FLAT-PANEL ISSUE

Information DISPLAY

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SID

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Displays for Gen 3 Wireless Terminals

- LC Modes for Wide Viewing Angles
- Displays for Portable Communications Devices
- AMLCD Tutorial, Part 2 of 3
- Business Projectors
- Computex Taipei 2001 Report
- PC Expo 2001 Report

SEPTEMBER 2001
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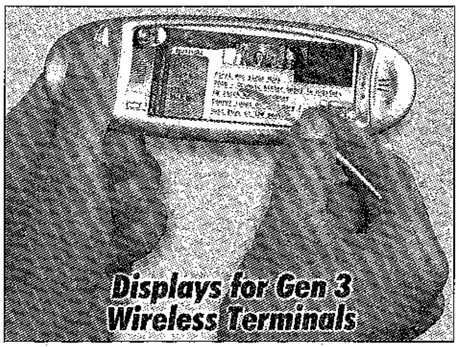
Information DISPLAY

COVER: There's gold in them th'ar hills – the hills of displays for portable communications devices, that is – and display manufacturers are proposing many displays based on different technologies to compete for that gold. But what does a major manufacturer of portable devices say about the likely winners and losers? For the answer, see the article beginning on page 18.



Nokia

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Next Month in
Information Display

SID 2001 Review Issue
- Overview
- Microdisplays
- LCDs
- Emissive Displays
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- Electronics and Interfacing

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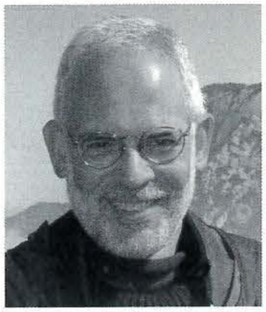
editorial



Kahn International

Display Innovations Scarce at PC Expo

PC Expo, now positioned as the exhibits portion of TECHXNY, may be New York's "largest and glitziest" computer show, but it was a lot less large and less glitzy this year than last. Four days after the close of the show – which ran from June 26 to 28 – the organizers had still not posted attendance figures on their elaborate Web site, and an e-mail request for show stats went unanswered.

But the show's contraction was clear without any stats. The main floor of the Jacob Javits Convention Center, which had been filled with booths last year, had a large, empty area that was curtained off in the rear. And the lower level, which had a large number of booths last year, this year had none. In a late-afternoon talk over sodas in the press room, one person was complaining about the lack of *chotchkes* – New Yorkese for "giveaways" (in this case) – and his children's likely disappointment as a result. Indeed, the number of *chotchkes* (and the amount of imagination behind them) was sorely limited – an indication of reduced marketing budgets this year.

Eric Ullman of Dantz Development Corp. (which was promoting an upgrade to its flagship product, Retrospect Backup for Windows) confirmed the reduced traffic compared to last year, but noted that the press was out in full force. "Well, you guys all work here, right?"

Interesting display-related developments were few and far between, but there were some to be found.

Keyspan was showing its new USB 2.0 PCI card for Wintel and Mac PCs which also supports the old USB Ver. 1.1. The upgraded USB standard supports 480 Mb/s, far more than the 1.5 or 12 Mb/s of the older USB standard. Even though USB 2.0 devices are not yet available, the major players are coming out with cards now. Keyspan's president Mike Ridenhour explained that this is because the introduction of NEC's USB 2.0 chip has made it easy to make cards. Keyspan will be coming out with a PCMCIA USB 2.0 card soon, and perhaps a PCI combo with FireWire.

It is feasible to drive a VGA display at 480 Mb/s, Ridenhour said, but at the latest USB developers' conference there was no talk of display applications; it was imaging and storage applications people were talking about. Drivers are the hold-up now. Microsoft had just put beta drivers on its Web site in the week preceding PC Expo, but only for Windows ME and 2000. Microsoft will not be providing driver support for Windows 98 and earlier versions, Ridenhour said, but Keyspan and other companies will license privately developed drivers and make them available.

UMAX will have a USB 2.0 scanner in the fall, and confirmed that they need the time to test drivers. A UMAX representative said that developmental USB 2.0 models are significantly faster than existing FireWire models, even though the rated speeds are similar.

MARGI Systems was showing its new Presenter-to-Go™ presentation module for the HandSpring Visor's SpringBoard expansion slot. Watching the projection of MARGI's PowerPoint sales presentation from a three-pound projector by PLUS driven by the Visor/MARGI combination had much of the fascination of N-gauge model electric trains: It's surprising that such a Lilliputian system

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Information DISPLAY

a view from the hilltop

Are We There Yet? . . .

by Aris Silzars

The two girls, three and six years old, were peacefully observing the freeway traffic and the California landscape gliding past from the back seat of their parents' minivan on a typically sunny Saturday morning. Their parents had decided to take a drive to explore a new area about fifty miles from their present home in the east bay. It was beginning to look more and more like there might be an interesting new career opportunity developing there. A new display start-up with a rather strange name, but with lots of investor money, had made Richard an offer that he just might not be able to turn down. And it was beginning to look like his wife Emily could also advance her career by a move to this new location.

As they drove, their conversation touched on a number of topics, one of them being why it was necessary to change homes and lifestyles every time a new job came along. What a disruption it was to have to sell their existing home, find and buy a new one, move all of their possessions, and find new doctors, dentists, and all those other services that we take for granted once located. Richard suggested that maybe one day, after he was better established in his career, they would try to create a business that was location-independent. That way they could find a home location they liked because it matched their desired lifestyle and not because it was near their places of current employment. He wondered if the continued development of the Internet and of electronic communications would help him accomplish that.

They were only slightly more than halfway into their drive when Danielle, the older girl, began to ask, "Are we there yet?" Alexandra, the younger, didn't say much yet but Emily could see that she was beginning to squirm in her car seat as a clear indication that this ride had better have a quick conclusion. As Mom and Dad explained that they would be there in about twenty minutes, the question "Are we there yet?" became more frequently heard and with growing frustration. After all, five minutes can seem like an eternity to a three-year-old stuck in a car seat – just about the same as that last half-hour in an economy airplane seat on a flight from Hong Kong to Chicago, shall we say.

For Danielle and Alexandra, "There" was anywhere that would at least temporarily end the confinement of their car seats. And the sooner the better! If this next destination also involved the offering of food, that would be a major positive. "Daddy, I'm getting hungry." "Mommy, I think I'm going to need to go to the bathroom." And finally from the younger one, a robust scream that could no longer be contained or ignored.

For the parents, with their plans of significant career changes and the relocation of their home, this question of "Are we there yet?" had a very different context. Perhaps they would feel more comfortable where "there" was *after* they made their decision whether to accept this new opportunity or not. But then there would still be the even longer-term plans that Richard and Emily were beginning to contemplate for careers that would allow them to pick whatever location they wished while still earning a good income doing what they most enjoyed.

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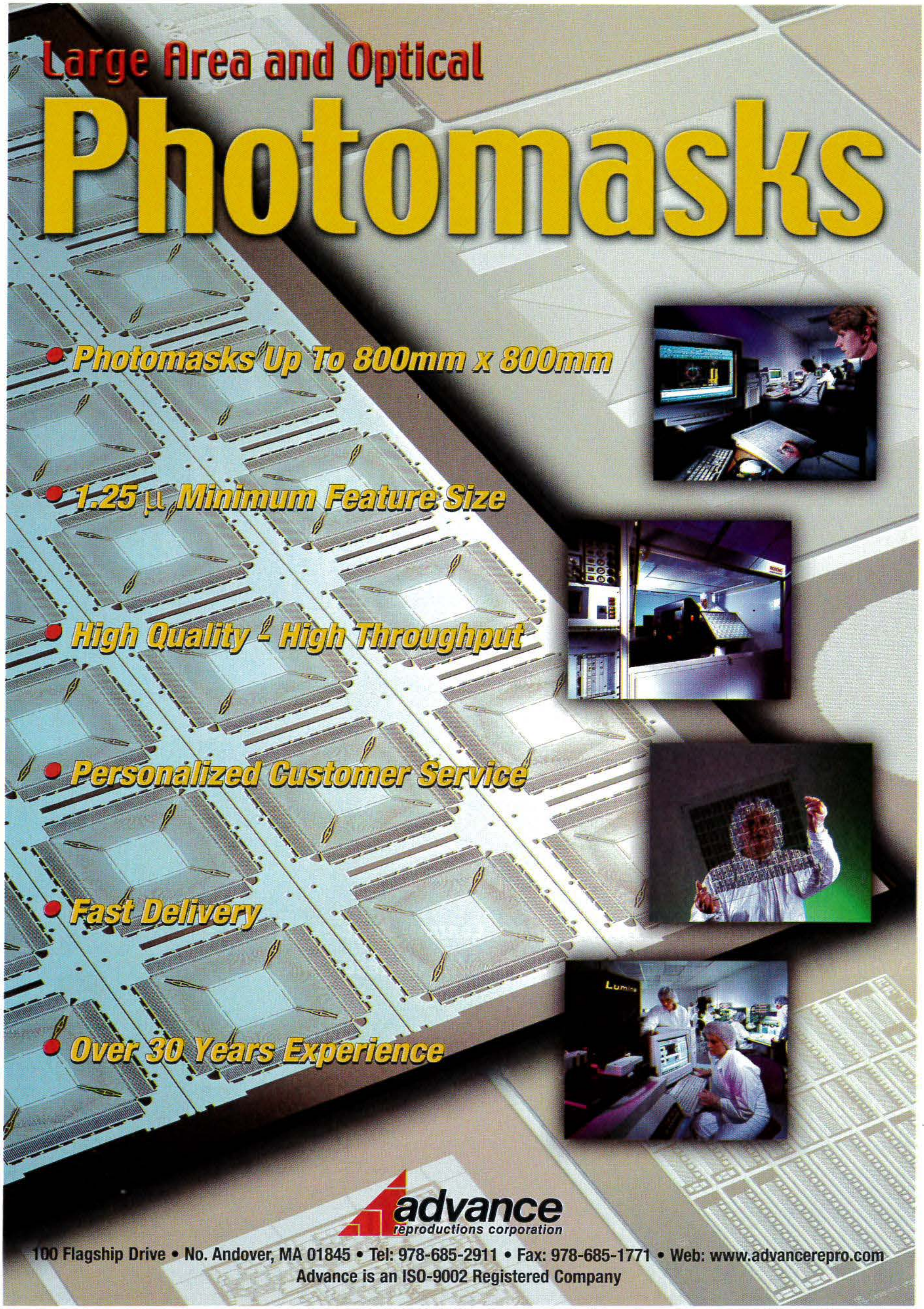
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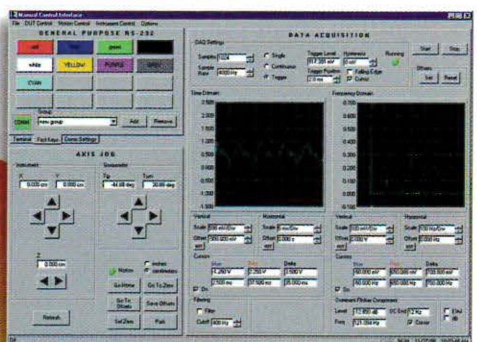

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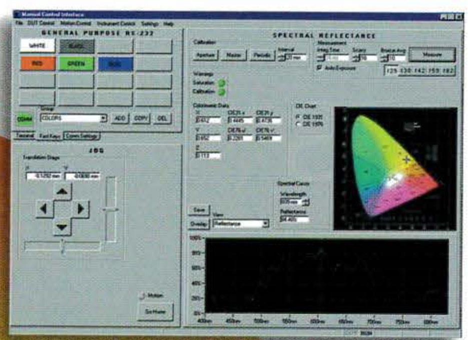

