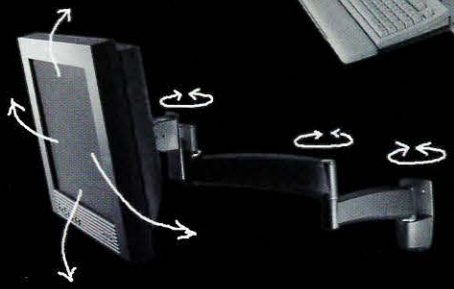

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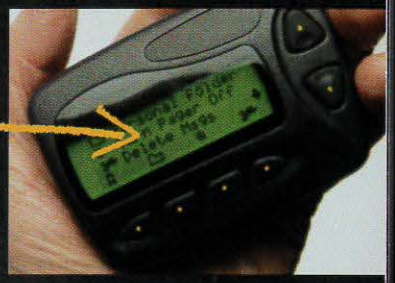

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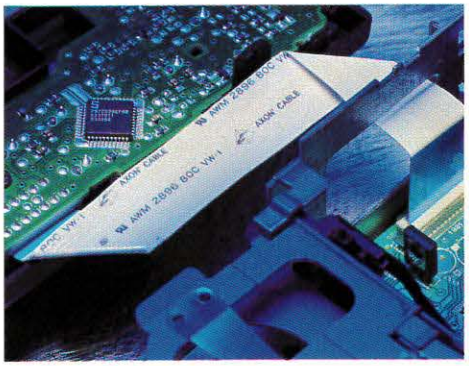

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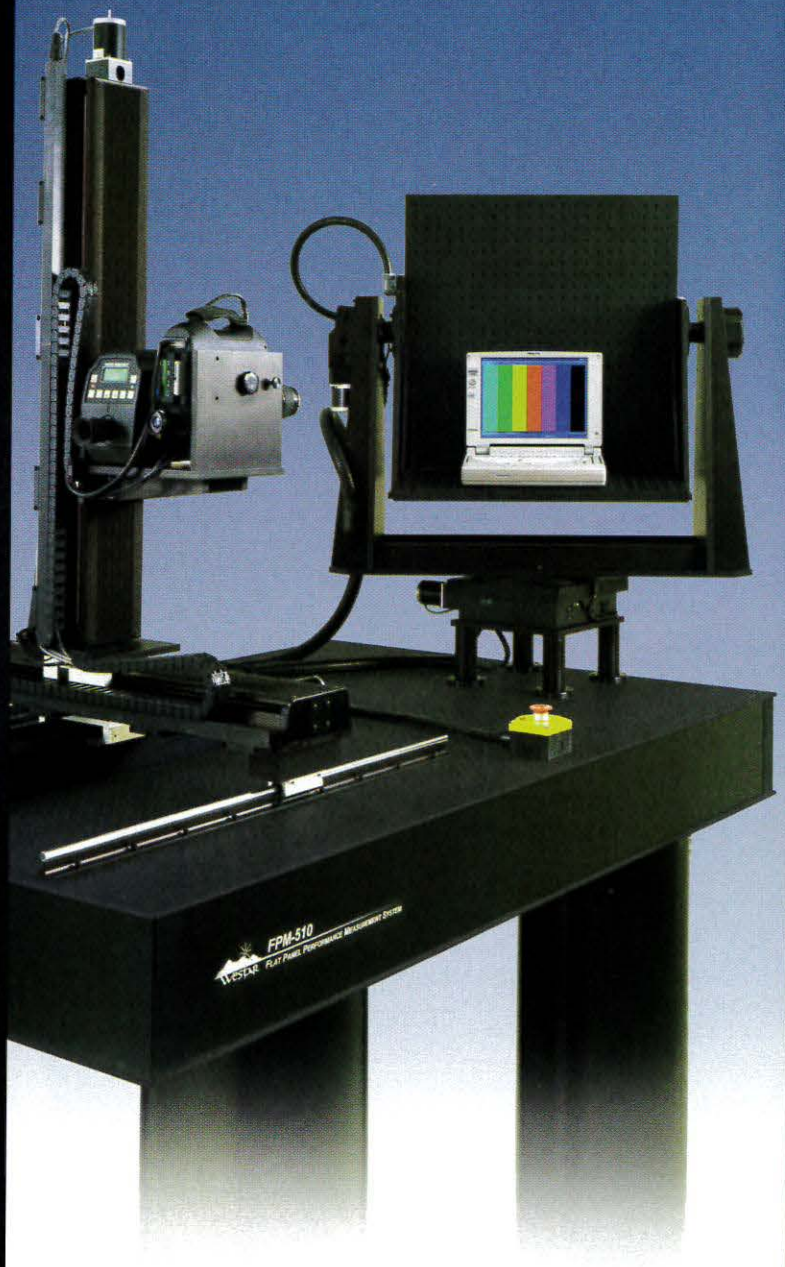

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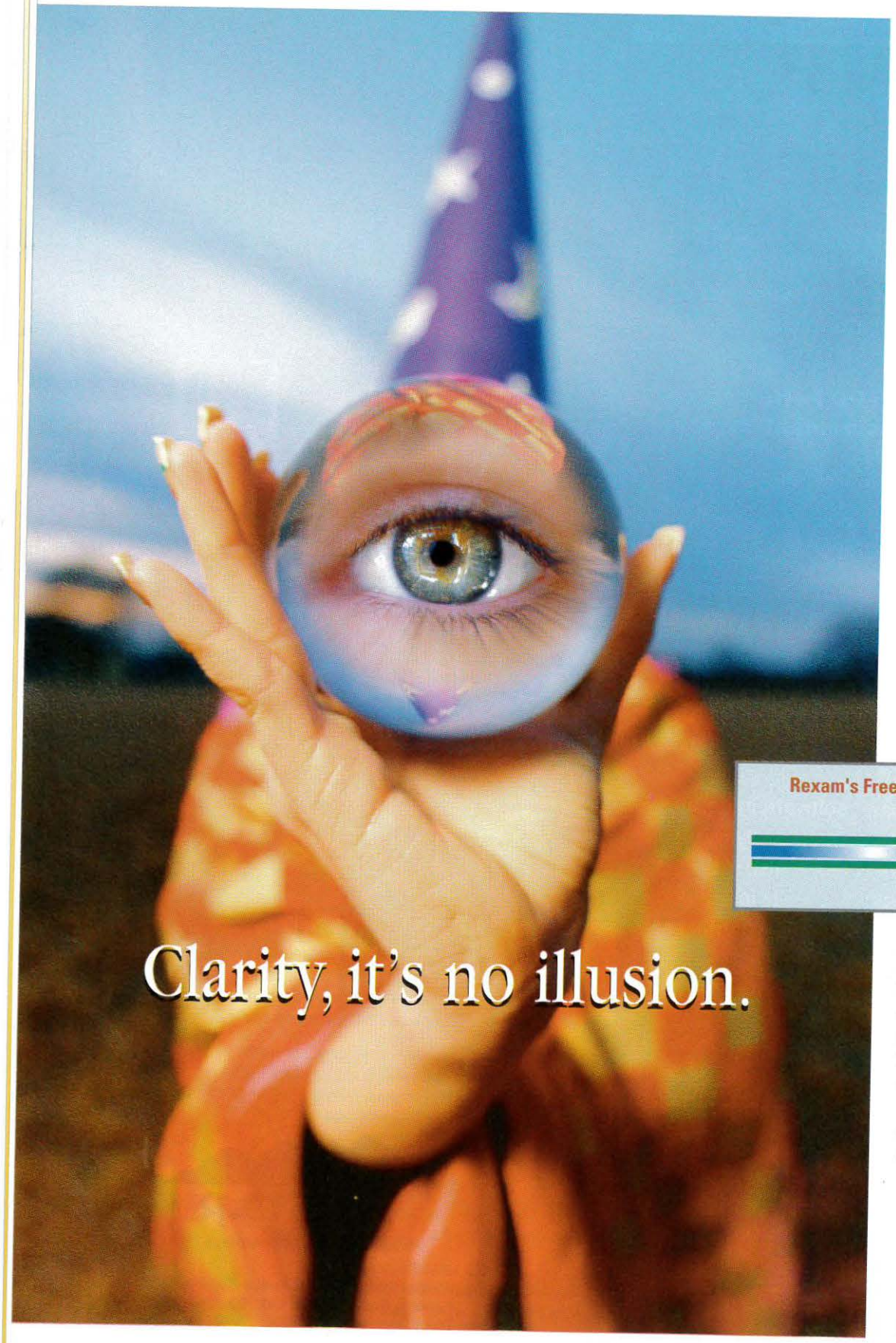

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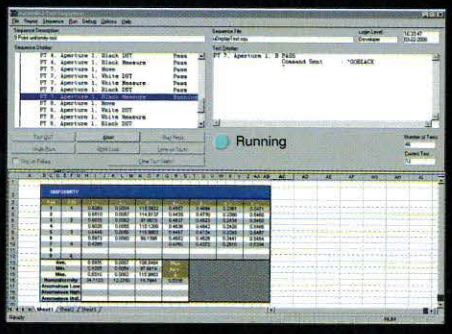

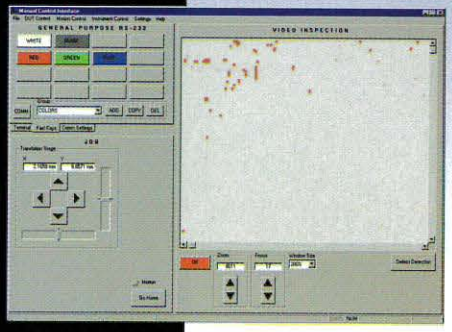

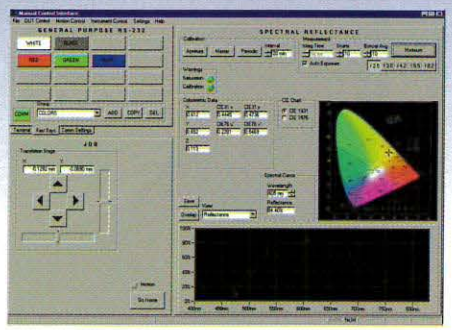

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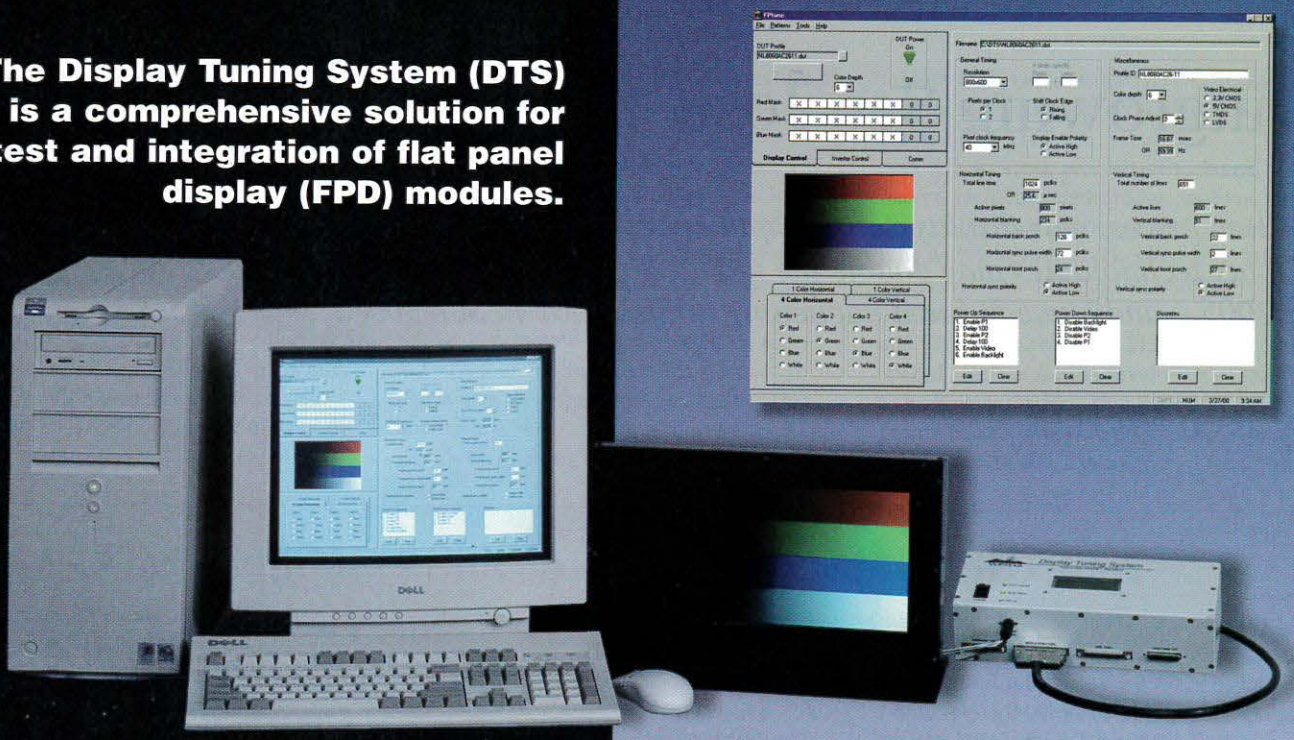

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Circle no. 15

Outgrowing San Jose

Falling prices, new display-centric appliances, and newly commercializable display technologies may double the global display market to $85 billion by 2005 – and one can see it happening at SID 2001 in San Jose.

by Ken Werner

SAN JOSE, California, is arguably the ideal location for the Society for Information Display's annual International Symposium, Seminar & Exhibition. So why is the upcoming 32nd edition of this path-breaking international display event the last that will be held in San Jose for at least the next ten years? Simple. The SID Symposium – particularly the trade-show portion – has gotten too big to fit into the San Jose Convention Center (SJCC). SID needs space to grow, and the SJCC cannot supply it.

With that said, SID 2001, to be held June 3–8 at the SJCC, is slated to break previous attendance and exhibitor records, and to provide a technical program consisting of more than 300 papers of unusually high quality – so the "last San Jose SID Symposium" should be one to remember. The headquarters hotel is the Fairmont Hotel, which is just two blocks from the convention center (see map).

The annual SID International Symposium has become the leading international forum for electronic-display technologies and products, as well as their underlying science. It is covered by technical and business journalists from around the world. Because of steady growth, this year's symposium will once again contain the largest exhibition of displays, display components, display-manufacturing equipment, display test and measurement equipment, display controllers and electronics, backlights, display products and materials, software, services, and publications ever held in North America. By late January, more than 250 exhibitors had already booked over 480 booths.

The Display Technology Showcase (DTS), a highly successful feature of the exhibition for several years, will be back with more displays, more categories, and a wider variety of signal sources. DTS provides cross-technology comparisons of displays of similar sizes intended for similar applications – operating from the same signal sources in a controlled environment.

This year's DTS will add "laboratories" to demonstrate and compare new display technologies, platforms, interfaces, and applications. As with all of DTS, the laboratories will be in a controlled non-commercial setting that provides an opportunity to learn through observation and discussion with our professional peers. The organizers are planning to include new plasma displays, LCoS rear projectors, small-format mobile displays, digital television, LCD TVs, and digital interfaces, along with other categories.

John Robinson for SID

Last year's SID Exhibition was lively. This year's is expected to be even larger.

Ken Werner is the editor of Information Display.

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"Each year we improve the DTS infrastructure to provide high-quality analog and digital video signals in a wider range of formats over a wider range of interfaces to provide attendees with a richer experience," said Jack Gershfeld, Chairman of Altinex, Inc., and DTS Technical Director. "This year, the highest screen resolution is going up to 2560 × 2048. We will supply whatever digital TV formats participants require, and we will try to add a couple of bells and whistles to the information and control side of things," he said.

This year, instead of being held in its traditional tent near the show floor, DTS will be held in a dedicated light-controlled section of the SJCC's concourse level adjacent to the SID registration area.

Display Week will kick off with four 4-hour short courses on Sunday, June 3rd, and four tracks of 90-minute seminars on Monday, June 4th. There will also be three morning tracks of 90-minute seminars on Friday, June 8th. The seminar program was reinvigorated last year, with new seminar tracks on emerging technologies, resulting in a substantial increase in the number of registrants. That approach is being continued and enhanced this year, with sessions on LCoS technology, digital-interface standards for HDTV, digital interfaces for displays, and reflective LCDs, just to name a few.

A rich six-track program of technical papers, including applications sessions, vendor exhibits, and a series of applications tutorials will be held from Tuesday, June 5th, to Thursday, June 7th. The tutorials include presentations on displays for hand-held products and FPD measurements. There will be two special sessions for the developers of technologies and products that have won SID/*Information Display* Display of the Year awards for the last 2 years.

The "Capital of Silicon Valley" Welcomes SID 2001

San Jose's most famous attraction is San Francisco, the unique and marvelous city 50 miles to the north. But San Jose and the surrounding area offer remarkable riches of their own, not the least of which are the companies and people of Silicon Valley, northern California's remarkable engine for technical innovation and the generation of wealth.

San Jose's McEnery Convention Center (SJCC) is located in downtown San Jose within easy walking distance of the elegant Fairmont Hotel (the headquarters hotel) – one of the few places in San Jose where Californians dress more formally than we do. Just across Market Street from the SJCC is the lovely Hyatt Sainte Claire Hotel. This National Historic Landmark has the smallish rooms typical of the 1920s, when it was built, but they were lovingly renovated in 1992, and the St. Claire's main public room is a 1920s masterpiece.

The Crowne Plaza Hotel is across San Carlos Street from the SJCC, and the San Jose Hilton and Towers is physically connected to the convention center. There are two other downtown hotels, and half a dozen hotels clustered near the San Jose airport, which is only 3 miles away. These include the Wyndham, Airport International Inn, Radisson, Hyatt San Jose, Doubletree, and Hanford. A hotel reservation form appears elsewhere in this issue and on the SID Web site. We encourage you to make hotel reservations as early as possible. Although there are a large number of hotels in San Jose, the high level of commercial activity and the many conferences and social events held in the area often mean that hotel rooms are in short supply.

Among the area's technical and non-technical attractions are the Intel Museum in the Robert Noyce Building at Intel's headquarters in neighboring Santa Clara (408/765-0503), and the Tech Museum of Innovation, which is about halfway between the SJCC and the Fairmont Hotel (408/294-TECH, www.thetech.org).

The San Jose Museum of Art, also just a few steps from the Fairmont, shows works from the permanent collection of New York's Whitney Museum and a wide range of changing exhibitions emphasizing 20th-century art. The Peralta Adobe, built in 1797, is San Jose's oldest building, and is open as a museum.

The Rosicrucian Egyptian Museum contains over 5000 Egyptian artifacts, including mummies and a replica rock tomb. It is the largest Egyptian collection on the West Coast. The Winchester Mystery House is an elaborate 160-room Victorian house built by an eccentric heiress to the Winchester firearms fortune, which has many irrational architectural details, such as stairs that lead nowhere and doors that open onto walls (408/247-2000, www.winchestermysteryhouse.com). The famous Lick Observatory, 25 miles south of San Jose atop Mount Hamilton, has a 120-in. reflecting telescope and a 36-in. refractor for the use of visitors (408/274-5061).

Japantown in San Jose is the site of a Buddhist church, the Japanese-American Historical Museum, a Sunday morning farmer's market, and a variety of shops. San Jose and Okayama, Japan, are "sister cities," and the Japanese Friendship Gardens in Kelley Park (408/277-5254) are patterned after Okayama's Korakuen Park. The San Jose Historical Museum (408/287-2290) is also located in Kelley Park.

One of the famous California missions, Mission Santa Clara de Asis, founded in 1777, is located on the campus of the University of Santa Clara. Its lush gardens contain some of the oldest cultivated plants in California, including an original Castillian rose bush and the oldest grapevine in northern California. Speaking of grapevines, although the wineries of Napa and Sonoma counties north of San Francisco are generally more famous, there are some excellent wineries in the Santa Clara Valley, including Mirassou and J. Lohr. Check with the Santa Clara Valley Wine Growers Association (www.scvwga.com) for directions and visiting (and tasting) hours.

In addition to tourist attractions, various opportunities for entertainment will be available about the time of SID 2001. *Cyrano*, a play adapted by Frank Langella from Edmond Rostand's classic *Cyrano de Bergerac*, will run at The San Jose Repertory Theatre every day from June 2–10 (info@sjrep.com, 408/367-7255). For more events, check www.sanjose.org starting in mid-April, or ask for a San Jose calendar of events when checking into the hotel.

Keynotes

The Tuesday morning Plenary Session will feature keynote presentations by Claude M. Leglise, Vice President of Intel's New Business Group and General Manager of the Home Products Group; and Dr. Yoshito Tsunoda, Executive Vice President of Fujitsu Hitachi Plasma (FHP) Display, Ltd.

Leglise, who was born in Paris and received his M.S.E.E. degree from ENSAM in Paris before receiving his M.B.A. from Stanford University, will speak on new opportunities for displays in the home.

Tsunoda received his M.S. degree at the University of Tokyo, and began his career in Hitachi's Central Research Laboratory. He is now in charge of Sales & Strategy for Fujitsu Hitachi's PDP (FHP) business. Tsunoda's address is entitled "ALIS PDP – Key Device for a Digital Wonderland in the 21st Century." The plasma-display panel, says Tsunoda, is a key device for the coming network-based digital-imaging society, and digital HDTV is one of the most promising products using PDPs. FHP, which was established last July, has been concentrating on creating the new digital-PDP HDTV market. FHP invented and developed the ALIS PDP, a breakthrough technology for realizing inexpensive high-quality digital HDTV for the 21st century. FHP is now planning to release three ALIS PDPs (42-, 37-, and 32-in. models) in 2001 for digital-HDTV use. In his talk, Tsunoda will describe FHP's business strategy, the details of ALIS technology, the product concept of relatively small-screen digital HDTV receivers using ALIS PDPs, FHP's new mass-production facility, and FHP's view of the network-based digital-imaging society that is in our immediate future.

Intel

Claude Leglise, Intel V.P. and General Manager of the Home Products Group, will give a keynote address on new opportunities for displays in the home.

Getting to San Jose

San Jose is served by San Francisco International Airport (SFO) for international and North American flights and by San Jose Airport (SJC) for regional (and some North American) flights. Those of you who have taken Southwest Airlines to SFO in the past should be warned that Southwest discontinued its service to SFO in early March, but will be serving Oakland and San Jose. Better check with your friendly travel agent.

Depending on traffic, it takes between 45 and 90 minutes to drive from SFO to downtown San Jose, and about 10 minutes to do so from SJC. Rental cars are readily available, but perhaps the most convenient and economical means of transportation from SFO is the South Bay Flyer shuttle bus, http://www.landyacht.com/html/route1.html, telephone 888/463-5937, toll free; reservations are not required. The South Bay Flyer can be boarded in front of SFO's new Courtyard "A" at approximately 15 minutes before the hour. Other boarding points are at domestic terminals in front of all blue pillars on the center island outside the baggage claim area on the *lower level* at approximately 10 minutes before the hour. But the shuttle does not run every hour, so check the schedule on the Web site or by calling the toll-free number. The fare is $20.00, which must be paid in cash, by travelers check, or South Bay Flyer flight coupons issued by United Airlines.

For $36 for one person, and $10 for each additional person going to the same address (cash only), shuttle service to downtown San Jose is available from the South & East Bay Airport Shuttle (telephone 800/548-4664) 24 hours a day, 7 days a week. The shuttle provides door-to-door service for every passenger, so you may find yourself making interesting detours into residential neighborhoods in Palo Alto and Sunnyvale. Pick-up is from the center island on the departure or upper level outside the airline ticket counters at all terminals, but the company prefers that you first call the 800 number when you arrive at SFO.

For those flying directly into San Jose Airport, there are many downtown hotels that provide complimentary shuttle service. Ask where to find the courtesy phones (from some arrival gates it is very easy to miss them). A taxi costs about $10–12 to the downtown hotels.

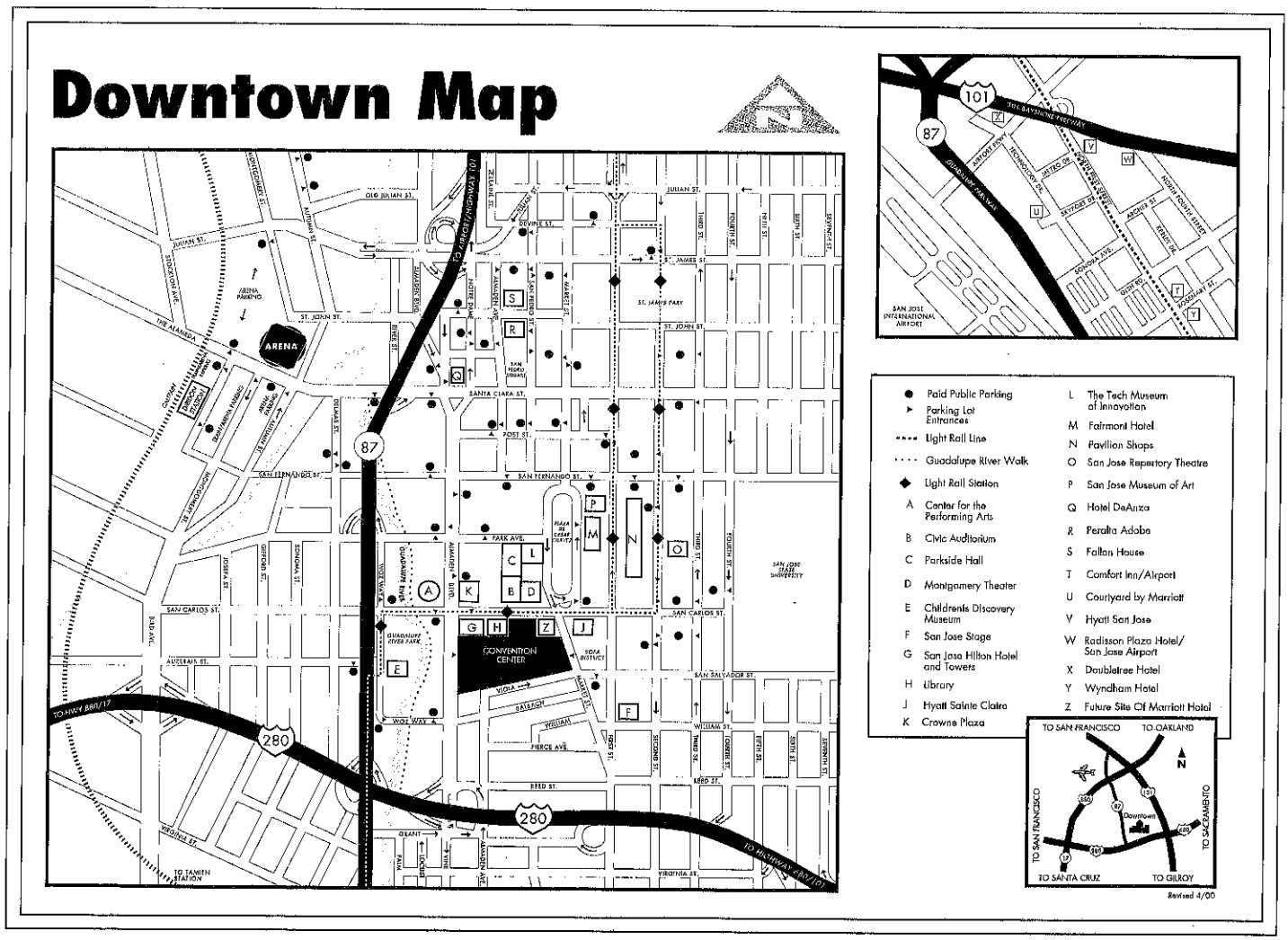
Technical Program

The technical sessions will be anchored with 39 invited papers. Among them are

- *PhotonLink™: An Optical Interface for Remote Digital Displays* (Yung Sung Son *et al.*, PhotonAge, Inc.)
- *New Emitter Techniques for Field-Emitter Displays* (Jong Min Kim *et al.*, Samsung Advanced Institute of Technology)
- *Xe-Discharge Backlights for LCDs* (Shigeo Mikoshiba, The University of Electro-Communications, Tokyo)
- *Scrolling Color LCoS for HDTV Rear Projection* (Jeffrey A. Shimizu, Philips Research Laboratories)
- *Low-Cost Flexible AMLCDs* (Roger Stewart, Alien Technology)
- *Organic Light-Emitting Device (OLED) Technology for Vehicular Applications* (Janice Mahon, Universal Display Corp.).

Among the many peer-reviewed contributed papers are

- *Multi-Format Digital Display with Content-Driven Display Format* (Graham Cairns *et al.*, Sharp Corp.)
- *Transposed Scanning: An Enabler for Super-Slim CRTs* (M. P. C. M. Krijn *et al.*, Philips Research Laboratories)
- *Development of a High-Definition 32-in. PDP* (T. Kosaka *et al.*, Fujitsu Hitachi Plasma Display)



San Jose Convention and Cultural Facilities

San Jose's compact downtown area places the Convention Center, downtown hotels, cultural and entertainment facilities, good restaurants, and interesting architecture within convenient walking distance.