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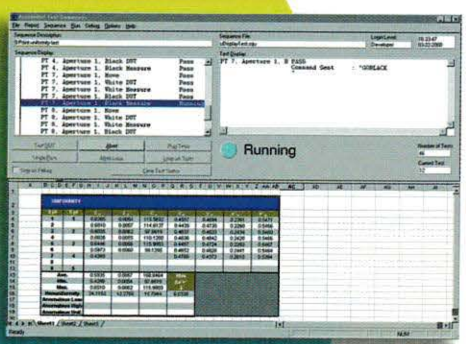

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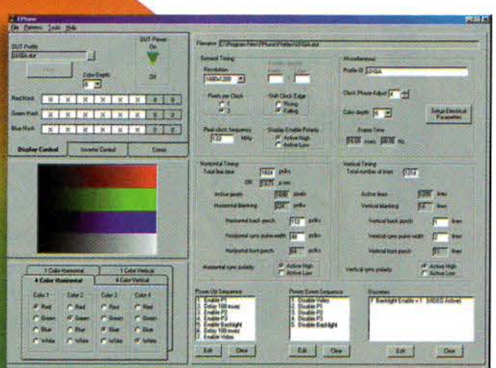

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LC Modes for High-Performance Monitors

IPS and MVA LC technologies provide solutions for the limitations of earlier LC modes in demanding applications, but each technology has distinct advantages and disadvantages.

by Minoru Akiyoshi and Robert Dunhouse

DEVELOPING display monitors for use in industrial and commercial applications presents unique challenges. The multimedia, graphics, CAD, and other professional fields require large high-resolution displays that can manage very large amounts of data. Likewise, medical-imaging systems require very high-quality images. These markets require not only large display size and high resolution, but also an ultra-wide viewing angle, uniformity, high contrast, fast response time, good color saturation, fine gray scale, and a small footprint.

Fortunately for industrial and commercial users, recent liquid-crystal (LC) technology developments have overcome the technical shortcomings of early LC solutions and now offer a viable alternative to the bulkier and more power-hungry cathode-ray tube (CRT). In particular, multi-domain vertical-alignment (MVA) and in-plane-switching (IPS) LC modes hold promise for those seeking LC-based technology with good off-angle viewing. But these two approaches, with all their variations, are not created equal. A good understanding of the underlying technology and the advantages and disadvantages of each approach are essential in making important decisions regarding which technology to employ in an industrial system.

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Traditionally, the CRT display was preferred over the LCD for industrial applications primarily because of the CRT's superior viewing angle. However, the CRT's comparatively large size and high power consumption make it an imperfect solution. Therefore, industrial users have sought a flat-panel display (FPD) with image quality and viewing angles comparable to those of the venerable CRT. Until recently, much of the LC-development effort has fallen short of the goal. Early thin-film-transistor (TFT) LC technologies such as twisted-nematic (TN) LC with added retardation film produced steadily improving – although still insufficient – viewing angles. Such approaches were also deficient in other important areas, such as contrast, color shift, and response time.

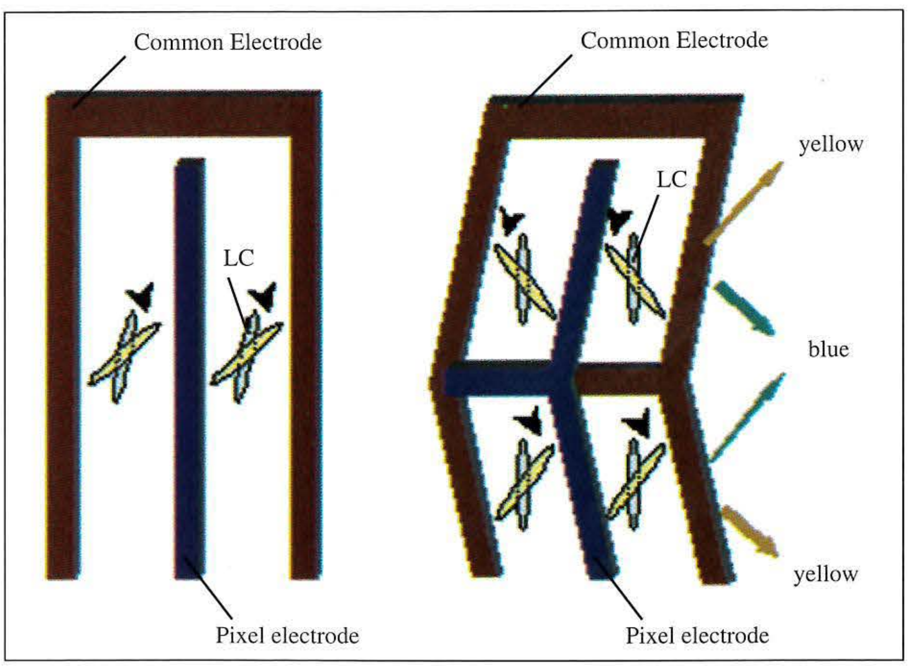

***Fig. 1:** The color shift experienced at viewing angles greater than 45° in the conventional in-plane-switching (IPS) electrode configuration (left) was virtually eliminated in dual-domain IPS, in which an angular electrode arrangement (right) creates two different orientational domains for the LC molecules.*

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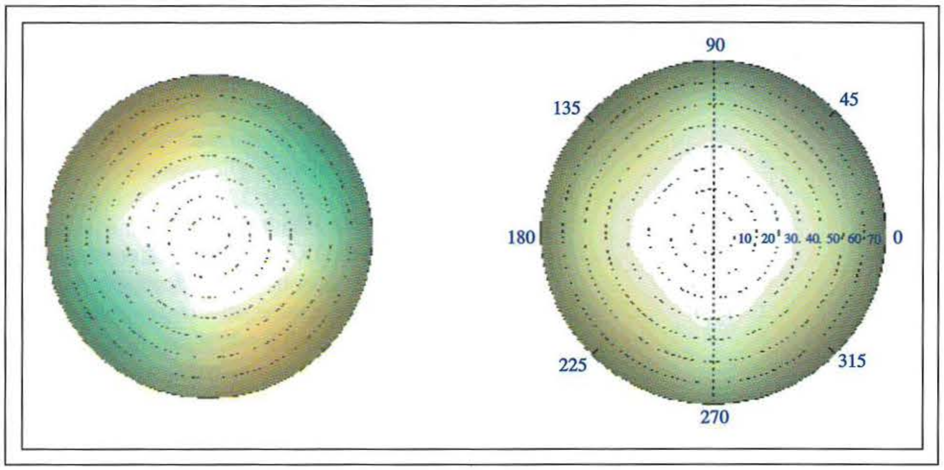

Fig. 2: The dual-domain IPS mode (right) reduces off-angle color shift by 50% compared with that of conventional IPS (left).

We believe that the MVA and IPS techniques represent the current state of the art in LC technology. These two methods offer image quality and other performance attributes that make them attractive alternatives to the CRT for many industrial and commercial applications. At the same time, each of these methods takes a unique approach to addressing the problems presented by earlier LC technologies. The viewing angle becomes less of an issue, but factors such as contrast, response time, color shift, power consumption, and technological roadmaps become critical considerations.

In-Plane Switching

IPS-LCDs – which were commercially available before MVA-LCDs – contain electrodes that are all mounted on the same substrate, instead of being divided between inner and outer substrates as is the case in the traditional TN and MVA LC modes. In the absence of electromagnetic excitation, the IPS LC molecules lie parallel to the substrates and each other, as well as to the cell's electrode pair. When voltage is applied, the LC molecules rotate freely to align themselves with the field while at the same time maintaining their parallel orientation relative to the substrates and neighboring molecules (Fig. 1, left).

The fact that the IPS molecules are not anchored to a substrate, as they are in TN- and STN-LCDs, accounts for a significant advantage over those technologies. In the operational mode of these displays, the further a TN or STN LC molecule is from the anchored end of the chain, the more it attempts to align itself with the field between the two electrodes, at right angles to the substrates. This deviated alignment, in addition to turning the pixel ON, also produces an unintended angular dependency of the light leaving the cell. In other words, the color, shading, and contrast of the image change at increased viewing angles.

On the other hand, because the molecules in an IPS display are untethered and because they are subjected to a field that is parallel to the substrates, they too are always parallel to the substrates. Therefore, molecular orientation does not vary, and viewing angles of 160° are possible. Color integrity in an IPS-LCD is maintained, although brightness can drop off as viewing angle increases.

Early IPS-LCDs presented three issues: color shifts at a 45° viewing angle, slower response time, and higher power consumption. But subsequent IPS developments effectively addressed these technical issues. The color shift at a 45° viewing angle arose from the molecules' being in a single domain, which was defined by the simple parallel-line configuration of electrodes in conventional IPS displays. A solution was found by configuring the electrodes in an angular pattern (Fig. 1, right), which produced two domains, each of which largely compensated for the angular dependency of the other. This "dual-domain" IPS mode reduces off-angle color shift by 50% compared with that of conventional IPS (Fig. 2). By adjusting LC viscosity, controlling panel gap, and optimizing electrodes, designers were able to make dual-domain IPS 50% faster than the original IPS displays.

In conventional IPS, placing both electrodes in a single plane created a power-consumption issue. Since each cell contained two light-blocking electrodes, early IPS pan-

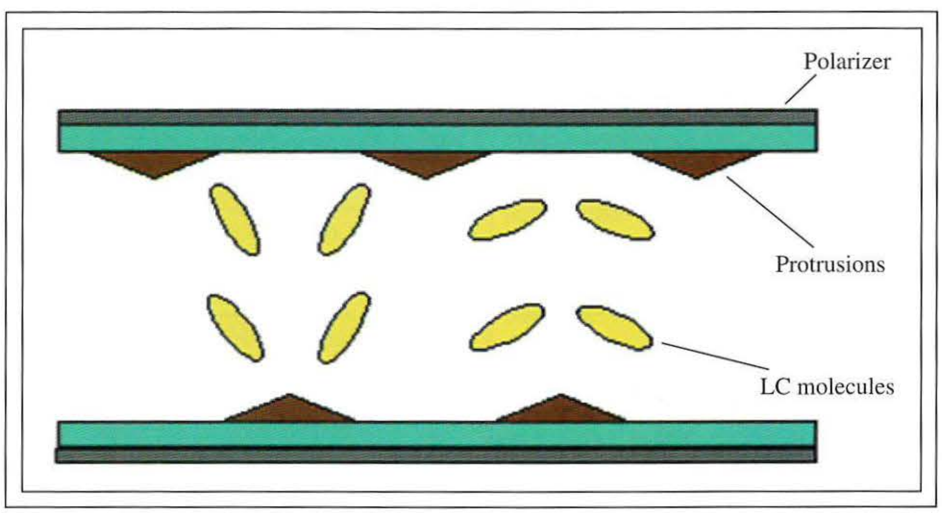

Fig. 3: Multi-domain vertical-alignment (MVA) LCDs employ an LC mode with predominantly vertical alignment in combination with multi-domain alignment to provide good image quality and wide viewing angles. In the OFF state (left), MVA molecules are aligned in a predominantly vertical direction, which increases the molecules' ability to block light, producing a very black dark level and a high contrast ratio of 300:1.