- *A 12.1-in. SVGA Microencapsulated Electrophoretic Active-Matrix Display for Information Appliances* (P. Kazlas *et al.*, E-Ink Corp. and IBM T. J. Watson Research Center).

Special Events

The President's Reception and the Awards Banquet will be held Monday evening, June 4th. (Tickets for the Awards Banquet must be purchased in advance.) The formal opening of SID 2001 will be on Tuesday morning. The exhibitor reception, formerly held in the exhibit hall on Tuesday evening, has been eliminated this year in order to make more room for company-sponsored off-site events and the evening panels. The topics for the evening panels are "What Must the U.S. Government Do to Assure the Military's Flat-Panel-Display Needs?" (which will start with the recognition that the old approach of basing supply on a U.S. manufacturing base did not work), and "Very-Low-Cost Flat Panels: Paths, Shortcuts, and Dead Ends."

At the gala Wednesday luncheon, the annual SID/*Information Display* Display of the Year Awards will be presented. The luncheon speaker, Dr. Christopher W. Tyler, Associate Director of the Smith-Kettlewell Eye Research Institute in San Francisco, California, will speak on "The Historical Development of Perspective Display in Art." This year's special event, "Casino Night at the Banker's Club," will be held on Wednesday evening, June 6th. ■

FPD Technology in Korea

Korea now leads the world in TFT-LCD manufacturing, and is investing aggressively in a variety of FPD technologies.

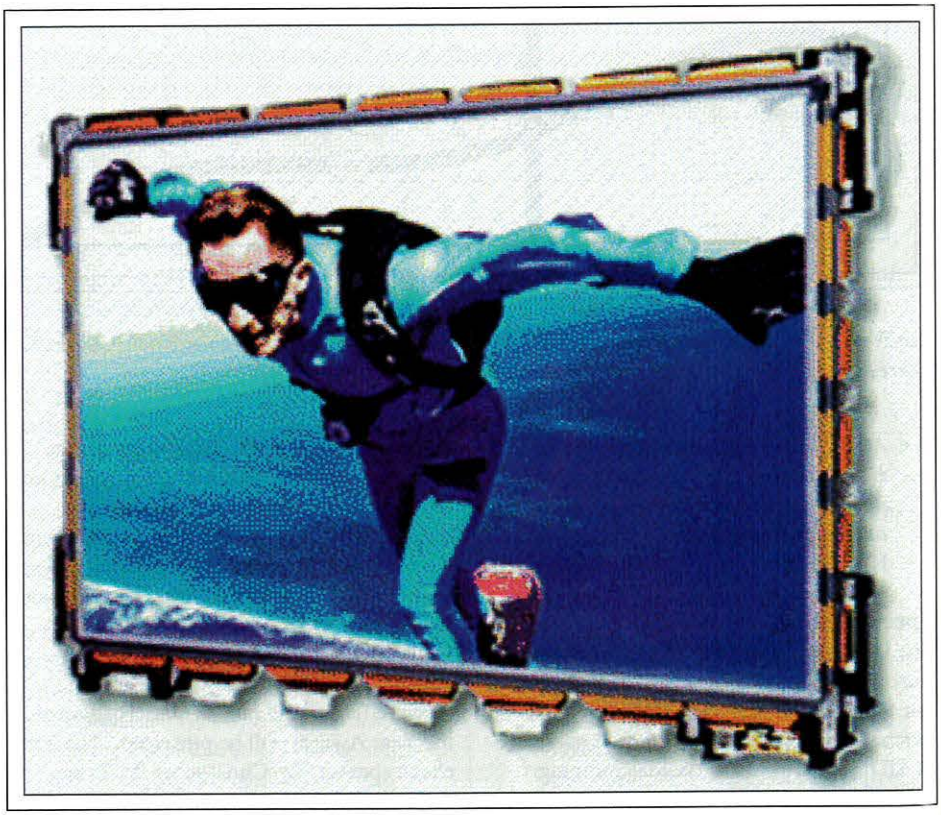
by Myunghwan Oh

THE KOREAN DISPLAY INDUSTRY, led by Samsung and the LG Group, are investing more than 2 billion U.S. dollars in the development and production of large, bright, high-definition liquid-crystal displays (LCDs) and plasma-display panels (PDPs) using new fifth-generation substrate glass.

Recent developments have been significant and wide-ranging. Samsung Electronics has developed a 24-in. WUXGA TFT-LCD panel for engineering workstations and desktop monitors, while LG.Philips LCD has produced a 20-in. fast-response TFT-LCD television having a wider-than-expected viewing angle. Hyundai Electronics, in spite of financing problems resulting from the dissolution of the Hyundai Group, has made a 21-in. UXGA TFT-LCD panel on its 550 × 650-mm manufacturing line. In addition, Hyundai successfully applied its new Fringing Field Switch (FFS™) technology to the company's LCD video-monitor panels, resulting in monitors that have a wider viewing angle than conventional models.

Samsung and the LG Group agreed to adopt a common 1200 × 1000-mm glass size for fifth-generation TFT-LCDs. They are also considering the possibility of using many common components and materials, for which they would share specifications.

The Korean PDP industry is in an early stage, but PDPs have already been developed for both desktop monitors and television (Fig. 1). Samsung, LG Electronics (not to be confused with LG.Philips LCD), Orion Electric, and UPD Corp. (descended from Hyundai) are competing to manufacture wide-format bright PDPs having higher definition (2 Mpixels in a 60-in. WXGA display) and higher luminance efficiency (greater than 2.5 lm/W) with longer lifetime (greater than 20,000 hours).



Samsung SDI

Fig. 1: *Samsung SDI's 37-in. PDP module is one of a wide range of plasma displays which the Korean display industry is preparing for large-scale production.*

Myunghwan Oh *is a Research Fellow in the New Frontier Research Program at the Korean Institute of Science and Technology (KIST), and is the National Project Manager for developing flat-panel-display technologies at the Electronic Display Industrial Research Association of Korea (EDIRAK); telephone +82-2958-5761; fax +82-2958-6909; e-mail: mho@kist.re.kr.*

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But the ability of Orion Electric and UPD Corp. to compete toe-to-toe with Samsung and LG in R&D and manufacturing has been compromised by financing problems arising from the restructuring and dissolution of their management groups. Talented scientists and engineers are essential, but there is still no substitute for ample resources. LG Electronics has used its resources, for instance, to develop its original selective-erase technology for fast driving of large PDPs.

Significant problems remain, such as high power consumption (several hundred watts for a 50-in. PDP) and elevated manufacturing cost (more than US$150/in.). The solutions will depend on developments in materials, components, and manufacturing equipment.

The organic-light-emitting-diode (OLED) and field-emitter-display (FED) industries are very young in Korea. Not long ago, developers of these technologies dreamed only of a niche market for small displays with fast-moving images. But IMT-2000 – the Korean national project on mobile telephone and PDAs initiated in 2000 – changed that, and made OLEDs exciting and attractive to all display manufacturers in Korea.

The market size for OLEDs is estimated to be US$3.5 billion by 2005. This has motivated several component makers, as well as Samsung and LG, to seek R&D partners for the mass production of full-color and/or multicolor OLEDs suitable for dynamic-motion displays with 4–5-in. diagonals. LG Electronics has already developed and fabricated a 2-in. full-color prototype OLED for mobile telephones.

In the FED area, Orion Electric developed a 3.5-in. full-color low-voltage display for mini-TV applications in 1999. Samsung developed a 5-in. full-color FED in 1998 and a 9-in. carbon-nanotube (CNT) FED in 1999. Fundamental research on strip cathodes and DLC-coated Spindt-type emitters, as well as on low-voltage phosphors, continues in academic institutions.

Seeing into the Future

Samsung Electronics plans to develop a 30-in. LCD TV if the projected market size looks large enough. Engineers at the Samsung Group are developing a new reflective 30-in. TFT-LCD for workstations and low-temperature-polysilicon (LTPS) TFT-LCDs for fast-moving-image displays. LG.Philips LCD will soon produce some 20-in. LCD TVs for multimedia applications, as well as large monitors (over 18 in.) and poly-Si TFT-LCDs for IMT-2000 PDA and camcorder displays. Hyundai Electronics plans to manufacture large-area (over 21 in.) UXGA TFT-LCDs and to develop small- and medium-sized TFT-LCDs for automotive-navigation systems and audio-visual system applications.

Throughout 2000, Korean manufacturers invested aggressively and labored energetically to develop the technology for digital TV and HDTV.

The technology of Korean PDP manufacturers is still 2–3 years behind Japan's. To increase throughput and lower the cost of production, Korean manufacturers will probably have to develop advanced processing technology and manufacturing equipment. LG is establishing a PDP production line for 40- and 60-in. panels now, and intends to expand production capacity to 900,000 units per year by 2005. This year, Samsung will establish PDP production lines with a capacity of 300,000 units per year, and expand production capacity to 1.56 million units per year by 2005.

Samsung Electronics and LG.Philips LCD will continue to develop manufacturing technology for the mass production of WUXGA TFT-LCDs and high-definition PDPs. Their intention is to increase the yield and through-

Table 1. Korean Investment in LCDs

Company	Line Type	Factory Site	Glass Size (mm)	Production In	Throughput (10,000 sheets/month)
Samsung Electronics	2	Kihung	370 × 470	Feb '95	4
	3	Kihung	550 × 650	Oct '96	3.5
	3.5	Cheonan	600 × 720	Feb '98	4.5
	4	Cheonan	730 × 920	Oct '00	3
LG. Philips LCD	2	Kumi	370 × 470	Aug '98	6.6
	3.5	Kumi	590 × 670	Nov '97	6.6
	3.5	Kumi	680 × 880	Dec '00	6
Hyundai Electronics	2	Ichon	370 × 470	1996	2
	3	Ichon	550 × 650	Q4 '97	0.9
	3.5	Ichon	620 × 720	Q2 '00	4

Table 2. Korean Investment in PDPs

Company	Status	Production Capability (1000 pieces/month)	Product	Investment (US$M)	Fab Location
Samsung SD I	R&D	1	42 in. wide	20	Cheonan
Orion Electric	R&D	3	42 in. wide	51	Kumi
LG Electronics	R&D	0.3	40 in. (4:3)	18	Kumi
UPD Corp.	R&D	0.3	42 in. wide	21	Ichon

Table 3. Projected PDP World Market (Estimated Word Market)

(units: 1000 panels)

Year	2000	2001	2002	2003	2004	2005
Units	3,050	6,100	10,100	15,900	24,300	31,000

Source: NRI

put of panel production through improvements in outgassing and glass work processes. The Korean FPD industry in general is intent on developing original technologies with core competencies in areas such as industrial properties. The focus is on low-cost processes for the manufacture of high-quality products.

In statements over the last few years, industry executives have repeatedly stressed their belief that mutual cooperation among LCD manufacturers around the world is necessary to standardize FPD products. Of particular interest is the standardization of technical specifications of FPD components, materials, and production equipment. ■

SID '01

Symposium, Seminar, and Exhibition

San Jose, California

San Jose Convention Center

June 3–8, 2001

Poly-Si TFTs for Plastic Substrates

Poly-Si is likely to be the first TFT technology applied to high-resolution displays on plastic substrates, and there is now a process that permits high-quality TFT fabrication on plastic.

by Tsu-Jae King

ELECTRONIC DEVICES are becoming more pervasive in our personal and professional lives. This has driven research into flat-panel displays (FPDs) that consume less power, weigh less, are more rugged, and cost less than previous designs. Liquid-crystal displays (LCDs) – both transmissive and reflective – remain the dominant technology, but future low-cost approaches such as organic light-emitting diodes (OLEDs) have the potential to become important.

All these displays still require active-matrix thin-film-transistor (TFT) addressing to achieve good contrast and reliability. If these displays can be produced on flexible substrates with integrated display-driver circuitry, we will be able to have more robust displays – desirable for portable electronic devices such as cellular telephones and personal digital assistants – which can be rolled up or folded.

Active-Matrix Design

Active-matrix LCDs (AMLCDs) employ one or more TFTs in each picture element, or pixel, to display an image. A TFT functions as an electronic switch that electrically isolates the pixel when it is not being addressed so that the charge stored on the pixel electrode (and consequently the voltage applied to the LC) can be maintained over one time frame.

Tsu-Jae King *is an Associate Professor in the Department of Electrical Engineering and Computer Sciences and Director of the Micro-Fabrication Laboratory at the University of California at Berkeley, Berkeley, CA 94720; telephone 510/643-2739, fax 510/642-2739, e-mail: tking@eecs.berkeley.edu.*

All of the pixel transistors together form the "active matrix" integrated circuit, which is used to address the display by sequentially turning on one row of pixel TFTs at a time (Fig. 1).

When turned on, a pixel TFT must have a sufficiently high drive current to fully charge the pixel capacitance and consequently cause the voltage on the pixel electrode to be equal to the voltage on the data line to which it is connected. This must happen within one line time – the period over which a single scan line is driven.

The required TFT drive current is typically about 1 μA. Ideally, this drive current should be achievable with a gate-to-source voltage (V_{GS}) of less than 25 V to avoid the need for expensive high-voltage display-driver IC chips. A pixel TFT must have a sufficiently low leakage current when it is turned off so that enough charge does not leak off the pixel electrode to change the voltage by more than

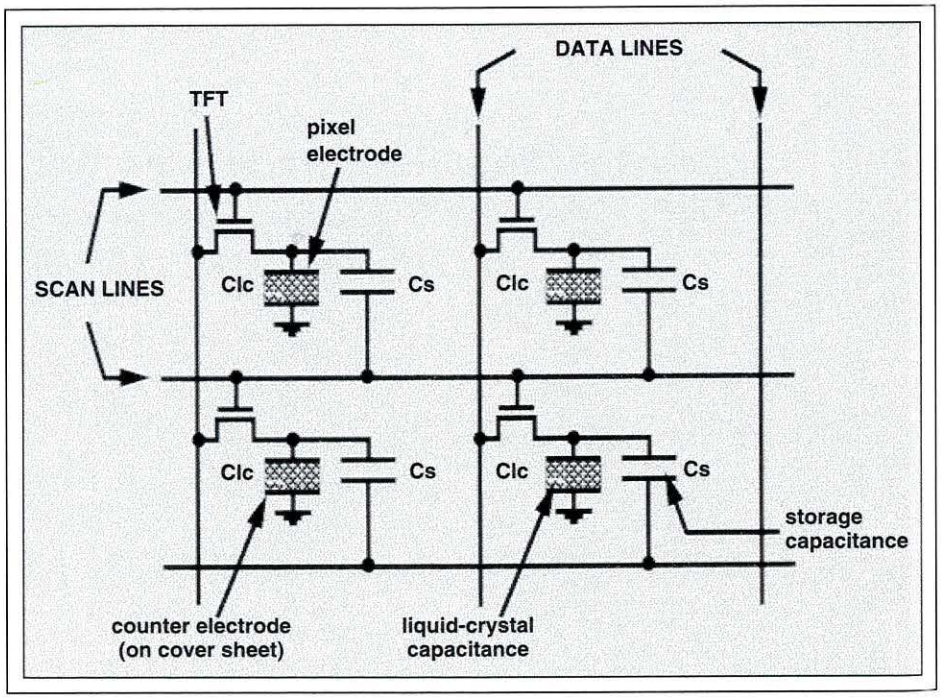

Fig. 1: *An active-matrix LCD typically employs thin-film transistors to allow each pixel to be addressed independently.*

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one gray level. The maximum allowable leakage current is typically less than 1 pA for $-10\ V \leq V_{GS} \leq 0\ V$.

Almost all AMLCDs produced today employ either amorphous-silicon (a-Si) or polycrystalline-silicon (poly-Si) as the TFT channel material. a-Si TFT technology is less expensive than poly-Si TFT technology and it can meet pixel-TFT performance requirements. Poly-Si TFT technology provides a superior transistor drive current, which is beneficial in two ways. First, the size (width) of a poly-Si pixel TFT can be much smaller than that of its a-Si counterpart. As a result, pixel aperture ratios can be larger with poly-Si TFT technology. This can be an important advantage for small displays which have small pixel size.

Second, poly-Si TFTs can be used to implement high-speed (greater than 300 kHz) complementary metal-oxide-semiconductor (CMOS) driver circuitry directly on the active-matrix substrate. This drastically reduces the number of connections to the display, which simultaneously improves reliability and lowers production and assembly costs. This monolithic integration of driver circuitry is necessary for high-density displays used in viewfinder and projector applications, where the fine-pitch requirement that must be imposed on the bonding of driver-IC chips may make it difficult or impossible to make the necessary connections.

Plastic Substrates

The glass used in AMLCDs is thin, brittle, and relatively inflexible. Optically transparent polymeric substrates are preferable for flexible displays. But they generally can not be subjected to temperatures of greater than 150°C for extended periods of time because of their low glass-transition temperatures. This poses a significant challenge for TFT process technology because temperatures greater than 250°C are generally needed to achieve good device performance (drive currents of about 1 μA) and reliability that are necessary for the monolithic integration of low-power CMOS display-driver circuitry.

Groups around the world are pursuing several approaches to the attainment of high-performance CMOS transistors on plastic for future FPD application. These include the fabrication of TFTs directly on plastic substrates, as well as the transfer of transistors or circuitry to plastic substrates. Poly-Si TFT technology is likely to be the first to be applied to the manufacture of high-resolution displays on plastic substrates because of the performance limitations and manufacturing challenges associated with competing large-area electronics technologies. Two approaches to the achievement of high-performance poly-Si TFTs on plastic substrates have particular promise.

Direct Fabrication on Plastic

In the fabrication of a poly-Si TFT, poly-Si film formation and gate-dielectric formation are critical process modules that affect TFT electrical performance (Fig. 2). A high-quality poly-Si film can be formed on an oxide-coated plastic substrate by depositing an a-Si film and crystallizing it using a short-pulse (several tens of nanoseconds) excimer laser. The pulsed-laser crystallization technique is compatible with coated plastic substrates because the laser energy is completely absorbed by the Si film.

For example, with a 500-nm-thick SiO_2 coating layer, the substrate surface is subjected to temperatures above its softening point for less than 100 msec, so that the substrate is not damaged. One issue in the laser-crystallization technique is the large statistical variation in grain size in laser-crystallized films because of the inhomogeneity of the laser beam, the pulse-to-pulse variation in laser-energy fluence, and the high sensitivity of the average grain size to film thickness. The grain-size variation results in poor TFT performance uniformity. This problem can be reduced by using multiple laser shots, but this solution reduces process throughput.

A high-quality gate dielectric is critical for good TFT performance and reliability. Silicon dioxide (SiO_2) has been the preferred gate-dielectric material because it forms an excellent interface with Si. In order to attain a high-quality SiO_2–Si interface with low deposition, a high-density plasma-deposition process must be employed. For example, the electron-cyclotron-resonance (ECR) chemical-vapor-deposition (CVD) technique achieves a high-quality interface, although it yields poor oxide bulk properties. By capping a thin ECR-CVD SiO_2 layer with a plasma-enhanced CVD SiO_2 layer, good TFT performance characteristics can be obtained without exceeding 150°C.

Researchers at the Lawrence Livermore National Laboratory and the University of California at Berkeley were the first to demonstrate that poly-Si TFTs with high drive current (an effective carrier mobility greater than 60 cm^2/V-sec) could be directly fabricated on polymeric substrates without exceeding 150°C by using multiple-pulsed excimer-

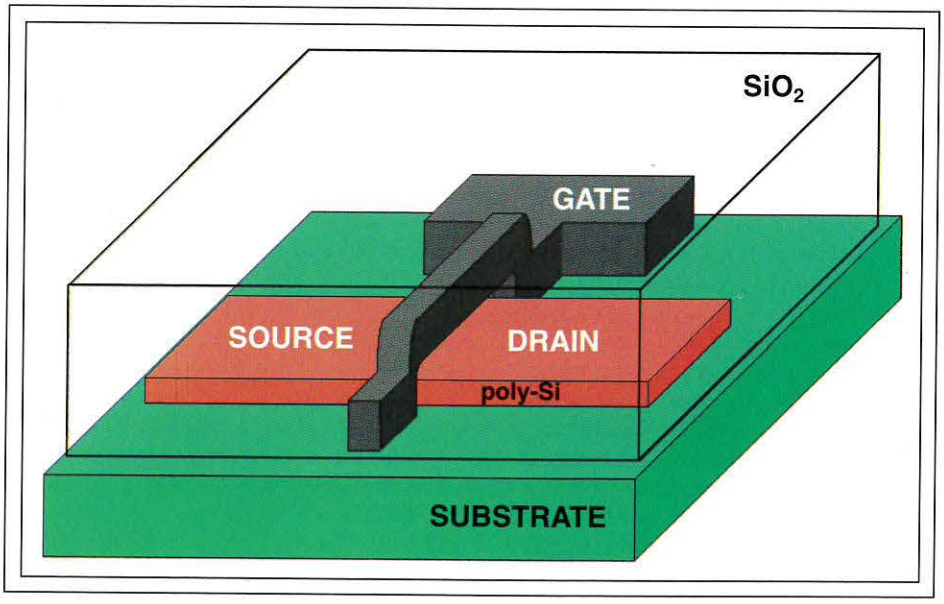

Fig. 2: In this basic poly-Si TFT structure, the current flowing through the channel beneath the gate from the source to the drain is controlled by the voltage on the gate. SiO_2 is used as a passivation layer, as well as the insulating dielectric between the gate and the channel.

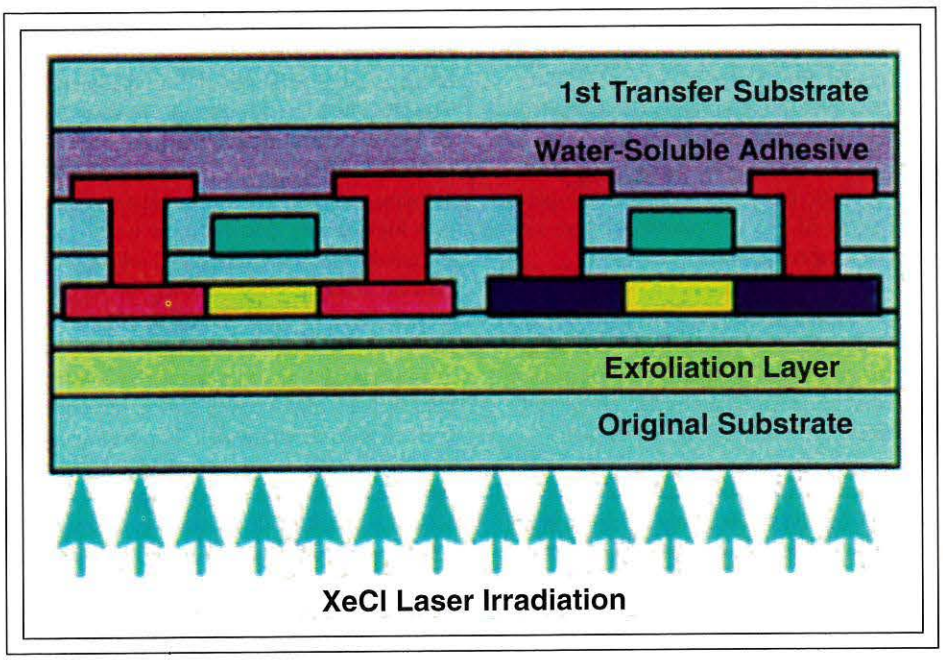

Fig. 3: In the SUFTLA process, excimer-laser irradiation is used to detach poly-Si TFT circuitry from a glass substrate and subsequently transfer it to a plastic substrate.

laser annealing to crystallize the TFT channel and dope source/drain regions. More recently, researchers at Sony Corp. achieved poly-Si TFTs on plastic with high drive current (an effective carrier mobility exceeding 250 cm^2/V-sec) and low leakage current of about 1 pA per micrometer channel width without exceeding 110°C. These results indicate that poly-Si TFTs fabricated directly on plastic substrates will be able to meet the performance requirements of future FPDs.

Transfer onto Plastic

In addition to the limitation on substrate processing temperature, polymeric substrates pose a technological challenge for lithographic processes because they shrink during thermal processing and swell during wet processing. The shrinkage rate can be reduced to acceptable levels (less than 1 ppm/hour) by pre-shrinking the substrate, which can be accomplished by heating it at the maximum allowable processing temperature for more than 10 hours, but this increases the substrate cost. Further alignment problems associated with water absorption can be avoided by heated drying of the substrate before lithographic exposure.

One way to avoid the significant challenges of the direct fabrication of transistors on plastic substrates is to fabricate circuitry on a temporary substrate that can tolerate higher processing temperatures, and then transfer the circuitry to a plastic substrate. A new transfer technology called surface-free technology by laser annealing (SUFTLA) was recently demonstrated to yield high-performance poly-Si TFTs and circuits on polyethersulphone (PES) substrates.

In the SUFTLA process, a glass substrate is coated with an exfoliation layer of hydrogenated a-Si followed by a buffer layer of SiO_2. High-performance poly-Si TFT devices and circuits are then fabricated on the coated substrate using a process that uses a substrate temperature of no more than 425°C. The TFT circuitry is then attached to a transfer substrate using a water-soluble adhesive. The exfoliation layer is irradiated with an excimer laser through the glass substrate, and the rapid evolution of hydrogen causes the buffer oxide layer to be detached from the glass substrate (Fig. 3). The buffer layer is then glued onto a plastic substrate using a non-water-soluble adhesive. Finally, the transfer substrate is cut and soaked in water to detach it from the TFT circuitry.

The SUFTLA process has been used to transfer an 18 × 17-mm test chip onto a polymeric substrate. The characteristics of the poly-Si TFTs after transfer were identical to those prior to transfer, so excellent device and circuit performance were obtained on plastic. Effective carrier mobilities of 125 and 63 cm^2/V-sec were achieved for n- and p-channel TFTs, respectively, with low threshold voltages (less than 4 V) and steep subthreshold swings (less than 0.3 V/decade). Data-driver circuitry operated at clock frequencies up to 2 MHz for a power-supply voltage of 7.0 V. These are the best TFT results obtained to date on plastic, and they satisfy all of the TFT-performance requirements for future FPDs. Thus, the transfer process appears to be the most promising approach to plastic electronics for the near term, particularly for small displays, cards, and tags.

The Future Is Plastic

The trend toward lower-power, lower-cost, lightweight, and rugged displays will lead to more-demanding requirements for TFT technologies in the near future. This requires high-performance large-area CMOS electronics technologies that are compatible with plastic substrates. Of all the transistor technologies being developed for future FPD application, poly-Si TFT technology is likely to be the first to be applied to the manufacture of high-resolution displays on plastic substrates. The SUFTLA process circumvents significant issues in the direct fabrication of devices on plastic substrates, and is an especially promising technique for achieving small high-performance plastic displays. ■

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Eating Rice in Kobe

IDW drew well over 1100 display professionals to devour generous portions of the "second rice of industry" in Kobe's Portopia.

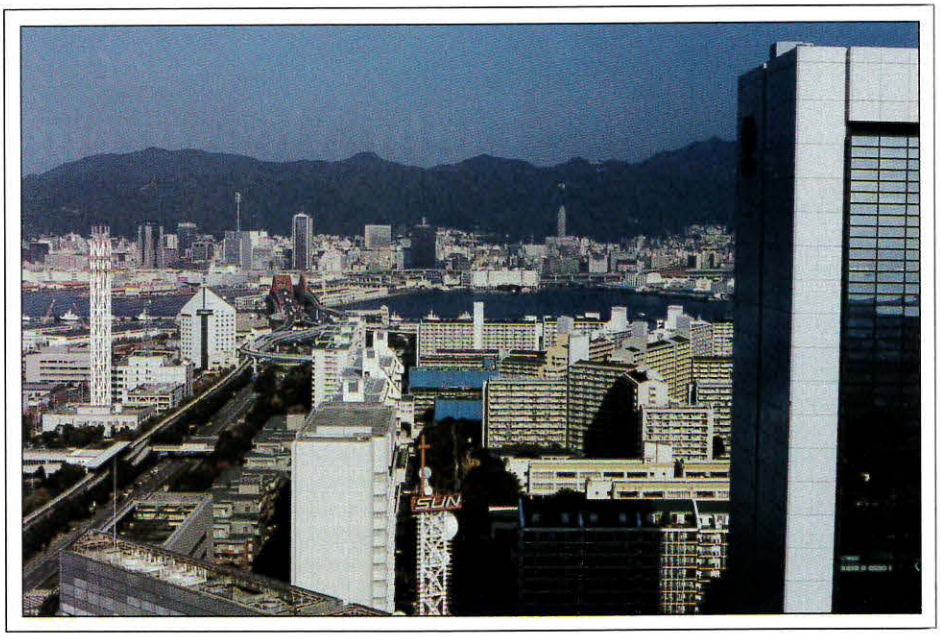
by Ken Werner

THE Seventh International Display Workshops that opened November 29, 2000, at the International Conference Center in Kobe, Japan, was, as expected, a world-class technical conference accompanied by a small interesting exhibition. In addition, it was a celebration of the 25th anniversary of the founding of the Japan Chapter of the Society for Information Display (SID), as was noted by Conference Chair Shigeo Mikoshiba (University of Electro-Communications, Tokyo) in his opening remarks.