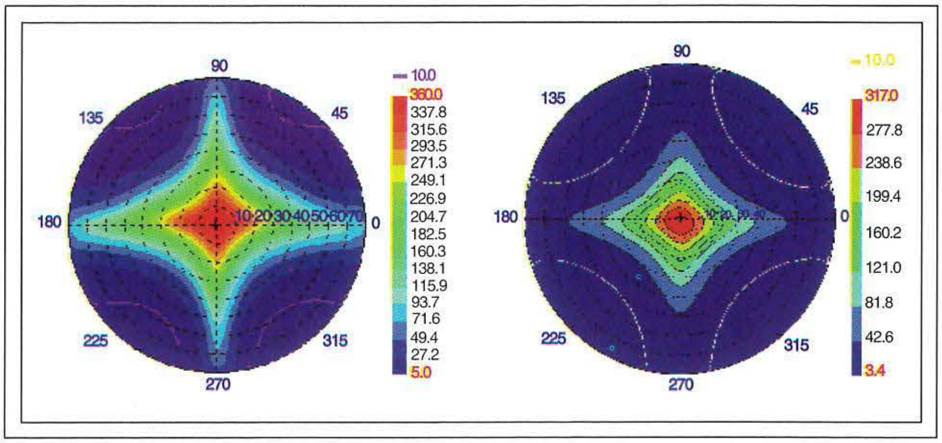

Fig. 4: The contrast of MVA (right) is high at viewing angles near perpendicular, but it does not hold up well at large viewing angles. The contrast map for NEC's dual-domain IPS technology, which it calls "advanced super-fine technology" (A-SFT), is on the left.

els required a brighter backlight. The additional power required for the backlight made these early panels unsuitable for battery-powered applications. New electrode structures have now reduced power consumption to about 24 W for a 15-in. panel that produces 200 cd/m^2.

Multi-Domain Vertical Alignment

MVA technology was introduced to compensate for the early disadvantages of IPS. MVA employs an LC mode with predominantly vertical alignment in combination with multi-domain alignment to provide good image quality and wide viewing angles. In the OFF state, MVA molecules are aligned in a direction that is predominantly vertical with respect to the two substrates, and the molecules are in two groups that are not aligned parallel to each other (Fig. 3). The vertical alignment of the molecules increases their ability to block light in the OFF state, producing a very black dark level and a high contrast ratio of 300:1.

Under electromagnetic excitation, the molecules swing through 90° to lie in a direction that is predominantly parallel to the substrates. The negative dielectric anisotropy of the vertically aligned molecules results in a response time of less than 25 msec, a dramatic improvement over that of conventional IPS- and TN-LCDs. Multi-domain alignment of the vertically oriented molecules is achieved using UV light to create angular protrusions within each LC cell. The UV process is a more reliable and productive manufacturing method than the traditional rubbing process which can introduce contamination into the LC, which produces defective displays. The LCs within each individual domain align along the cell's inclinations instead of at right angles, resulting in viewing angles of about 160°.

Comparing IPS and MVA

The IPS and MVA LC modes offer substantial improvements over their predecessors, but they are not the same, and they each have their strengths and weaknesses. MVA has good viewing angles, response time, and contrast ratio, but the alignment of MVA molecules can be distorted by a physical shock or vibration because the LC molecules are not anchored to a rubbing layer. As a result, MVA panels are not well suited to mobile applications. The contrast of MVA is high for ON and OFF modes at viewing angles near perpendicular, but it does not hold up well at large viewing angles (Fig. 4, right). The fact that the LC molecules in MVAs are not bound to a rubbing layer means that the restoring forces are relatively weak, which results in an optical response time at darker gray levels that is faster than that of IPS (Fig. 5).

NEC's A-SFT

In an effort to overcome the drawbacks of conventional IPS and MVA technologies, while incorporating the benefits of each, we at NEC have developed a dual-domain IPS technology that we've named "advanced super-fine technology" (A-SFT).

Typically, when customers look for the proper panel to serve their industrial needs, they focus on contrast ratio. But as more applications that require extreme viewing angles emerge, color shift becomes an important factor.

Until now, MVA panels have had an ON-OFF response faster than that of IPS panels. However, by adjusting LC viscosity, controlling panel gap, and optimizing electrodes, the developers of A-SFT have achieved an overall ON-OFF response time comparable to that of MVAs, and speeds in the middle gray scale of less than 25 msec.

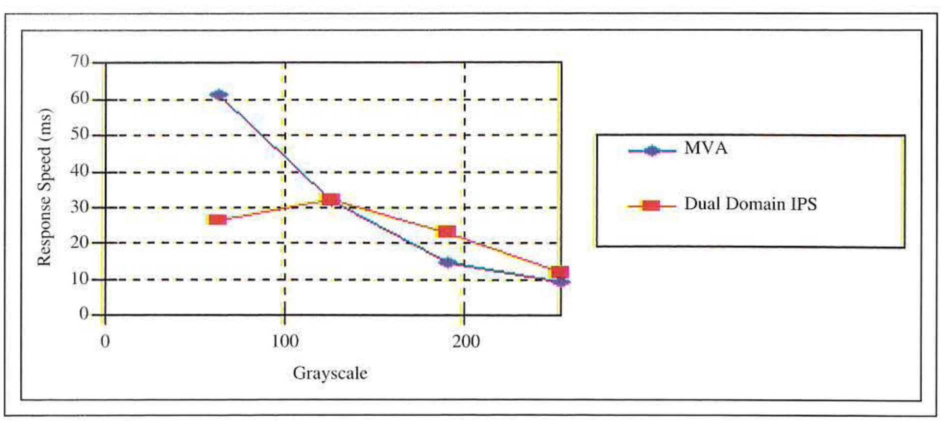

Fig. 5: Because the restoring force on the LC molecules in MVA displays is relatively weak, the optical response time at darker gray levels is slower than for IPS.

What the Future Holds

NEC is offering A-SFT LC technology as a very strong candidate for surpassing the CRT in color saturation, viewing angle, contrast, and response time. But there are certainly other LC modes under investigation with characteristics that are comparable to the MVA and IPS techniques. One of them is the optically compensated bend (OCB) mode, which has been successfully demonstrated but is not yet commercially available.

Today's advanced LC technologies finally provide industrial and commercial users with viable alternatives to the power-hungry and bulky CRT for industrial applications. Now that viewing angles of 160° have been achieved, LC developers can focus on factors such as power consumption, contrast, and response time – and current IPS and MVA techniques deliver acceptable performance in these areas. ■

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Displays for Portable Communications Devices

While mobile-telephone makers wait for the emerging-technology learning curve to turn, the LCD industry retains its grip on the market.

by Jyrki Kimmel

THE DEVELOPMENT of cellular-telephone systems and services in the 1990s has led to a new way of communicating both at work and in domestic life. The simultaneous boom of the Internet has initiated a digital convergence in which communications, entertainment, and information services will be brought together for the user in a seamless, interactive platform. Terminals are a varied lot at the moment, but whatever the user paradigm of the future will be, it is clear that the importance of the display will increase as more data is made available to the user at an ever faster rate.

In mobile telephones, this means enhancing the visual user experience while retaining high-quality voice-communications capabilities. Today, the typical mobile telephone has a film-compensated supertwisted-nematic (FSTN) liquid-crystal display, although promising candidates for replacing this established technology are on the horizon. Bringing the Internet to the mobile terminals equipped with the new displays will be an important enabler of a mobile information society.

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Development of Cellular-Telephony Systems

The development of portable communications devices and the extended coverage of cellular telephony were extremely rapid in the 1990s (Fig. 1). Moving from analog-based first-generation systems to digital cellular-telephone services such as the Global System for Mobile Communications (GSM) has been rapid, particularly in Europe and Asia. In the process, the cellular telephone has become an everyday product. In some countries, the market penetration of the GSM terminals already exceeds that of land-based telephones.

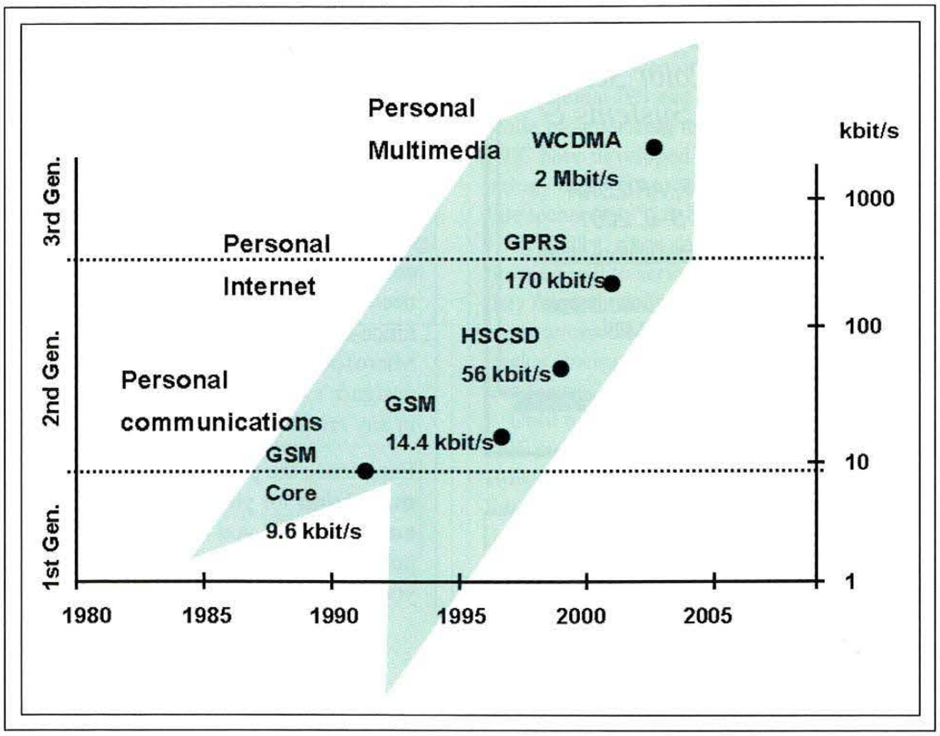

Fig. 1: Services for cellular networks have developed rapidly over the last decade, and will continue to do so as current plans are implemented.

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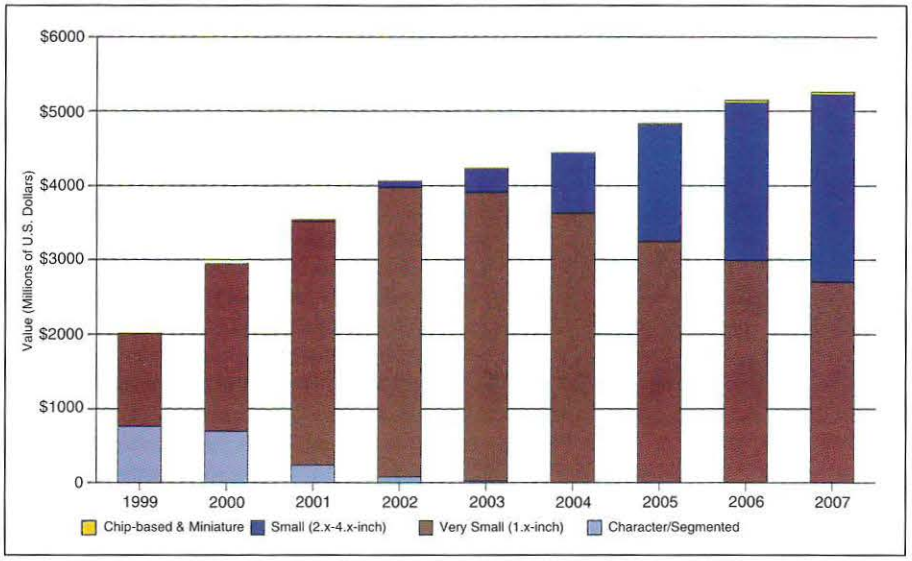


***Fig. 2:** In its latest report (May 2001), Stanford Resources predicts that the market for liquid-crystal cellular-phone displays (both monochrome and color) will grow steadily between now and 2007, with more capable graphics displays increasing their penetration of the market. Sales of chip-based and miniature displays will begin to appear midway through this period, but at levels that can barely be seen on the chart. (By permission of Stanford Resources, an iSuppli Company.)*

In preparation for the third generation of mobile telecommunications services, the present digital networks are being upgraded to allow for more data bandwidth and better voice quality. These developments are leading to an increase in the proportion of the bandwidth used for multimedia data in relation to that used for voice communications.