Mikoshiba also recalled the saying "Semiconductors are the rice of Japanese industry," meaning that just as rice nourishes the people of Japan, so do semiconductors nourish its industry. "Now," he continued, "people are saying that displays are the second rice of Japanese industry." All in all, 1128 people from 20 countries registered for the conference. Ranked by the number of registrants, the top five countries (regions) were Japan (751), Korea (167), U.S.A. (64), Taiwan (49), and The Netherlands (23). These attendees were treated to 302 technical presentations and papers – 302 bowls of "second rice." Mikoshiba commented on the high quality of the papers, and how gratified the organizers were at the steadily increasing attendance. As is the case with all meetings sponsored by SID, all papers were delivered in English.

In his opening address, SID President Aris Silzars commented on the remarkable progress made in display technology over the last 25 years and the impressive contributions to that progress made by members of SID's Japan Chapter.

"The future is much more uncertain than the past," Silzars said. "It now seems that the creation of a Japan Chapter of SID was an obvious thing to do and destined for success. But at the time, the risks were great. It is hard to imagine the world of 25 years ago, a world without PCs, home fax machines, laptop computers, or the Internet. Color displays were used only for television. But at the materials level, the foundations for today's technologies were established."



Ken Werner

This view of the Port of Kobe is from the Plein d'Etoiles lounge on the 30th floor of the Portopia Hotel, the headquarters hotel for IDW 2000. Portopia – everything in front of the red bridge – is an artificial island on which port and warehouse facilities, a convention center, museums, hotels, apartment blocks, and stores have been constructed. A small-gauge elevated railway runs regularly to the Kobe JR Station, and a jet-powered hydrofoil provides a convenient connection to Kansai airport.

Ken Werner *is the editor of* Information Display.

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"What will things look like 25 years from now," Silzars asked rhetorically.

- We will communicate with machines in normal language, and small devices will provide instant language translation at conferences such as this one. Hardware-based operating systems will make machines fast and robust.
- The Internet will have the same place in our lives that telephones had ten years ago. Voice–machine communication may have greater impact.
- Computer-generated personas will become commonplace. They will express our ideals and may be customizable.
- Computational and other devices must be simpler. We cannot have machines that require us to be experts in the operation of each of them.
- A wide variety of displays will be required for the devices of the world of 2025. Displays for portable appliances will be varied and will constitute an explosion, but large 3-D displays will take 50 years.
- Large wall-mounted PDPs and LCDs in sizes about as large as we would want will be available.
- CRTs will still be with us.
- LEDs will grow in display and lighting applications. Domestic and office lighting may use LED light bulbs.
- There may be new technologies, but very few.

Keynote Addresses

Past SID President Tony Lowe (Lambent Photonics, Ltd.) gave the first keynote address, "Displays of the Future: Managing Resolution, Power, and Bandwidth." He began by saying, "Despite great advances, displays are still inadequate in many of the applications in which we wish to use them." He then cited many examples.

- WAP services have increased the need for bigger screen size, higher resolution, better reflectivity, and color in displays for mobile phones. The trend is to smaller overall device size, so future displays may cover the entire surface of the phone, with input through touch on display.
- Reflective displays have inadequate reflectivity and viewing angle. Current limits are 35% reflectivity for a monochrome display with one polarizer, 15% for a color display with one polarizer, and 35% for a monochrome Bragg-effect display without a polarizer. But these limits can be exceeded by using polarizer-free stacked cells and subtractive color filters.

Jenny Needham

Despite their serious expressions, Kent Skarp (left), of the Swedish LCD Center, and Ernst Lueder, of the University of Stuttgart, at a Portopia restaurant during IDW, were reportedly relaxing.

Lowe compiled specific power consumptions (mW/cm^2) for different display technologies from a variety of sources and scaled them to an A4 page for comparison. Reflective poly-Si AMLCDs came out with a specific power consumption of 3.5 mW/cm^2, while FSTNs had 0.47 mW/cm^2 (excluding backlight in both cases).

When a display is updated infrequently as in some of the new technologies, it has very low power consumption. One conclusion Lowe drew from this analysis is that wearable displays – LCDs or OLEDs – can compete in power consumption with larger backlit AMLCDs. He also said, "We will see clear market segmentation by application because no technology is ideal for all."

For larger displays, Lowe observed that the goal of mimicking the quality of ink on paper is not feasible today. The display technology exists, but it cannot be implemented with acceptable cost and system performance.

For displays viewed at large distances, sizes over 60 in. must be tiled or projected; sizes under 60 in. are mostly monolithic at present. Lowe encouraged his audience to part with the conventional way of viewing large displays for the home. "Instead of thinking of displays at the standard home viewing distance, think of looking at them from a closer distance to overfill the visual field, like IMAX. We need a higher resolution for this, but it would create a whole new viewing experience."

"In the future," said Lowe, "we will be able to make pseudomonolithic displays from tiles or by the use of plasma projection." But when we do that, we run into the system limitations of addressing large numbers of pixels and addressing a display over long cable distances.

In order to overcome the limitations of traditional analog and digital-video interfaces, Lowe proposed using optical fiber, which would have adequate capacity, for instance, to drive IBM's new WQUXGA display, which needs 19 Gbits/sec to update. A DTA project

improved the cost/performance of fiber by a factor of 3–4 by incorporating electrical compatibility at each end. Just plug it in.

An attractive application for such an optical cable/interface, in addition to large displays, is wearable computers with high-resolution displays. Today's display cables for wearable computers are rather thick, heavy, and rigid. A floppy optical cable would be much better.

Lowe noted that his company (LPL) was formed to commercialize the DTA approach.

The Post-PC Era Starts Now

In the second keynote address, Masao Suga, V.P. and General Manager of the Mobile AV Network Division, Digital Media Network Company, Toshiba, Tokyo, Japan, took as his topic "Mobile Audio-Visual Network Strategies in the 21st Century."

Toshiba retained the top rank in laptop-PC market share in FY 99. According to IDC, he said, the total market is 20 million units in 2000, rising about 8% a year. But Toshiba expects faster growth than IDC starting in 2002 because only 20% of the total PC market is laptop; 80% is desktop. Toshiba believes the "mobile networked lifestyle" will produce a strong shift from desktop to laptop sales.

"Today we need standard interfaces for displays in the era of the wireless Internet," Suga said. The shift to multimedia data phones expands the mobile communications terminal market, with a projected 22% CAGR during the period 1999–2002. Europe and Asia have a bigger share and faster growth than the U.S. In Japan, multimedia phones will use MPEG-4 for video starting in 2002.

The mobile phone is a strong candidate for "post-PC" computing. Suga said he expected 350 million WAP/i-mode phones to be sold, compared with 120 million PCs. Within 5 years, 80% of phones will be connectable to the Web.

What kind of displays do people want? Toshiba has a new 800 × 480 portable DVD player. Customer feedback is that they want a bigger display and higher screen resolution. Toshiba will use the same display sizes for laptops, a new DVD player, and digital AV devices.

Common standards are very important to Toshiba because digital AV product cycles give them only 6 months for product development, and they cannot provide electronics development for different displays. Standard interfaces and standard sizes are required.

Another important display platform is digital still cameras, of which 10 million units were to be shipped by the end of 2000, with a CAGR of 20%.

Toshiba is also developing a stamp-sized SD-format Bluetooth card for next year. It is slated for digital cameras and other SD products, Suga said.

Ken Werner

Fujitsu-Hitachi Plasma Display's ImageSite 32-in. pre-production PDP, shown at the IDW exhibition, had an optical notch filter on its front surface that filtered out the orangish portion of the red emission to produce very rich and deep reds.

Technical Sampler

In a technical program of 302 papers, we can do little more than provide a sampling of the papers we actually heard presented, and that, in turn, is necessarily a small fraction of the total. Paper numbers are given here to make it easier to find the full written version of the paper in the *IDW '00 Conference Digest* (available from SID Headquarters, office@sid.org).

In Paper AMD1-1, "Technology of Large-Size and High-Resolution Poly-Si TFT-LCDs," T. Higuchi and his colleagues from Toshiba's LCD Research and Development Center in Saitama, Japan, described two key technologies in the design of Toshiba's 15- and 10.4-in. LTPS UXGA TFT-LCDs: the selection-switch circuit and the dual-drive technique to overcome the decrease in the charging period and the increase in the time-constant of bus lines in high-information-content displays. In the dual-driving method, the time constant of scan lines is reduced to one-fourth, and the time constant of scan lines is reduced to under 2 sec for a 20-in. display. The same approaches should work for QXGA and QSXGA displays.

In Paper AMD1-2, "Concept of a System on Panel," Yojiro Matsueda and his co-workers at Seiko-Epson Corp., Nagano, Japan, discussed the requirements for fabricating a digital system entirely on the display panel – a system on panel (SOP). Thin-film microelectronics for an SOP would include a microprocessor and other high-speed elements that require a semiconductor electron mobility of 500 cm^2/V-sec and 1-μm CMOS design rules. This compares with the 50–200 cm^2/V-sec mobility and 2–3-μm CMOS design rules of today's LTPS displays with integrated drivers, and with the 0.5–1.0-cm^2/V-sec mobility and 3–5-μm NMOS design rules of conventional amorphous silicon. So, in terms of key thin-film semiconductor properties, we are just a factor of 2 or 3 away from where we need to be. SOP is possible, albeit demanding. It will be realized in the near future, and will widen the applications for TFT-LCDs, the authors said.

There are two feasible architectural approaches to SOP: static memory in each pixel or frame memory in the data driver. The frame-memory approach works with all kinds of AMLCDs, and does not degrade the aperture ratio as static pixel memory does.

But SRAM in pixels is better than frame memory from the point of view of power consumption. Once addressed, a pixel does not need to be re-addressed until data is changed. Because the SRAM approach does impact AR, it is most suitable for reflective TFT-LCDs or TFT-OLEDs.

Do Digital Interfaces Make Sense for CRTs?

In "Digital Interfaces and the CRT Display" (Paper CRT1-3), Robert L. Meyers of Hewlett-Packard, Fort Collins, Colorado, questions whether digital interfaces make sense for CRTs. He noted that it is currently not feasible to use digital interfaces beyond 1200 × 1600 at 60 Hz for screens larger than 15 and 17 in. because it becomes too costly. Digital's extra cost is not justified in very cheap monitors. So 15- and 17-in. high resolution is the digital window right now. The PC industry cannot go to digital across the board, Meyers said.

Myers looked in detail at a few digitally interfaced CRT monitors in systems and concluded that neither approach actually requires a digital interface. He stated that a digital interface cannot be justified for CRT monitors, at least not in the mainstream market, if it merely duplicates the function of current analog interfaces.

So, is there something else that would provide the motivation to shift now? Yes, says Myers, citing the Digital PV-Link proposal to enable significant new features and performance which takes advantage of the digital interface to radically change the architecture of the PC display system. Among these features are conditional update of the display and multiple, addressable displays on a single interface. This architecture requires the display interface to be moved farther back into the graphics system. Myers believes this will occur, although the system will need major restructuring and new standards will have to be developed.

In Paper FMC2-1, "Development of Color Filters for Reflective LCDs," T. Yamashita and his associates from Toray Industries, Japan, described the development of a red element for color filters that is much closer to an ideal red than existing elements, with high transmittance and high color purity. They also addressed another problem. In reflective LCDs, it is difficult to control white balance because reflected ambient is not predictable. In particular, whites are often yellowish. A deeper blue pulls the white point from yellow toward blue, and this can be implemented so that brightness is only slightly reduced.

Are LEDs Ready for Large LCD Backlights?

F. Yamada and Y. Taira of IBM Research, Japan, presented Paper FMC3-2, "An LED Backlight for Color LCDs." If the output of RGB LED arrays is compared with that of fluorescent lamps (FLs), the LED looks considerably better in terms of color gamut. When an LED backlight replaces an FL backlight in a laptop PC or desktop monitor, even without changing the color-matrix filter (CMF) that was optimized for FL, color reproduction and transmittance is slightly better in the LEDs.

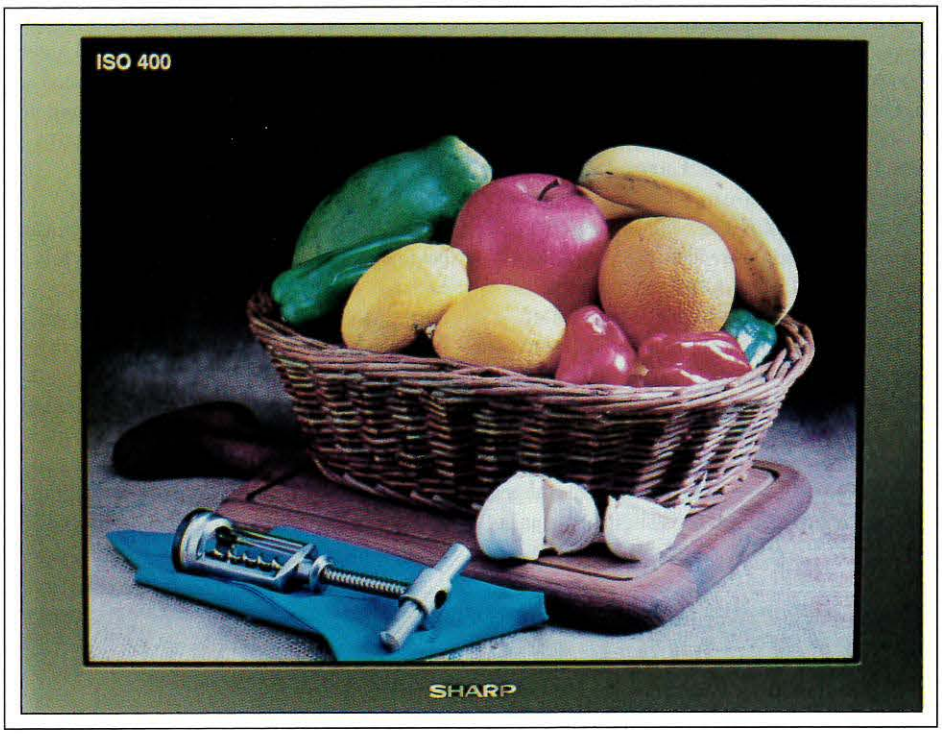
Plots of efficiency *vs.* LED current are very different for red, compared to blue and green, so simple dimming destroys color balance. The efficiencies of LEDs now range from 50 to approximately 100% that of FLs, and they're getting better.

LED backlights can be used for field-sequential-color displays. The backlight can be designed with an R, G, and B LED for each LC pixel, with each LED occupying one-third the area of the LC pixel, and with the LCD being refreshed at three times the overall frame refresh rate. The authors have found that sensitivity to flicker is less in sequential displays than in spatial-color displays, which helps the cause.

Although LEDs are promising for laptop- and monitor-class backlights, the promise is compromised by integration issues and the

Ken Werner

Sharp's 3.9-in. reflective color quarter-VGA display has a specified reflectance of 40% and consumes just 92 mW.



Ken Werner

Sharp also showed this 28.3-in. QSXGA (2560 x 2048) TFT-LCD module, with a four-channel TMDS interface that impressively displayed still images with a pixel density of 116 ppi.

fact that the maximum power capacity of an LED is currently limited to about 50 mW per LED, which is not enough.

In the Q&A period, an audience member asked about the relative price of LEDs and FLs. The answer was that a few hundred LEDs are needed for a laptop-sized backlight. The LED alone costs $50, which is high.

In "Driving and Interface Technology for High-Resolution AMLCDs" (AMD4-1), K. R. Schleupen (IBM T. J. Watson Research Center, Yorktown Heights, New York), said the trend toward AMLCDs with higher screen resolutions is challenging driving and interface technology.

The trend is to move to digital monitor interfaces, mainly for cost reasons but also to increase functionality. Such interfaces use a digital receiver–transmitter pair to provide the link between workstation and monitor. There are currently three competing physical layers for this link: the gigabit video interface (GVIF), a Sony concept that is capable of transmitting a Gbit/sec on a single pair, and the more familiar LVDS and DVI interfaces.

In addition to these standards, higher-level protocols have been developed using advanced data-compression techniques. Based on these developments, four AMLCD companies in Japan – Hitachi, IBM, Sharp, and Toshiba – have co-developed a next-generation video interface called the Digital PV Link. It is a high-level protocol that uses packetized video. It is independent of the physical layer, supports multiple-systems operation, can daisy-chain displays, and supports tiled displays. It includes a frame buffer on the monitor side. "This is a very exciting new idea," Schleupen said.

A dual-link OpenLDI or DVI interface can drive monitors up to a 2048 × 1536-pixel 60-Hz frame rate and 24 bits/pixel (at up to 5.36 Gbits/sec). Screen resolutions higher than this require different system architectures, such as using four genlocked PCI graphics adapters to drive a QSXGA monitor. Each adaptor drives a 640 × 2048 vertical stripe in the 2560 × 2048 display, and does so with a data rate larger than that for LVDS or DVI of approximately 900 MB. Multihead graphics cards are now available that can do this job while taking up only one PCI slot. More-advanced approaches, including shared memory among multiple graphics trips, will have to be developed for even more demanding displays.

Greater integration of display controllers and optimized system architecture are reducing the cost of display electronics, setting the stage for a steep increase in the number of desktop AMLCDs sold. This has been an historic year for high-image-content displays. Notebook displays have gone to SXGA+ and UXGA. Desktop-monitor displays have gone to wide UXGA, QXGA, and QSXGA. Prototypes have gone to QUXGA and wide QUXGA.

In "Light-Emitting Diodes for Solid-State Illumination" (Paper PH1-2), G. O. Mueller (presenter) and R. Mueller-Mach of LumiLeds Lighting (San Jose, California), announced their company's development of a green LED with twice the efficacy of previous green LEDs. The company, which is a joint venture of Philips Lighting and Agilent Technologies, has accepted its first order for green traffic lights using the new LED. The rapid conversion to LED traffic lights from incandescent lamps is due to the fact that their cost is paid back in one year on the power savings alone. As LEDs go from signal applications to lighting, there must be color constancy with temperature, the authors said.

Following up on a paper given at IDRC in September, Alexandra Rapaport and her colleagues at the University of Central Florida presented "Optically Written Displays Based on Up-Conversion of Near-Infrared Light" (Paper PH1-3). This new type of display uses a near-IR diode laser operating at about 970 nm and a display medium consisting of a transparent polymer containing particles of crystals doped with Yb^{3+} and other rare-earth ions. The Yb^{3+} ions absorb the laser energy and transfer it to the other dopant ions. Fluoride crystal hosts co-doped with Tm^{3+} produce blue light at about 480 nm; and with Ho^{3+} or Er^{3+} produce green light at about 550 nm and red light at about 660 nm, respectively.

The group would use its upconverting crystals in ground-up form in a host material, and emitter locations would generate RGB as subpixels. The materials provide much better gamut than CRT phosphors, and a system based on this scheme could approach about 18 lm/W, said the authors. This approach is attractive because near-IR diode lasers are getting less and less expensive, and they are highly efficient compact devices. No vacuum chamber or high voltage would be necessary.

Speaking to a standing-room audience, Sashiro Uemura and his colleagues from Ise Electronics Corp., Japan, presented a review of "Carbon-Nanotube Field Emitters" (Paper CRT4-3). Over the last 2 years or so, a variety of interesting materials and devices have been reported, including

- A lighting element.
- A diode-type flat panel.
- An x-y addressable triode-type flat panel.
- Application of graphite nano-fibers (GNFs) to VFD-like medium-sized displays.
- Nanografibers (NGFs) produced by dc arc discharge in hydrogen gas, which have a very small inner channel of only 0.1 nm. NGF disks have even emission profiles measured at 135 mA/cm^2 across the top of the plateau.

An experimentally manufactured CNT-FED demonstrated stable and intense electron emission and a long lifetime for practical use, the authors reported.

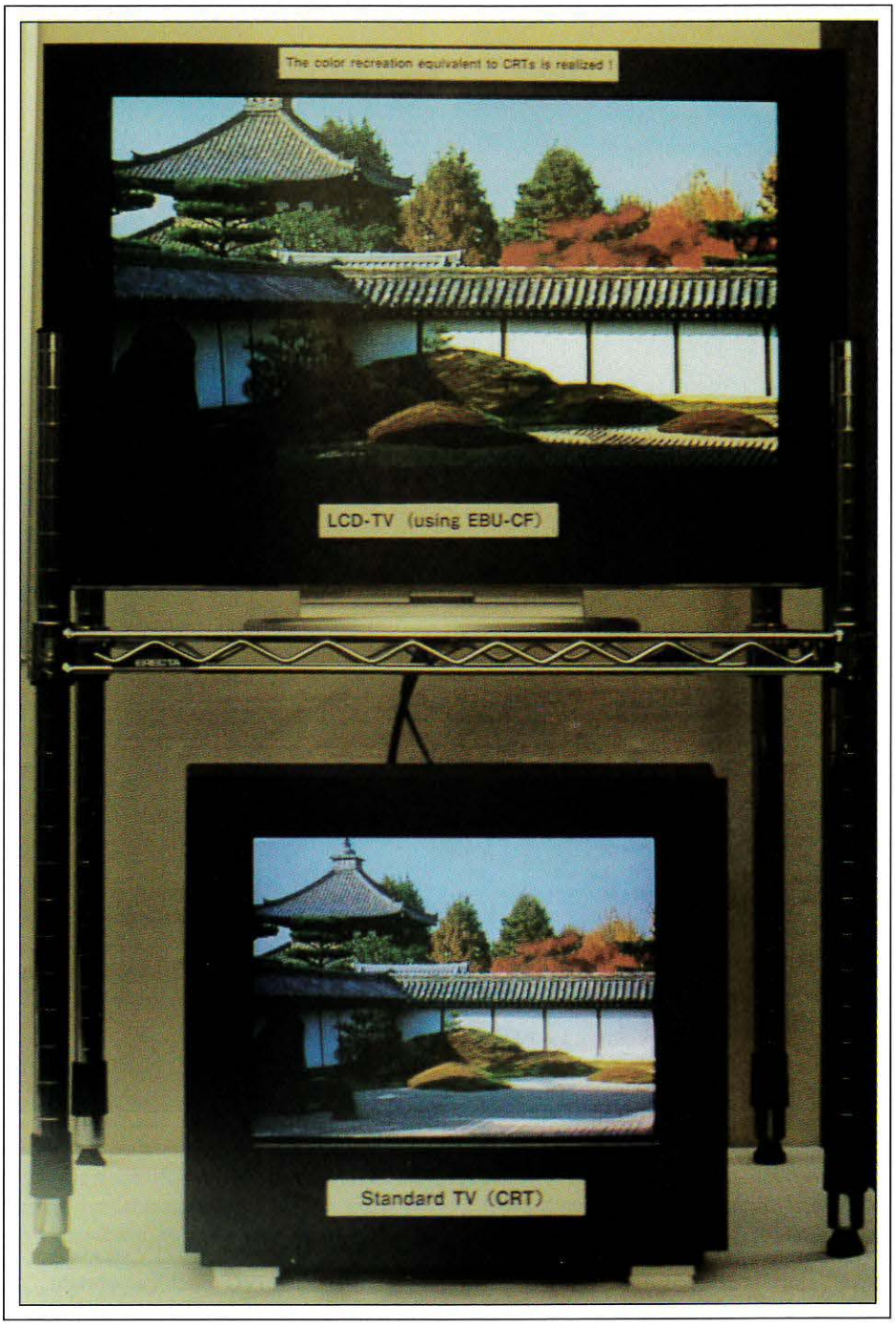
The advantages of CNT field emitters are that they have a large aspect ratio with sharp tips, require low-voltage driving, are mechanically strong, have long lifetime, and the graphite material is chemically inert, stable, and processed in normal vacuum (no need for UHV) and are environmentally friendly.

In "Surface-Stabilized Ferroelectric LCDs with Plastic Substrates Fabricated by Printing" (Paper PLC1-3), Ernst Lueder (University of Stuttgart, Germany) established the criteria for stable switching in SSFLCDs and the processes by which it is achieved. All layers – including polyimide orientation, etch-resist, and 0.8-μm-thick FLC or nematic LC layers – can be applied by flexographic printing, which are offset onto a letter-press roller covered with a polyimide pattern. Ink-jet printing can also be used. In either case, no photolithography is required.

A smart card containing an SSFLCD of this kind can be bent in a 1.5-cm radius – around the neck of a beer bottle, for instance – and still operate without degradation.

In answer to a question from the audience, Lueder identified the substrate as PES from Sumitomo. Sumitomo supplies the PES with a barrier layer. At Stuttgart, they add two more barrier layers, including an SiO_x layer with x = 1.4–1.6. Because this layer is unsaturated with oxygen, it is seized by unsaturated bonds if O_2 gets through the other barrier.

In "The Single-Panel D-ILA Hologram Device for ILA Projection TV" (Paper LAD4-1), T. Yamazaki and his colleagues from JVC (Kanagawa, Japan) described a new holographic color-filter material used in conjunction with JVC's 1.22-in. 4-Mpixel



Ken Werner

Toppan's new EBU-CF is the first matrix color filter that allows an LCD TV to equal the color gamut of a CRT and thereby comply with the color standards of the European Broadcasting Union (EBU), as the company demonstrated at IDW. If anything, Toppan's reds were a bit more saturated than the CRT's and a bit less orange.

Ken Werner

Downtown Kobe, on the other side of the bridge from Portopia and IDW, is a bustling city with varied and interesting neighborhoods.

D-ILA device. (D-ILA is JVC's version of LCoS, which is descended from Hughes ILA technology.)

The hologram color filter (HCF), which is made by Dai Nippon Printing from a DuPont Holographics photopolymer, has a total reflective efficiency of 40% in an optical system with a metal-halide lamp, and color that is generally better than the HDTV standard. This has allowed JVC to achieve a bright SXGA device, which has been designed into a 50-in. rear-projection HDTV set, which is commercially available.

In "Carbon-Nanotube-Based FEDs with Triode Structures" (Paper FED4-1), J. M. Kim and a small army of colleagues from three divisions of Samsung reported on several types of new triode structures for carbon-nanotube-based FEDs (c-FEDs).

The authors showed photos of their 10.4-in. microtip FED, which looked good. But the cost is high, the operating voltage is high (80 V), and scalability is poor (less than 20 in.). CNTs, on the other hand, are cost-effective, with preparation *via* CNT paste and thick-film processing.

Last year, a 9-in. 576 × 240 color FED with a diode structure was demonstrated; this year, a 15-in. VGA is planned. The next-generation FED will replace microtips with a CVD-CNT FEA and will replace diode structures with triode structures. The authors noted that triode structures are needed to give FEDs high brightness and full gray scale.

Larry Hornbeck and his colleagues from Texas Instruments Digital Imaging presented Paper LAD4-3, "DLP Cinema™ Projector Field Demonstrations: A Progress Report." After a well-presented historical, technical, and system summary, including the necessary specifications for digital cinema, Hornbeck came to the new information.

To date, over 1.1 million people have seen DLP on the existing 31 screens worldwide, with total screening time now at 25,000–34,000 hours. Most exhibitors find it very easy to work with DLP, and are amazed at the lack of problems, he said. The digital version of a presentation outdraws the film version in the same theater by 2:1, and weekly attendance holds up better. All exhibitors queried for TI's survey say that having only one digital projector limits booking flexibility, and all exhibitors say they need more digital movies. Film professionals like the images too, but want blacker blacks and more contrast in dark scenes.

All current projectors are made by TI, but now BARCO, Christie Digital, and Digital Projection are making systems available. The first digital distribution system and business model are under development and should be ready in less than a year.

Capital cost is a major issue. Film projection systems cost about $100,000; digital systems will be about twice that. Any viable business model must include cost sharing among content creators, distributors, and exhibitors. Hornbeck projected sales of digital-cinema projection systems at 2000–3000 units per year in 2002 and more than 10,000 per year in 2003.

In the Q&A period, Fred Kahn of Kahn International asked about gray-level noise, which many people have attributed to "quantum noise" from digital cinema's PCM system for rendering gray levels. Hornbeck said that this was probably the grain structure of original filmed-source material. Animated movies do not have it. *Star Wars 2* will be shot with digital cameras (from Sony and Panasonic). This will be the test for this theory. The noise, he said, might also be related to algorithms used to get 14-bit color depth. The algorithms are necessary because the mirrors on a DMD chip do not go fast enough for that much depth. But *Toy Story 2* used the same algorithms, and it looked good.

Hornbeck's slides were shown on a Digital Projection DLP projector, and this was followed by a digital-cinema presentation, which was impressive. Approaching the screen very closely, one noticed that the only "structure" that could be seen were the perforations in the screen that let the sound come through the behind-the-screen speakers.