A parallel trend is the development of short-range wireless office networks by leading cellular-network makers. These networks will encourage and accommodate further improvements in the data capabilities of portable communications devices. The kinds of advances seen in the mobile telephony services are expected in these terminals as well.

Portable data terminals of the future will increasingly be connected to the wireless network. The communications features of some devices may not be obvious to the consumer, but it is expected that new PDAs, electronic books, and even laptop computers will all be wireless in the future. The trend is exemplified by the common use of the GSM network today in downloading and sending e-mail either by using a portable telephone attached to a laptop computer *via* an infrared or a cable-based data link or by using a dedicated communications device that has these features built in along with a GSM phone. This is only the beginning of the era of digital convergence, which will be emerging with the new network standards.

Combining a high-quality display with a digital camera in a terminal will enhance the non-voice multimedia use of terminals in third-generation networks. Even today, communicator devices have digital-camera interfaces, but the narrow bandwidth of the GSM network reduces the usefulness of this feature. In the third generation, however, video telephony will become an attractive and powerful application.

Trends in Display Modules

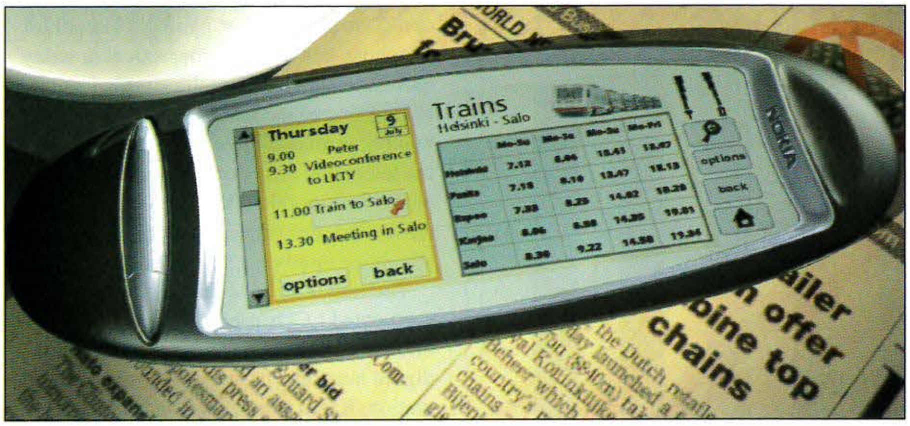
The need for two hands – holding the receiver of the telephone to one's ear with one hand while dialing a telephone number with the other – to operate the "plain old" land-based telephone has become impractical in today's mobile telephones, and the simple feedback of listening to the DMTF tone of the dialed number is unavailable. A display as part of the telephone has became an important element of mobile telephones because it allows the user to see the numbers as the telephone number is being dialed.

The first telephone displays were one-line segmented LCDs used only for showing the dialed number. When second-generation digital networks began to deliver more information, it was necessary to add more features onto the display. Icons were used to indicate signal and battery strength as well as notification of incoming messages, and more lines of text were provided for sending and receiving short messages. At Nokia, we launched a new type of terminal, which we called the Communicator, to take advantage of the 9.6-kbits/sec data channel of the GSM, and added a wider display to the device. Later, games started to appear on telephones, and the displays changed to graphics displays. Now, line-based displays are all but disappearing from the mobile market (Fig. 2).

Integration trends have become important. At first, "handheld" mobile telephones were bulky, containing several separate circuit boards, and the small display was held in place by the telephone frame connected with a zebra strip. As the terminals became smaller, the proportional size of the display increased, requiring the driver chip to be integrated with the display, first as chip-on-film (COF), but moving rapidly to chip-on-glass (COG). As display size increased, backlight design advanced together with light-emitting-diode (LED) efficiency, making it possible to create a backlight with fewer LEDs that was still quite uniform. This, in turn, made it possible

Table 1: Evolution of Display Modules in Recent Nokia Cellular Telephones

Phones (Nokia Model)	Resolution	LCD Power (approximately)	Number of LEDs (Display Backlight)	LED Power (Display Backlight)
2110	4 lines of 12 characters	60 µA × 7.2 V	8	~250 mW
6110	84 × 48 pixels	100 µA × 3.6 V	6	~150 mW
7110	96 × 65 pixels	100 µA × 3.6 V	4	~100 mW



Nokia

Fig. 3: Nokia's vision of a third-generation wireless terminal.

to reduce the power consumption of the display (Table 1). Present display modules are complex assemblies incorporating LED illumination for the keypad and on/off controls, and sometimes even loudspeakers in the same module.

The Third Generation and New Demands

The first GSM implementations utilized the GSM phase 1 framework. Phase 2 was scheduled for the latter half of the 1990s, and now includes increased data bandwidth, implemented by using multiple slots in the GSM channel space, enhanced-data-rate audio codecs, and packet-radio capabilities. This development is commonly called the Generation 2.5 cellular system, or GSM phase 2+.

One example of phase 2+ services is the Wireless Application Protocol (WAP), which enables Web browsing *via* proxies and filters in the network. A similar system, i-Mode in Japan, has Web capabilities as well. This development ultimately leads to the further use of audiovisual multimedia in mobile communications terminals.

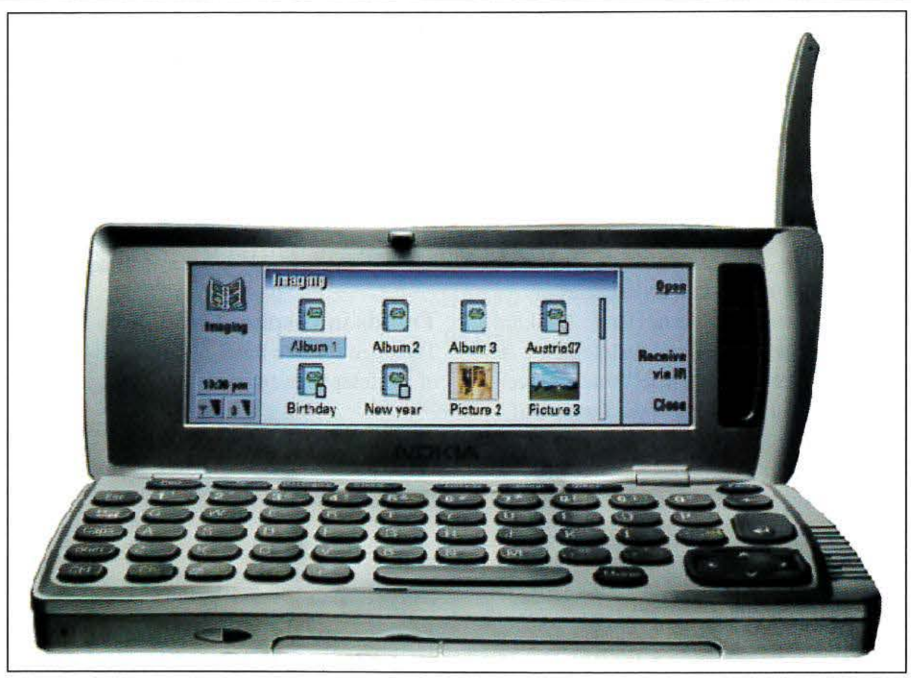
These demands have led to the development of the third-generation cellular-telephone system, which is scheduled for commercial launch in 2001, first in Japan and then elsewhere. The operator licenses for the third generation are already being sold or auctioned worldwide. The standards proposals define the maximum data speed of this new network to be 2 Mbits/sec to a stationary terminal – 200 times that of the basic GSM data speed. This will easily allow live video reception. The technology will be based on a wideband CDMA (W-CDMA) standard.

All wideband consumer and business applications require high-quality displays to be worthy of investment (Fig. 3). The portability of the terminals, power-consumption demands, and environmental concerns impose stringent requirements on these displays. Many emerging technologies have the necessary characteristics for a particular type of portable communications terminal, but none of these technologies can provide an "ultimate display" that would satisfy the demands of all the applications. A careful trade-off analysis is required for any new application of high-information-content displays .

Emerging Display Technologies

Although trade-offs are unavoidable, there are a number of emerging display technologies that may be able to help the consumer resolve the problem of viewing visual data content on a small device. In the Japanese market, mobile telephones with reflective color screens are already prevalent, and the same trend is being seen in gaming terminals and PDAs. The color space of the displays is still quite poor, and the use of a frontlight is necessary when the ambient light level drops.

Today, frontlight designs are quite good, resulting in a visually acceptable display concept. But the power consumption is increased tremendously by using a frontlight, driving the display at video rates, and perhaps choosing an active matrix to drive the display. In mobile phones, this can be detrimental to the



Nokia

Fig. 4: Nokia's 9210 Communicator with a transmissive AMLCD (the U.S. version will be the 9290) offers e-mail and fax capabilities.

basic voice-communication functions of the terminal.

This thinking leads to a search for more-efficient displays, but all the attractive candidates have drawbacks. Reflective LCDs, for example, are always facing a compromise between reflectivity and color-filter thickness. Organic emissive displays (OEDs), in particular, are being hailed as the new promising display for mobiles because of the inherent efficiency of the material. But this may be fallacious reasoning when applied to high-information-content displays. OEDs have good efficiency when operating under direct drive, but multiplexing leads to a drop in efficiency [see Mark T. Johnson and Aad Sempel, "Polymer-LED Matrix Displays," *Information Display* **16**, No. 2, 12–15 (February 2000)]. And avoiding multiplexing by using an active-matrix backplane may result in prohibitively high power consumption.

Researchers do not seem to be satisfied with the current backplane alternatives because of the nonuniformity associated with organic displays. Internal compensation of the transistor circuits so that gray scale can be driven at constant current steps is quite a different problem from driving an LC. There are also concerns about the lifetime of OEDs. Among these is that differential aging of the different color emitters may produce a shift in the color balance over time. All active-matrix OEDs still seem to be in the laboratory stage, and resolving current production problems is surely a challenge to the display industry.

Low-temperature-polysilicon (LTPS) backplanes have the potential to be used in mobile terminals because they allow increased functionality to be placed on the glass. Just incorporating the row and column drivers under the LCD seal area would be a benefit to the phone maker because it saves space and reduces the number of connections.

Plastic substrates are a topic that resurfaces now and then. For a mobile-telephone maker, the reduced weight of plastic displays is the key benefit. Flexible displays might open up new possibilities, but, so far, good color displays on plastic have not been seen on the market. This includes plastic OEDs, which present their designers with formidable challenges in developing barrier layers that effectively block the migration of oxygen and humidity for a prolonged period of time. In general, plastic displays have larger seal areas around the active area, which leads to inefficient use of valuable space in the user interface. And, so far, it has also been necessary to make the ITO lines wider because of the lower process temperatures required, leading to displays with modest pixel pitch.

The alternative to direct-view displays is to tackle the power-consumption problem by using virtual displays. The virtual-display makers have offered their microdisplays to the mobile-telephone market, stating that their displays would provide an economical way to read e-mail, fax messages, *etc.* But many mobile-telephone makers already have this capability in their current product line, using a simple direct-view display. For example, the latest Nokia model, the 9210 Communicator (the U.S. version will be the 9290) uses a transmissive active-matrix LCD (AMLCD) for these functions (Fig. 4).