Evening Invited Papers

Although there were many invited papers scattered throughout the program, it is an IDW tradition to have an evening session of longer invited papers, much like an additional keynote session, although it is not called that.

The first evening invited address, by H. S. Kwok (Center for Display Research, Hong Kong University of Science & Technology), was "Development of Liquid-Crystal–on–Silicon Microdisplays." Reflective LCoS displays, Kwok began, can be used in direct-view or projection applications. There are a variety of reflective LC modes; the most widely used for LCoS is conventional TN.

Analyzing the different modes by means of parameter-space diagrams for reflective displays reveals that mixed TN birefringence mode (MTB) is attractive because the parameter space varies in a very predictable way when the meaningful input variables are changed. What is essential for time-sequential color is an MTB mode that is minimally dispersive. Kwok showed interactive software that incorporates the parameter-space analysis and shows reflection spectra *vs.* wavelength as the various parameters are adjusted. Kwok's group has used the software to identify several attractive LCoS modes, which they are using now.

Ken Werner

Music Square in Kobe, in a neighborhood of houses built in Western style during the Victorian period, was a popular weekend destination for both locals and tourists.

In HDTV and virtual reality – which have been identified in a Battelle study as the top two applications for the future – LCoS will compete with poly-Si TFT light valves. In comparing the two, Kwok said that the cost of a 0.9-in. XGA TFT light valve is now about $300, while a 0.8-in. SXGA LCoS should be about $200 based on foundry costs and assuming a 50% yield and 50% profit.

LCoS is now approaching *f*/2.8, which is comparable to TFT. This is not the conventional wisdom, which has it that optical throughput is better with TFT light valves.

The key to LCoS business survival is yield, said Kwok. Currently, yield is quite low. The IC fab is no problem. There are some issues with LCoS fabs, such as charge retention on the silicon side, cell-gap control, and rubbing *vs.* photoalignment. The market is there, concluded Kwok, but other technologies are available to compete. LCoS technology is attractive, but we cannot wait around too long. More details are available at www.cdr.ust.hk.

The second evening invited address was to have been a paper on the progress in OLEDs by C. W. Tang, but he was unable to come. Replacing him was Jacques Deschamps (Thomson Plasma, Moirans, France), one of the "grand old men" of plasma-display development, whose topic was "How PDPs Were Developed in the Past and How They Could Be in the Future."

Acknowledging that PDP history had been well covered in the conference by Mikoshiba, Weber, Uchiike, and Shinoda, Deschamps said he would give a French view of the story. But his perspective turned out to be something that was more general: why developing color PDPs was so surprisingly difficult on several fronts and why it took so long.

Looking to the future, Deschamps quoted Stanford Resources projections that the consumer market for PDPs will exceed the business market for the first time in 2003. But manufacturing remains costly and complex. "Increasing R&D on manufacturing processes, materials, and equipment is essential to resolve this [cost] issue," Deschamps said.

Deschamps noted that he had just retired from Thomson. Heiju Uchiike, as moderator, used the "Q&A" period to invite congratulatory comments on Deschamps' career and retirement from PDP stalwarts Larry Weber, Roger Johnson, Shigeo Mikoshiba, Tsutae Shinoda, and K. Nonomura. This miniature *festschrift*, clearly preplanned, earned the audience's warm approval, and the honoree was obviously moved.

Exhibits

IDW contained a fairly small exhibition (27 participants), but an interesting one. ***Sanyo*** showed its Slim View "Super Slim LC Rear Projection Display" TV/monitor. Triply folded optics produced a package only 330 mm deep for the 50-in.-diagonal 4:3 screen. The engine uses transmissive high-temperature poly-Si displays from "another Japanese company." When questioned by *ID* on "Who makes the screen?" Sanyo's representative said, "It is a secret." The Super Slim is made in XGA and SVGA versions, both of which produce 700 cd/m^2 from a 150-W UHP lamp and a total input power of 270 W. The XGA version costs ¥1,650,000! The unit was displaying only still images, which looked good.

Sharp introduced a new product, a 3.9-in. quarter-VGA reflective color HR-TFT-LCD module (HR represents high reflection). With a reflectance of 40%, a contrast ratio (CR) of 25:1, and 262,144 colors, this display looked very good exhibited under bright fluorescent desk lamps. The power consumption is 92 mW, the module weighs 32 g, and the intended applications are PDAs and hand-held PCs.

Also shown was a good-looking prototype 11.3-in. SVGA reflective color HR-TFT-LCD module with 30% reflectance, 20:1 CR, 262,144 colors, and a power consumption of 0.8 W. The intended application is in subnotebook PCs.

Sharp was also showing a 28.3-in. QSXGA (2560 × 2048) TFT-LCD module with a four-channel TMDS interface that was very impressive displaying still images. Specifications included 200 cd/m^2, 300:1 CR, and 116 ppi.

Also on display was Sharp's by-now familiar LC-28HD1 28-in. wide-format TFT-LCD HDTV, with thin Bose speakers attached, which sells for ¥1.1 million. The unit was showing a Digital High-Vision video of a jazz group and slow pans of New York City. When the slow pans were across textures – such as distant shots of skyscrapers where window patterns act as textures – diagonals produced non-subtle artifacts. Similar units have received similar criticisms at other exhibitions. Given Sharp's corporate commitment to LCD television, it is puzzling that the company would allow the LC-28HD1 to be shown in public with such deficiencies.

Panasonic did much better with its EDTCF08 22-in. wide-format VGA TFT TV module using the OCB (optically self-compensated birefringence) LCD mode, which gives the module a 16-msec response time. That, says Panasonic, is the fastest in the industry. The unit was demonstrated with slow-panning nature scenes and scenic photography. There were some minor smearing and edge artifacts, but this was a highly viewable TV display with nicely saturated colors and good performance on still images. Panasonic claims that the EDTCF08 has a wider color gamut than CRTs.

Pioneer was showing its newly developed PDP-502MX 50-in. wide-format XGA (1280 × 768) PDP that uses a new dynamic false-contour-free driving method, has a built-in row and column doubling for NTSC and VGA signals, and has a large dark-room contrast ratio.

The traditional Fujitsu cell structure used in most color PDPs realizes each column of subpixels as a vertical channel open on the top (the side toward the viewer). In the PDP-502MX, Pioneer encloses each subpixel on all sides except the top. This provides five walls on which to apply phosphor instead of three, thus increasing illumination efficiency, and it eliminates light leakage to vertically adjacent cells. In addition, Pioneer says, it is using an improved blue phosphor that delivers a better balanced white. The results of all this wizardry were impressive. This is a very good-looking display.

Heiju Uchiike (Saga University, Saga, Japan) looked on approvingly. He said Pioneer and Panasonic are offering the best-performing PDPs now, with FHP a notch down. But Heiji Uchiike was being modest, which is typical of Uchiike-san.

This modesty was verified by the performance of the ***FHP*** ImageSite 32-in. PDP. This 1024 × 852 650-cd/m^2 (white peak) panel uses the ALIS driving method, consumes 200 W, and features a fanless design. The color temperature is 10,000 K and the PDP uses an ACC filter. "In Japan we like high color temperatures," explained Keiichi Betsui, Manager of Fujitsu's Display Laboratory in Akashi, Japan. On the display's front surface is a homogeneous film, which is a notched filter that removes the shorter-wavelength (orangish) portion of red, giving a very pure red. The results were striking, with bright pure whites, rich reds, good performance on moving images, and superb detail on still images. Betsui told *ID* that Uchiike had worked on the design, and Uchiike was clearly pleased with the panel's performance.

Uchiike said that the panel will be on sale in 2001 at a price they hope will be about $100 per diagonal inch for a complete TV receiver. Even with the relatively modest screen size (for a PDP), this would be a breakthrough product at $2995.

Toppan Printing Company was showing its new EBU-CF matrix color filter (CMF), the first to comply with the color standards of the European Broadcasting Union (EBU) when combined with a backlight containing matching phosphors. To show that an EBU-CF-equipped LCD TV can really match a CRT's color gamut, Toppan was showing various scenes on standard CRT TV and an LCD TV using the EBU-CF. The results were impressive. If anything, Toppan's reds were a bit more saturated than the CRT's and a bit less orange. Not surprisingly, the CRT's image was a bit brighter.

Ise Electronics was showing the Noritake itron line of VFDs and the very bright carbon-nanotube light sources.

Hunet showed the latest version of its field-sequential-color (FSC) 1.5-in. quarter-VGA LCD with 265 ppi. These displays always look better than one would think a quarter-VGA display should look because of the FSC. Hunet claims a 2-msec response time.

Hunet has been working to get agreements with cellular-phone customers, and they now have some, said Etsuro Mori. Volume manufacturing is scheduled to begin in 2001, with the price estimated to be $20 apiece at 1 million per month. Since the demand of cellular-phone manufacturers is likely to exceed that number, the company expects no trouble delivering at that price.

When Hunet was at COMDEX, where there was substantial interest from makers of e-books and PDAs, they were asked if the company could supply a 3.8-in. display. The answer, said Mori, was no, not at this time. "We are a small company and cannot do everything at once. We are very confident in the demand for our technology."

In 2001, IDW will be combined with Asia Display. The combined event, among the most important in the annual display calendar, will be held in Nagoya, Japan, October 16–19. For more information, access http://www.sid.org/conf/idw2001/idw2001.html. ■

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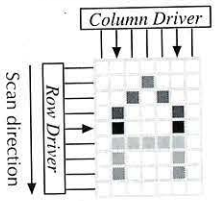

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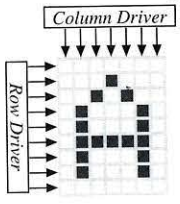

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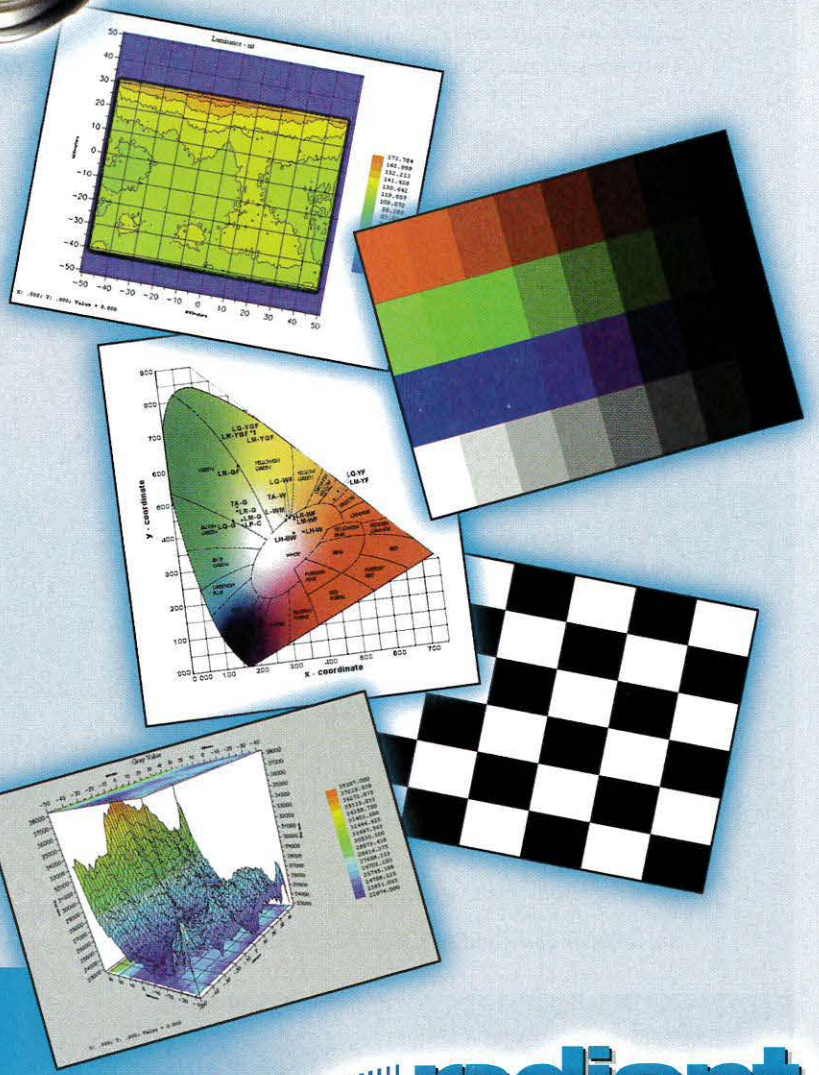

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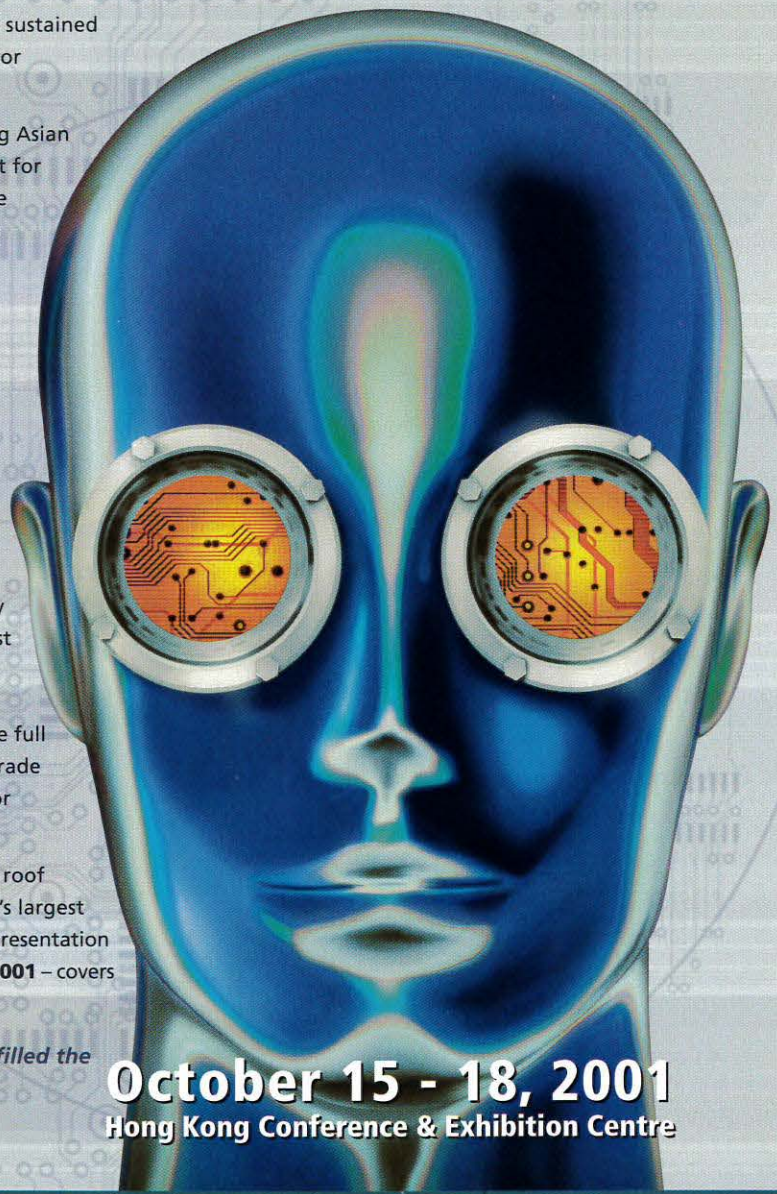