Thus, the microdisplay makers have started to look into third-generation systems, trying to find a market for SVGA color-sequential displays. This is a promising trend, but as either a phone accessory or an integral mobile-telephone part, these displays still require the user to utilize a separate input mechanism before fully benefiting from using the microdisplay.

The Best Display?

There are a number of promising technologies on the market to help resolve the problem of showing more visual content in a small space. But in many cases, the user paradigm has not been determined, or the displays consume too much power to handle the new demands well. Emerging technologies are still facing a learning curve, and while the mobile-telephone makers wait for the curve to turn, the LCD industry still has a firm grip on the market. ■

Fabricating Color TFT-LCDs

Displays are made with a demanding set of processes similar to those for making ICs, but while IC makers save money by making their chips smaller, display users insist on having displays that are larger.

by Sang Soo Kim

THE PRESSURE TO REDUCE the manufacturing cost of thin-film-transistor liquid-crystal displays (TFT-LCDs) is as constant and intense as it is in the semiconductor industry. To increase productivity, integrated-circuit (IC) makers continuously reduce the sizes of c-Si chips and transistors in order to increase the number of chips per wafer (Fig. 1). But this strategy does not work for LCDs because the panel sizes that users demand most get steadily larger, not smaller. Still, by increasing the number of panels produced on a single substrate, the cost of TFT-array processes can be reduced (Fig. 2). This process requires that the size of the glass substrate be steadily increased so that the number of LCD panels fabricated upon it can increase (Fig. 3). New generations of process equipment must be continually designed and built to achieve these increases.

The fabrication processes this equipment must implement will be described below. We can assume that the display being fabricated is a color TFT-LCD that uses an inversely staggered amorphous-silicon (a-Si) TFT as the active-matrix switching element.

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Fabricating the TFT Array

The manufacturing process used to fabricate an a-Si TFT array is very similar to that used to fabricate c-Si semiconductor devices. The various steps, including cleaning, deposition of thin films, photolithography, and wet and dry etching of the thin films, are also very similar. The difference between the a-Si TFT process and the c-Si semiconductor process is that a semiconductor layer is deposited onto a glass substrate in the a-Si TFT process, while Si wafers are used as the substrate in the c-Si semiconductor process. Today, the critical issues in the processing of TFT arrays include the development of a low-resistance gate bus line, uniform and fine etching, and improved lithographic accuracy. TFT-array technologies are aimed at achieving high precision, large aperture ratio, and low power consump-

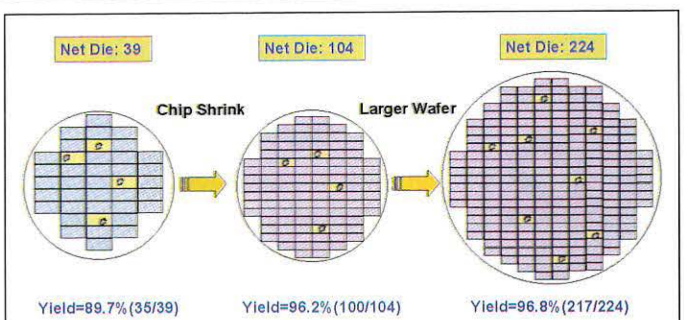

Fig. 1: IC makers increase productivity by continuously reducing chip size and increasing wafer size to increase the number of chips per wafer.

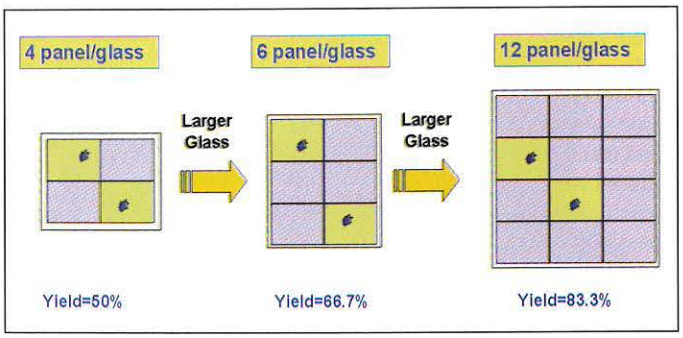

Fig. 2: The IC makers' size-reduction strategy does not work for direct-view LCDs, but LCD manufacturers can still reduce the cost of TFT-array processes by increasing the number of panels produced on a single substrate.

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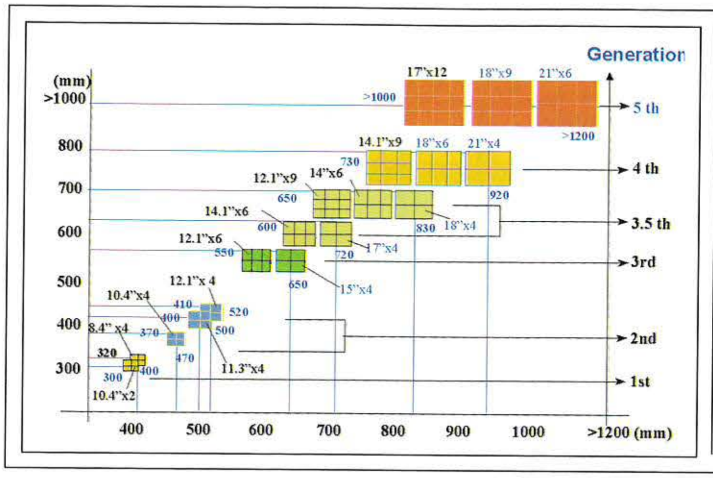


Fig. 3: *For more panels to be put on a glass substrate, the substrate size must be steadily increased, which requires the continual design and construction of new generations of process equipment.*

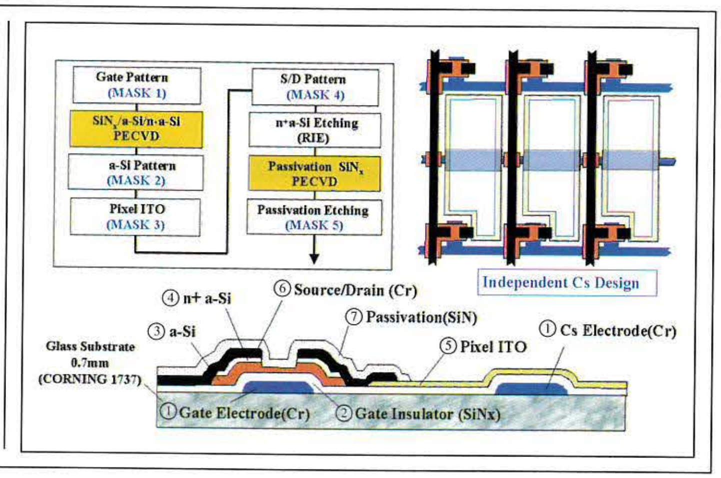


Fig. 4: *The processing of an a-Si TFT array is complex. This flow chart outlines the processes for making an a-Si TFT array using a bottom-gate TFT structure and an independent storage capacitor.*

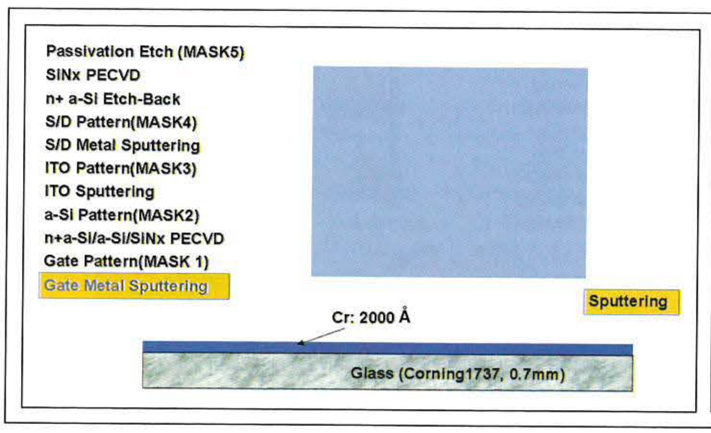


Fig. 5: *TFT fabrication: Gate-metal deposition by sputtering.*

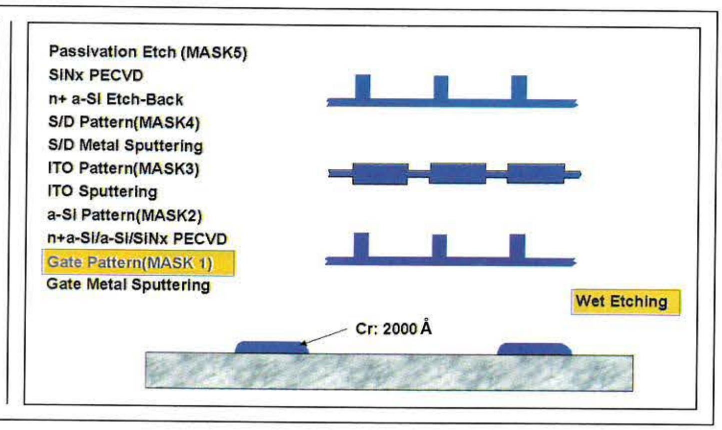


Fig. 6: *TFT fabrication: Gate-metal patterning (1st mask).*

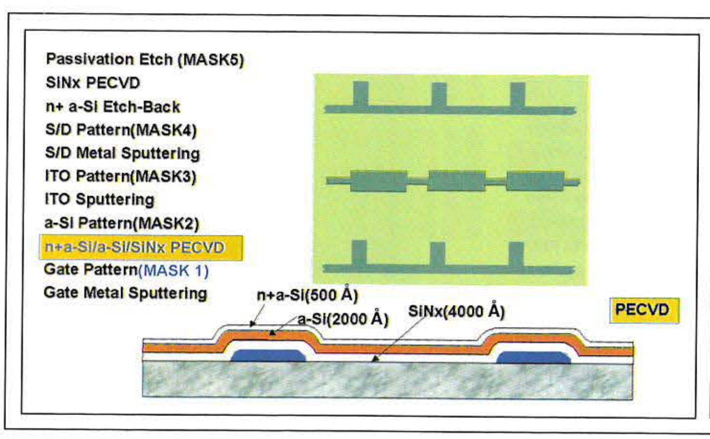


Fig. 7: *TFT fabrication: Deposition of* n^+ *a-Si/a-Si/*SiN_x *triple layer using PECVD.*

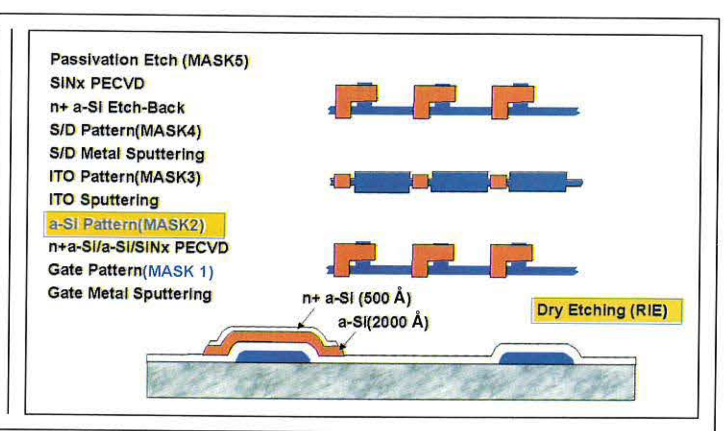


Fig. 8: *TFT fabrication: Patterning of a-Si islands (2nd mask).*

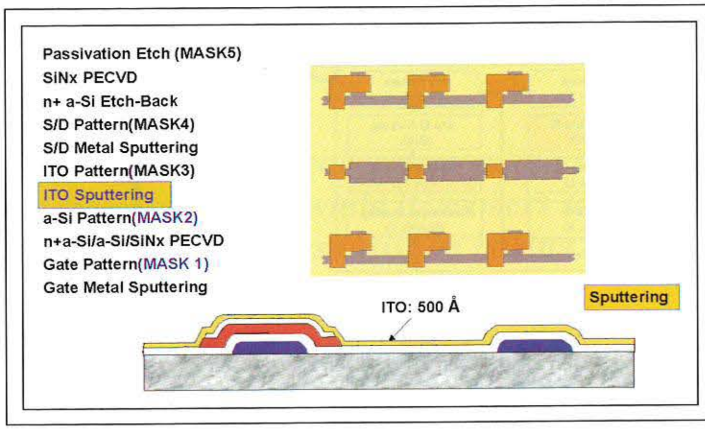


Fig. 9: *TFT fabrication: Pixel ITO deposition by sputtering.*

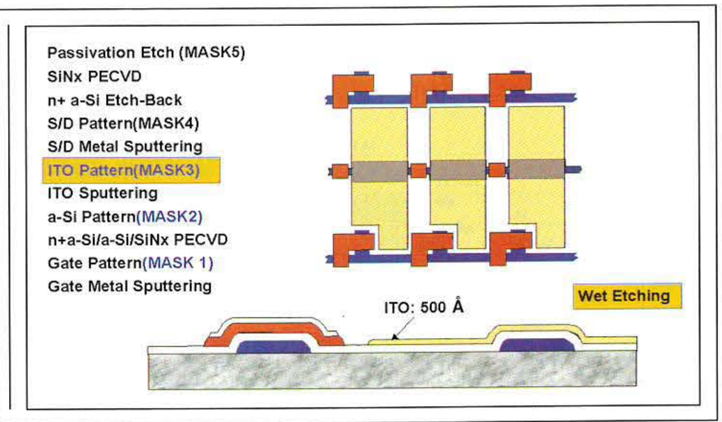


Fig. 10: *TFT fabrication: Patterning of pixel ITO (3rd mask).*

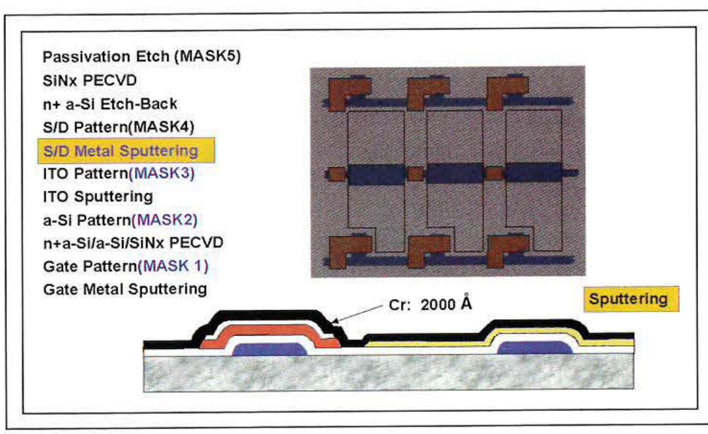


Fig. 11: *TFT fabrication: Data bus line and S/D metal sputtering.*

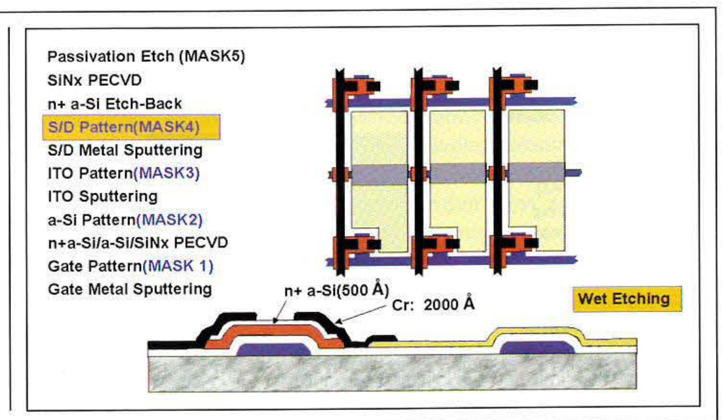


Fig. 12: *TFT fabrication: Data bus line and S/D patterning (4th mask).*

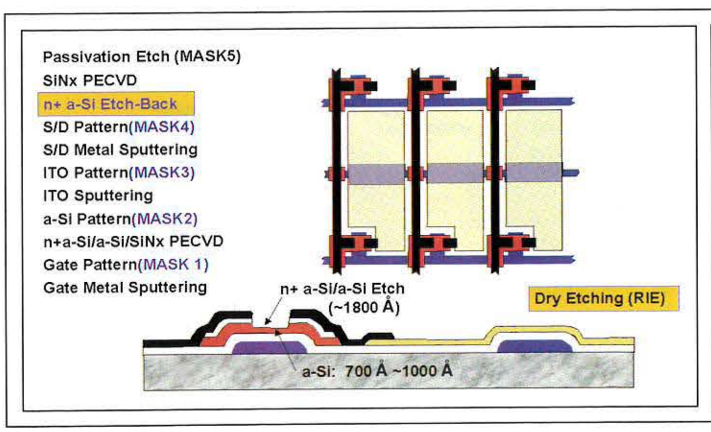


Fig. 13: *TFT fabrication: Etch-back of n^+ a-Si using the S/D layer as a mask.*

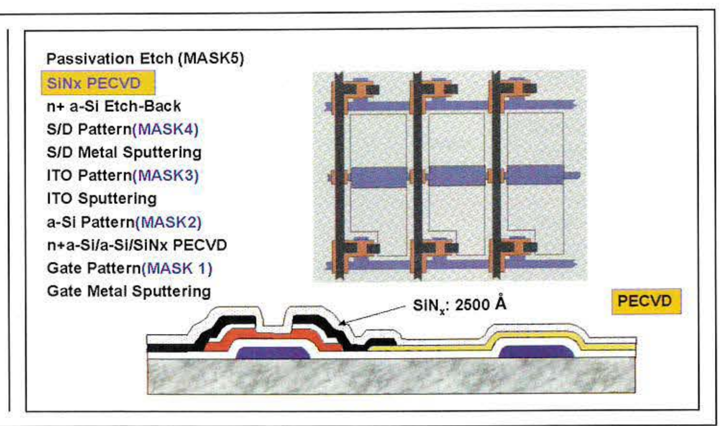


Fig. 14: *TFT fabrication: Passivation SiN_x deposition using PECVD.*

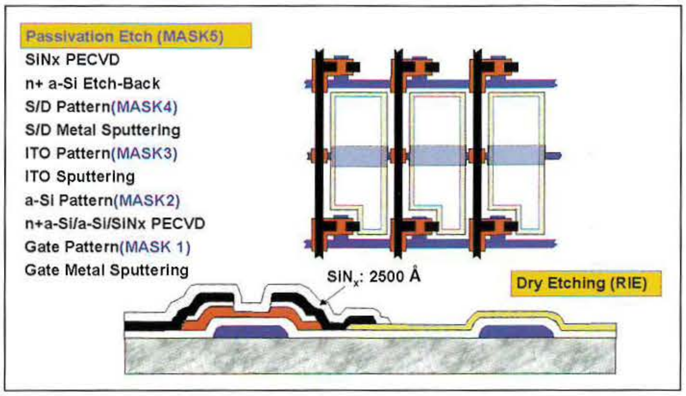


Fig. 15: TFT fabrication: Passivation SiN_x etch using RIE (5th mask).

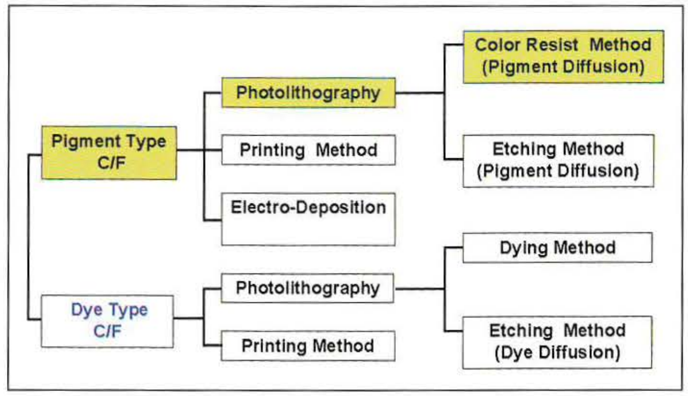


Fig. 16: Color filters can be made with either dyes or pigments, utilizing various coloring methods.

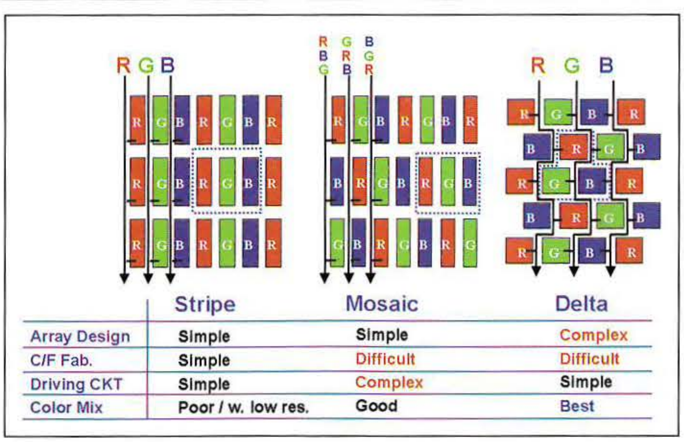
tion, in addition to large screen size. Active-matrix LCD (AMLCD) manufacturers are also competing to minimize the number of array processes by reducing the number of photomasks and simplifying the thin-film-formation and etching processes.

In the bottom-gate TFT-array fabrication process, the first layer consists of the gate electrodes and gate bus lines, which can have one or two metal layers. Some storage capacitors can be constructed by using a part of the gate electrode as a storage-capacitor electrode (which is called the Cs-on-gate method), while other capacitors are constructed independently of a gate bus line. If the independent Cs lines are constructed simultaneously with the gate bus lines using the same metal layer, there is no difference in the fabrication process between the Cs-on-gate method and the independent Cs bus-line method.

The processing of an a-Si TFT array is complex (Fig. 4). After constructing gate and storage-capacitor electrodes with 2000–3000 Å of a metal such as aluminum, chromium, tantalum, or tungsten, a triple layer of silicon nitride and a-Si is deposited by using plasma-enhanced chemical vapor deposition (PECVD). In the etch-back type of TFT structure, the triple layer consists of 4000 Å of SiN_x, 2000 Å of a-Si, and 500 Å of n^+ a-Si, which is deposited over the gate electrode in a continuous process, *i.e.*, a process without a vacuum break. For the etch-stopper type of TFT structure, 4000 Å of SiN_x, 500 Å of a-Si, and 2000 Å of n^+ a-Si are deposited.

Let us look at the etch-back TFT-fabrication process in more detail (Figs. 5–15). After defining the a-Si area by using photolithography and plasma dry etching, an indium tin oxide (ITO) layer is deposited with a thickness of about 500 Å *via* sputtering. Then, the pixel electrodes are patterned. About 2000 Å of metal is sputter deposited, while data bus lines and TFT electrodes are patterned by photolithography. Then the ohmic contact layer (n^+ a-Si) in the channel region is etched by dry etching using the source and drain electrodes as an etch-protect mask. Finally, a protective 2500-Å SiN_x layer is deposited by PECVD, and contact windows are opened.