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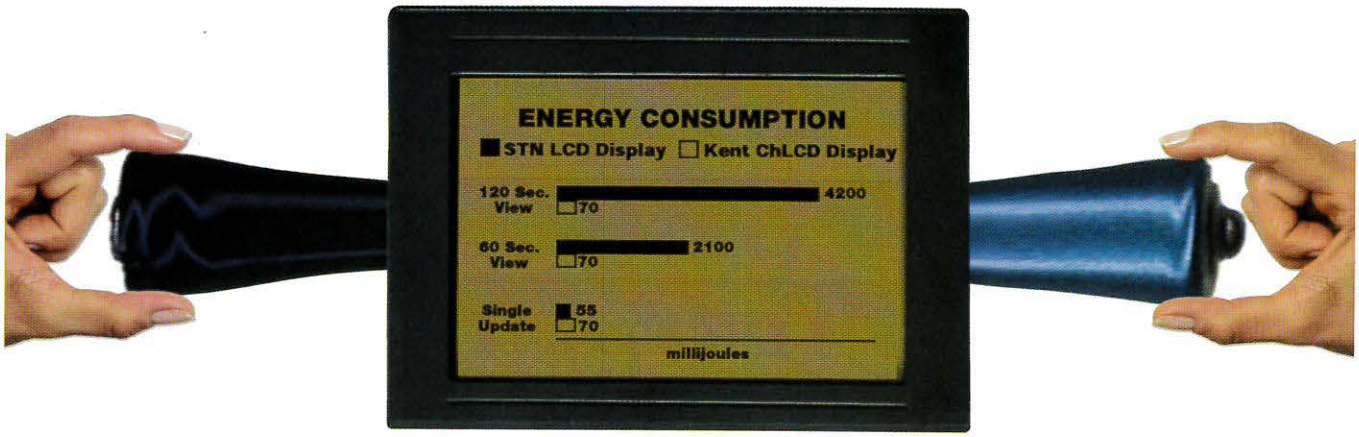

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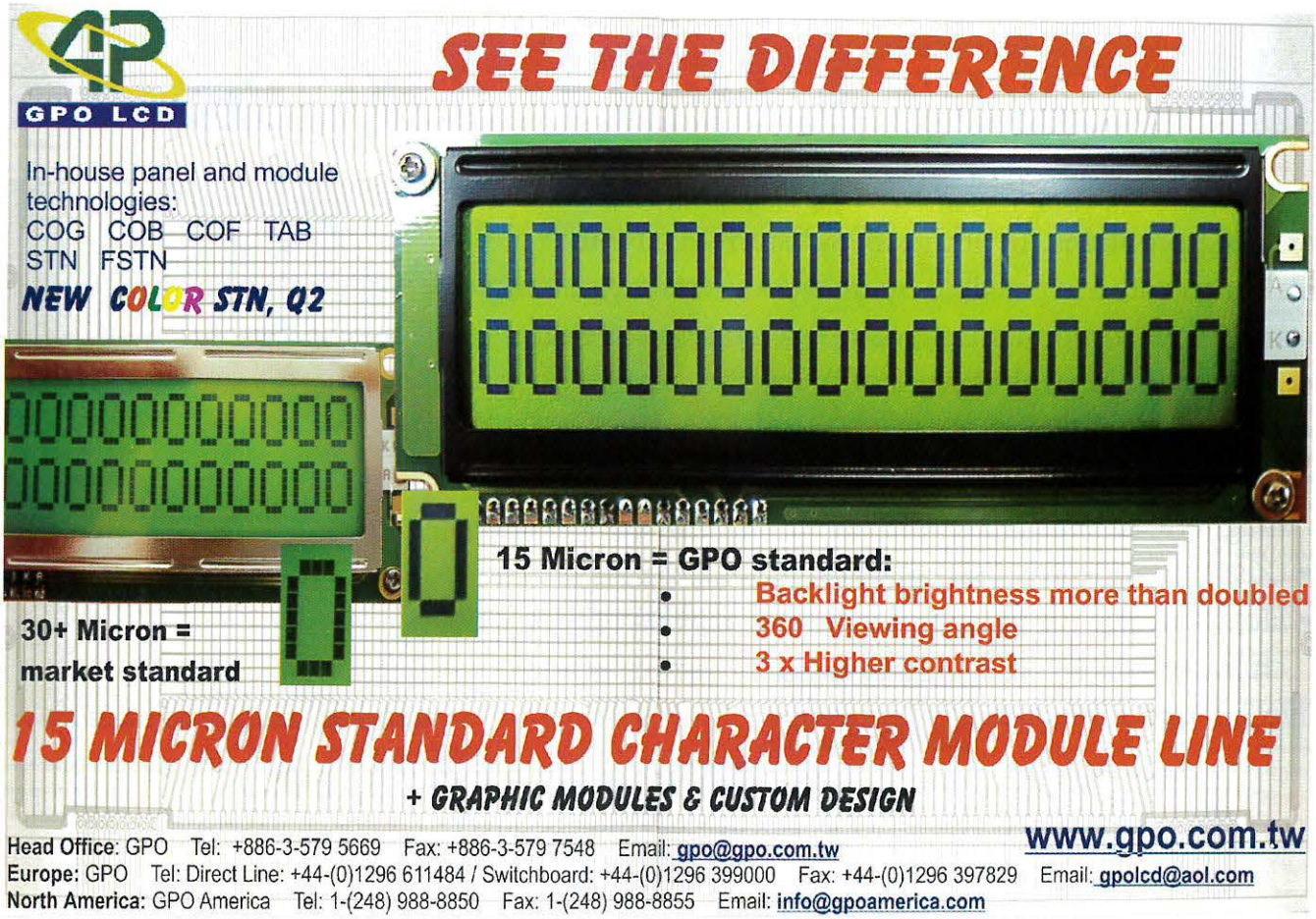

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a view from the hilltop

continued from page 4

out of four successfully, but not the fourth time? I didn't do anything differently that fourth time, so why the red "X" of an illegal operation? That and other peculiarities, such as slowly eroding disk space and suddenly lost printer drivers, don't exactly inspire confidence in these machines as reliable control points in my home or anywhere else in my life.

Given these apparent disconnects between the hopes and aspirations of the computer, software, and Internet providers and the reality experienced by us users, what can we expect to see in the future? Will this discrepancy be resolved, or are we doomed to a stress-filled life of one computer-created crisis after another?

Unfortunately, there is not much that we in the display community can do directly to fix these problems. The products we provide have great reliability and seldom need attention. Both CRTs and LC-based displays are sturdy devices that survive even the rough handling of cross-country and cross-continent shipments without requiring recalibration by the end customer. So what can be done to help with the software-created crises that are likely to get worse before they get better?

Somehow we must encourage the movement toward robust software products that will perform the functions they promise each and every time. These products must be immune to unauthorized attempts to change them. I would find great comfort in an operating system or other software that could only be changed by physically having to read the changes from a CD-ROM. The comfort of such protection (knowing that at least my operating system and my software are immune to invasion) would more than make up for any inconvenience, or small extra expense, of not being able to download updates from the Internet. At least I should be offered that choice in the products I buy. Then, whenever I wish, I could just back up my data files.

An astute attorney once told me that the only reason we have laws and written contracts is for when things go wrong. If we have an informal agreement and everything is going as we hoped, then there is no need for a written document. But when expectations diverge, then we need the protection of a written contract and sometimes even the courtroom. Have we engineers been so naive as to think that everyone would behave honorably

when using computers and the Internet? If we can't count on that in any other facet of our lives, why would it be different with computers? It is as if we have built our electronic houses with no locks on the doors. Anyone can just walk in and vandalize the contents. That seems like a rather naive and unscientific expectation of currently known human behavior.

My prediction is that we will have to struggle with the current situation for at least one or two more years. And it will continue to worsen. But sometime after that, there will finally be so much attention focused on these problems that it will force the major software company(ies?) to create the inherent protections that will allow us to conduct our computer business with a reasonable assurance of reliability and security. We can never expect to eliminate all bad behaviors but we can at least stop extending open invitations.

I would be interested in hearing your ideas on how we can create a more stable and secure environment for our computers and Internet-related activities. Perhaps we can gather them together and send them to the big software makers for their consideration.

Please share your thoughts with me by e-mail at silzars@attglobal.net or president@sid.org, by phone at 425/567-8850, by fax at 425/557-8983, or by the highly reliable and surprisingly secure method known as the U.S. Postal Service at 22513 S.E. 47th Place, Sammamish, WA 98075. ■

Aris Silzars is President of SID and lives on a hilltop overlooking Issaquah, WA.

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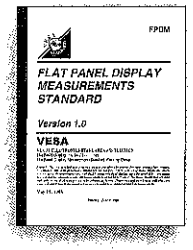

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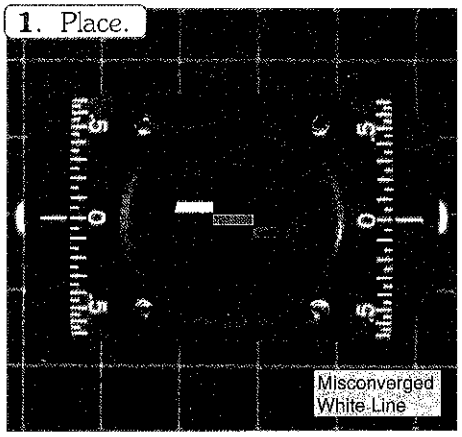

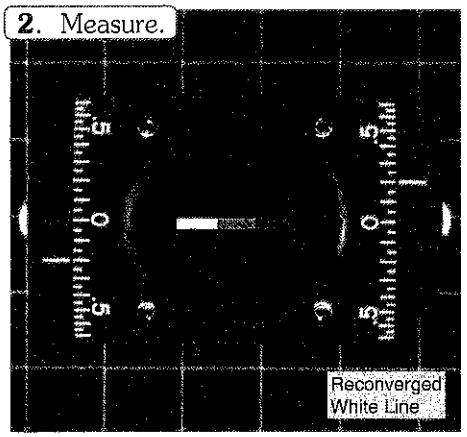

letters

The December, 2000 article, "The Promise of Plasma Displays for HDTV," by Larry F. Weber reveals the many innovative performance improvements for their beautiful 60-in. PDP. Dr. Weber also addresses design features directed towards a lower cost product. The use of a single scan for an XGA display and the use of low-cost soda-lime (window) glass for such a large display are notable achievements. However, their "fence electrode" design, which purportedly "eliminates the need for expensive transparent conductors," does not take into account that very inexpensive, typically an order of magnitude less costly than ITO, tin oxide coatings deposited on the float line as the glass is made are available. Also, a low-cost production-friendly process for etching tin oxide to high resolution (5-μm lines and spaces) (U.S. Patent No. 5,976,396) is available. The etching process is licensed exclusively to AFG Industries, Inc. (AFG) by Feldman Technology Corporation (FTC). AFG has developed an etching machine based on the FTC process and demonstrated its effectiveness and low cost in a production environment.

The use of low-cost tin oxide in association with photodelineated silver bus-bars (DuPont's Fodel®) optimizes the illuminance that can be achieved, minimizes the width of the bus-bar, and automatically provides the black stripe between adjacent pixels. The fence-electrode design reduces the cell aperture by the total electrode width and requires additional pixel space for the isolating black stripes as well as another operation. There are other advantages to the tin oxide/Fodel® approach, including the elimination of an expensive sputtering operation, but the availability of a process which reduces cost at the same time as enhancing performance is the way to go.

– Bernie Feldman
Feldman Technology Corp.

calendar

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June 3–8, 2001 San Jose, CA

INFOCOMM 2001. Contact: ICIA, 703/273-7200, fax -5924.
June 13–15, 2001 Las Vegas, NV

FPD Expo Taiwan 2001. Contact: Cher Wu, SEMI Taiwan, +886-3-573-3399, fax -3355.
June 20–22, 2001 Hsinchu, Taiwan

PC Expo 2001. Contact: CMP Media, 1-800-829-3976, e-mail: kfripp@cmp.com.
June 25–28, 2001 New York, NY

Microdisplay 2001. Sponsored by SID. Contact: Mark Goldfarb, Palisades Convention Management, 212/460-8090 x202, fax -5460, e-mail: mgoldfarb@pcm411.com.
August 13–15, 2001 Westminster, CO

10th Symposium on Advanced Display Technologies. Contact: Dr. A. Smirnov, +375-17-2398858, fax +375-17-2398486, e-mail: smirnov@gw.bsuir.unibel.by.
Sept. 18–21, 2001 Minsk, Republic of Belarus

8th Annual Symposium on Vehicle Displays. Sponsored by SID. Contact: Mark Goldfarb, Palisades Convention Management, 212/460-8090 x202, fax -5460, e-mail: mgoldfarb@pcm411.com.
October 15–16, 2001 Detroit, MI

Asia Display/IDW '01. Contact: AD/IDW '01 Secretariat, c/o The Convention, Annecy Aoyama 2F, 2-6-12 Minami-Aoyama, Minato-ku, Tokyo 107-0062 Japan; +81-3-3423, fax -4108, http://www.sid.org.
Oct. 16–19, 2001 Nagoya, Japan

Electronic Information Displays (EID 2001). Sponsored by SID. Contact: Chris Williams; +44-(0)-1635-298395, fax +44-(0)-1635-299214, e-mail: chris@logystyx.co.uk, URL: http://www.sid.org.uk.
Oct. 30–Nov. 1, 2001 Birmingham, UK

Color Imaging Conference 2001. Sponsored by IS&T and SID. Contact: SID HQ, 408/977-1013, fax -1531, e-mail: office@sid.org.
Nov. 5–9, 2001 Scottsdale, AZ ■

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