The etch-stopper TFT structure requires one more process step – chemical vapor depo-



	Stripe	Mosaic	Delta
Array Design	Simple	Simple	Complex
C/F Fab.	Simple	Difficult	Difficult
Driving CKT	Simple	Complex	Simple
Color Mix	Poor / w. low res.	Good	Best

Fig. 17: Of the many possible color-element configurations for LCDs, striped is the most popular, followed by mosaic and delta.

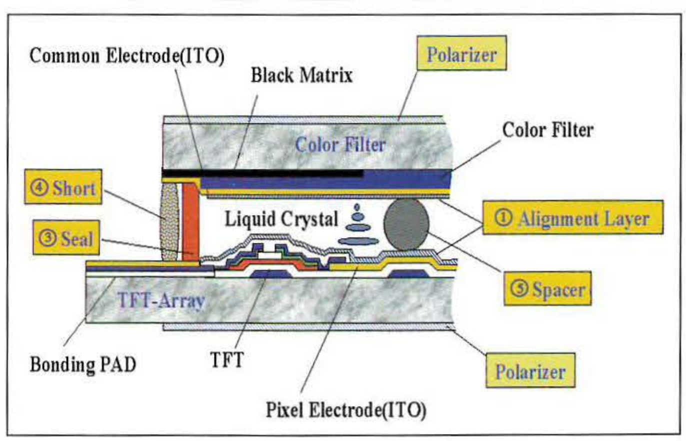


Fig. 18: The TFT-array and color-filter substrates are made into an LCD panel by assembling them with a sealant.

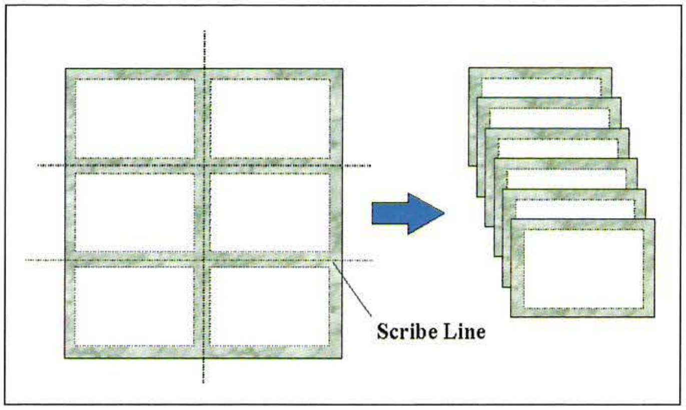


Fig. 19: Fully assembled LCD substrates are scribed using a diamond wheel and separated into individual cells.

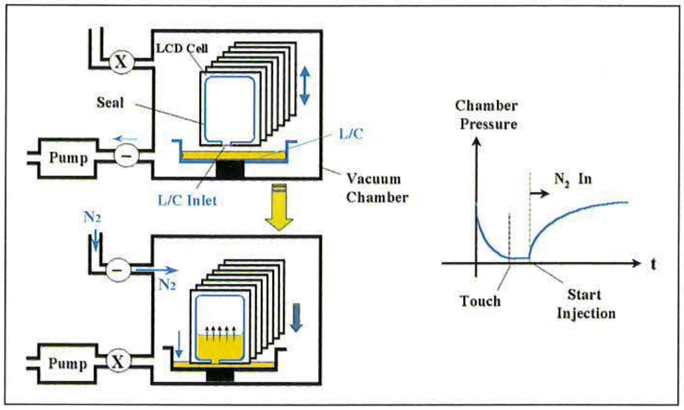


Fig. 20: The separated cells are filled with liquid-crystal material by vacuum injection.

sition (CVD) – than does the etch-back TFT structure. For etch-stopper TFT fabrication, an n^+ a-Si layer is deposited separately after the top insulator of triple-layer SiN_x/a-Si/SiN_x) is patterned. The a-Si area is patterned, and the n^+ a-Si layer at the top of etch-stopper is removed. The source and drain electrodes are formed using about 2000 Å of metal; then, about 500 Å of ITO is sputter deposited, and pixel electrodes are patterned. A SiN_x protective layer is then deposited by PECVD, and, finally, the contact windows are opened.

Fabricating Color Filters

Color filters can be made with either dyes or pigments, utilizing coloring methods such as dyeing, diffusion, electro-deposition, and printing (Fig. 16). There are several fairly common color-element configurations (Fig. 17). Among the many combinations of configurations and types of color-filter fabrication methods, the color-resist method, employing a striped RGB arrangement, is currently the most popular in the color-filter industry.

Between the blocks of color in the color filter is a black matrix made of an opaque metal, such as chromium, which shields the a-Si TFTs from stray light and prevents light leakage between pixels. A double layer of Cr and CrO_x is used to minimize reflection from the black matrix. The sputter-deposited black-matrix film is patterned using photolithography. To reduce cost and reflectivity, black resin – made by diffusing C and Ti in photoresist – can be used as a black-matrix material.

In the color-resist method, the primary color-filter patterns are formed by using a photolithographic technique. The color resist is negative and made by diffusing pigment in a UV-curing resin (such as an acryl-epoxy resin) and by dissolving the resin in a solvent. A red-colored resist is spin-coated onto a glass substrate on which a black matrix has previously been formed. A red pattern is then formed by exposing the red resist through a mask and developing it. The process is repeated using the same mask with a shifted mask-alignment technique for green- and blue-colored resins. A protective film is then applied, and 1500 Å of ITO for the TFT array's common electrode is sputter-deposited to complete the color filter.

Liquid-Crystal Cell Process

The TFT-array and color-filter substrates are made into an LCD panel by assembling the two substrates together with a sealant, while the cell gap is maintained by spacers (Fig. 18). The assembly is begun by printing a polyimide alignment film on a cleaned TFT array, and then rubbing the surface of the film with a piece of cloth wound on a roller, which orients the polyimide molecules in one direction. Similarly, alignment film is applied to the color-filter substrate, and this substrate is also rubbed. After the rubbing process, a sealant is applied to the periphery of the TFT-array substrate. To form electrical connections from the common electrodes on the color-filter substrate to the TFT array, the TFT-array substrate is coated with a conducting paste around the periphery. At the same time, spacers to control the cell gap are sprayed onto the color-filter substrate. (In some cases, spacers are sprayed on to the TFT-array substrate, and a sealant is applied to the color-filter substrate.)

The two substrates are then assembled after the sealant is pre-hardened. The sealant is then hardened completely with heat and pressure. Then, the assembled substrates are scribed using a diamond wheel and separated into individual cells (Fig. 19), and the empty cells are filled with liquid-crystal material by vacuum injection (Fig. 20). Finally, a sealing agent is used to seal the cell, and the polarizers are applied to both cell surfaces after a visual function test.

With this step, the liquid-crystal cell is complete, but it is very far from being a display module that can be sold to a manufacturer of end-user products such as notebook computers, desktop monitors, or portable terminals. For that, drivers, control electronics, and (usually) a backlight unit must be added to the cell. For a description of that process, please see the tutorial in last month's *Information Display*. ■

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Business Projectors: Technologies and Markets

Ultraportable projectors have become essential tools for the business presentation market, and manufacturers are breaking performance barriers every year. The next generation will feature wireless connectivity and networking abilities.

by Sweta Dash

THE projection-display industry serves many markets. The consumer market is synonymous with the big-screen-television market. The business market has become closely tied to the computer market because of the wide use of presentation software in meeting rooms. The business market has clearly shifted direction in recent years from bulky front cathode-ray-tube (CRT) projectors to portable poly-Si liquid-crystal-display (LCD) projectors. And the recent introduction of ultraportable – less than 10 lbs., and especially 3–5 lbs. – projectors using front LCD and front digital-light-processing (DLP) technology has taken the business market to the next level.

Market Overview

The overall worldwide unit consumption of projection displays of all types and for all applications is forecast to more than double from 3.3 million units in 2000 to nearly 7.2 million units in 2006 (Fig. 1). Consumer applications constituted the largest segment of the market in 2000, with 69% of the unit shipments and almost 51% of the market value.

Business applications constitute the next largest segment, with 25% of the unit shipments and 36% of the market value in 2000. The business-applications segment will experience strong growth in the coming 6 years, but the consumer segment will continue to dominate the market throughout the forecast period.

The total value of the projection market will grow from $11 billion in 2000 to $18 billion in 2006. The projected growth in value will be slower than the projected growth in

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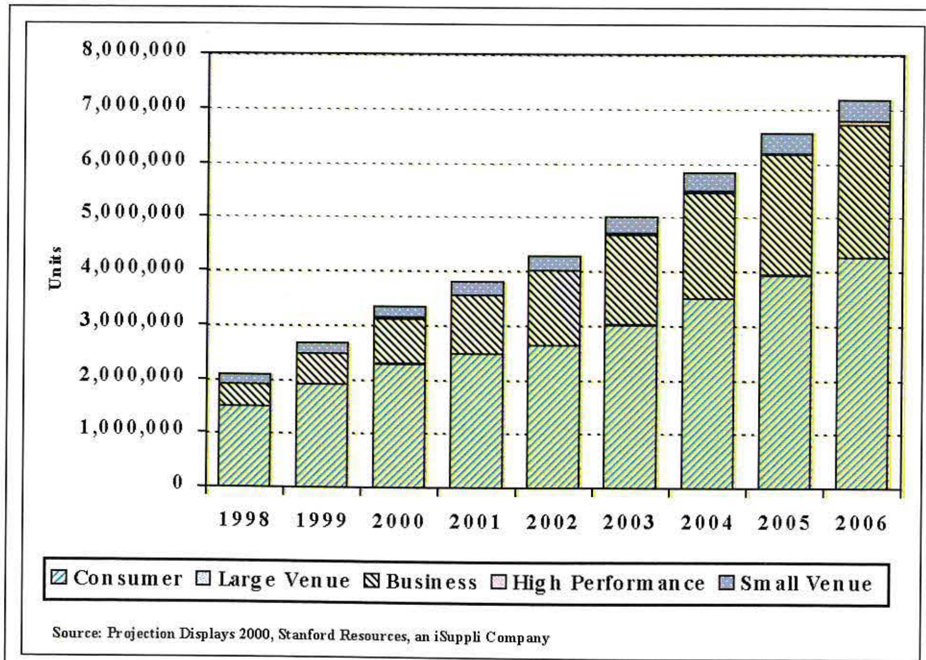

Fig. 1: *Worldwide projection-display unit shipments by application, 1998–2006.*

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unit shipments because price reductions are anticipated for all applications.

Business Applications

The business applications are broadly divided into two categories: (1) conference room and training and (2) sales and presentations.

Conference Room and Training. Three-panel poly-Si LCD projectors dominate this market; DLP technology has not been able to penetrate the segment. Liquid-crystal–on-silicon (LCoS) projectors, such as those based on JVC's D-ILA™ technology, are also targeted for use in conference-room applications. Most of these projectors have luminous output levels of more than 2000 ANSI lumens. Many suppliers have introduced projectors with levels above 3000 ANSI lumens, with some as high as 5000.

In terms of pixel format, conference-room applications are moving to SXGA at the high end, but the shift has been slow. As the notebook market shifts from SXGA to SXGA+ resolution, demand will grow for SXGA+ projectors.

Another trend in the conference-room market is toward digital connectivity. Conference-room LCD projectors will receive files from desktop computers over a local area network (LAN). Networked projectors allow remote discussions and meetings, as well as file transfers. Wireless connections will further increase the usefulness of conference-room projectors. It will be possible for conference-room attendees to be connected to host presentations as well as to other attendees.

Sales and Presentations. As the use of notebook computers becomes more popular, LCD and DLP projectors (especially the ultraportables) will increasingly be seen as essential tools for the business-presentation market. The already brisk growth has been driven by improvements in technology that have resulted in greater performance at each price level. LCD projectors still dominate this market, but DLP microelectromechanical-systems (MEMS) projectors have been consistently gaining market share. DLP projectors are the leaders in combining reduced weight with increased brightness. LCD projectors have been able to follow the lead and achieve similar weight and brightness gains.

LCoS ultraportable projectors are expected to gain market share with the introduction of 3–5-lb. projectors. Weight is an important criterion in the sales and presentation markets (Fig. 2). In terms of luminous output, the range is between 1000 and 1500 ANSI lumens, and a continuous shift to even higher levels is expected. XGA is the dominant pixel format now, but this will shift to SXGA and SXGA+.

Ultraportable projectors are becoming increasingly popular. In 1999, the introduction of 5-lb. DLP projectors was followed by the advent of 5-lb. LCD projectors. Last year, 3-lb. DLP projectors were introduced, and such projectors are now available with 1200 ANSI lumens. Soon, ultraportable projectors will be the mainstream product. They are compact, light in weight, and relatively inexpensive, and they will make inroads into other application segments, including home theater. Because most of these projectors are increasingly sold through computer channels, the distinction between business and consumer projectors will likely blur to some extent.

Technology Trends

The technology trends for business projectors, shown in Table 1, indicate increases in brightness and screen resolution, and decreases in weight, price, and panel and chip sizes. Business and consumer applications will tend to merge.

Luminous Output. Recent developments in lamp technology and the use of microlenses for LCD projectors have enabled front projectors to both use light more efficiently and increase luminous output. Among the most crucial developments are the ultra-high-power (UHP) metal-halide lamp, the ultra-high-efficiency (UHE) metal-halide lamp, and the high-pressure mercury lamp. Such developments have helped front projectors double their luminous output while using less power.

Recent advances have enabled poly-Si LCD projectors to surpass 5000 ANSI lumens. By the year 2000, most front LCD and DLP ultraportable projectors were able to produce 1000–1500 ANSI lumens. At the high end, three-chip DLP projectors produced 10,000–12,000 ANSI lumens, and LCoS projectors achieved 4000 ANSI lumens. With the help of increased efficiency and new lamp technologies, system light outputs will rise over the next 5 years. In 2000, projectors with 1000–1500 ANSI lumens dominated the market, but, by 2004, projectors that produce 2000–2500 ANSI lumens will dominate.

Pixel Format. Shifts in pixel format in the front-projection market are somewhat linked to the video capabilities of notebook computers because notebook PCs are generally connected to projectors for multimedia and data presentations. The notebook-PC market has shifted to the XGA format, and front projec-

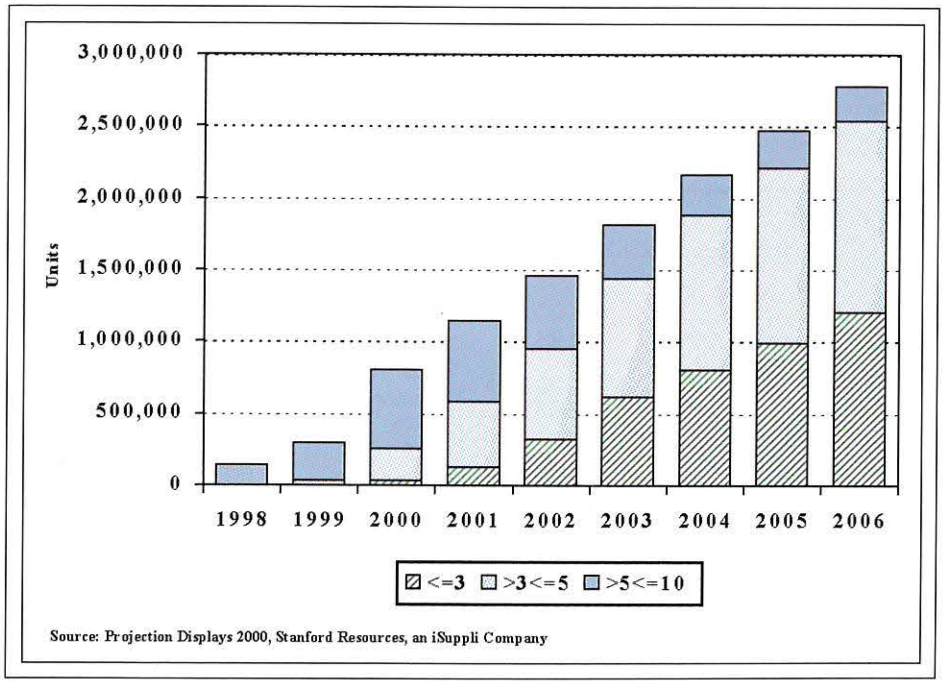

Fig. 2: Worldwide ultraportable projection-display unit shipments by weight, 1998–2006.

tors are following suit. Soon, notebook PCs with resolutions of SXGA+ (1400 × 1050) and higher will be introduced to meet the high-performance requirements of the workstation market, as well as the changing requirements of the notebook-computer market.

For the ultraportable market, front LCD and DLP projectors are usually offered in SVGA and XGA formats. The high-end conference-room and large-venue markets are already shifting to the SXGA format. For the conference-room and digital-cinema markets, JVC has already announced LCoS chips with SXGA+ (1600 × 1400) and QXGA (quad XGA or 2048 × 1536) resolution. In 2000, the majority of front projectors featured XGA resolution. By 2004, XGA will still be the dominant pixel format, but SXGA will have gained significant market share.

Weight. Five years ago, projectors were heavy (usually more than 20 lbs.) – and expensive products that were generally used in conference rooms and auditoriums. With the introduction of portable and ultraportable projectors, the sales and presentation market grew rapidly. Manufacturers are breaking weight barriers every year by using smaller displays and improving lamps and other components.

DLP projectors have been leading the way in the low-weight segment. However, suppliers of three-panel poly-Si systems have reduced the weight of their leading-edge projectors to 5 lbs. In 2000, many suppliers introduced 3-lb. DLP projectors, and, in June, PLUS Corp. announced a 2-lb. DLP projector for fall 2001 introduction. The introduction of these products will pressure manufacturers of front LCD projectors to introduce products of a similar weight. Ultraportable LCoS projectors are just being introduced.

Table 1: Business Projector Technology Trends

	2000	2004
Weight	>5 ≤ 10 lbs.	>3 ≤ 5 lbs.
Pixel format	XGA	XGA, big gain for SXGA
Lumens	>1000	>2000
	<1500 ANSI	<2500 ANSI
Panel and chip sizes	0.9 in.	≤0.7 in.
Price	$4–6 K	$2–3K
Applications	Business	Business, Consumer growth

In 2000, the majority of front projectors weighed between 5 and 10 lbs. By 2004, most will weigh between 3 and 5 lbs. Projectors weighing less than 3 lbs. will experience strong growth during the next few years.

Panel and Chip Sizes. There is a trade-off between light output and weight in a projector. The use of larger LCD panels or DLP/LCoS chips enables higher luminous output but increases system weight. In time, engineering refinements will lead to smaller displays without sacrificing brightness. Three years ago, 1.8-in. panels were first used in conference-room products to increase the luminous output of front LCD projectors from 1200 to 2100 ANSI lumens. And in 2000, these panels helped LCD projectors achieve greater than 5000 ANSI lumens.

Texas Instruments introduced 1.1-in. SXGA chips for three-chip DLP projectors in 1999. By early 2000, the company switched to 0.7-in. XGA chips to reduce costs and weight, which helped the projector slim down to 3 lbs. In the future, 0.5-in. chips will be used to maintain the trend in weight reduction. In the LCoS world, most chips are 0.7 or 0.9 in.

In 2000, the majority of front projectors used 0.9-in. panels or chips. By 2004, most of the front projectors will use panels or chips that are 0.7 in. or less, and there will be a downward trend to diagonals of 0.5 in. or less.

Seiko-Epson and Sony were the only two suppliers of poly-Si LCD panels for projectors in 2000. LCoS manufacturers, including IBM and JVC, began selling chips in 1998; however, IBM decided to stop producing the LCoS chip in 2000. Both Pioneer and S-Vision withdrew from the projection market in 1999. Displaytech and Aurora are successful in supplying LCoS chips for front and rear projectors to companies such as Everest and Samsung.

Systems Manufacturers and Branded Vendors

Across all projection technologies, there is a wide variety of production arrangements. At one extreme, a company such as Texas Instruments sells only display elements. At the other extreme, a company such as Seiko-Epson, which manufactures display panels as well as complete projectors, sells both under its own brand name and to other companies on an OEM basis. Between these two extremes are companies that either have manufacturing or assembly capabilities or use contract manufacturers to develop products under the brand name of other companies.

Systems manufacturers either sell projectors under their own brand name or sell products to other suppliers on an OEM basis. Japanese suppliers such as Sanyo and Epson currently dominate this market, but many new suppliers from Taiwan are entering the market ready to do contract manufacturing for major branded vendors. That could change the scenario in the future and make it more competitive, leading to lower system costs.

As far as branded vendors are concerned, InFocus Corp., which sells under the InFocus, Proxima, and ASK brands, dominates the world front-projector market, followed by other suppliers such as Epson, NEC, and Sony.

Poised to Go Mainstream

The sales and presentation market will continue to drive the growth of front projectors, and, as the use of notebook computers becomes more widespread, front projectors will be seen as essential business tools.

The world market for notebook computers was close to 23 million units in 2000. In comparison, the front-projector – LCD, DLP/MEMS, and LCoS – market is still very small at just 1.1 million units. The ultraportable market can grow faster, and the attach rate (to portable computers) can be higher if ultraportable-projector prices drop to levels comparable to those of notebook computers.

A low-end notebook computer is priced at less than $2000; a mid-range version is priced from $2000 to $3000, and a high-end model can run as high as $5000. Last year, most ultraportable projectors were in the $5000–7000 price range, followed by the $2500–5000 price range. Only a small percentage of products were priced below $2500.

The goal is to match the mainstream ultraportable-projector price to the mainstream notebook-PC price. Manufacturers are also hoping to reduce prices in order to reach a wider range of customers in both the business and consumer markets. Street prices for front projectors must reach the $2000 target to reach the consumer market. Rear-projection TV products are currently sold in the $1000–3000 price range.

The Next 5 Years

The worldwide unit consumption of projection displays of all types and for all applications will more than double from 3.3 million units in 2000 to nearly 7.2 million units in 2006, and the business-applications segment will experience strong growth. Front LCDs will continue to dominate the business market, but front DLP/MEMS and LCoS technologies will increase their market share through success in the ultraportable market. Projectors promise to get smaller, lighter, and brighter, and will advance toward higher resolutions. In the next few years, more emphasis will be placed on networking capabilities for connecting projectors to corporate intranets and the Internet. ■

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Circle no. 14

show report

Talking Turkey in Taipei

At the 21st Computex Taipei show, it seemed that every Taiwanese IT-hardware manufacturer had a 15-in. LCD monitor in its portfolio – and was ready to sell a lot of them cheap.

by Bryan Norris

ALL the major talking points at this year's Computex trade fair in Taipei, Taiwan, were inextricably linked: the proliferation of companies making LCD monitors, the continued steep drop in LCD prices, and the transfer of CRT- and, more recently, LCD-monitor production to mainland China.

On June 4, the opening day of the five-day show, one topic dominated discussion at the press conference: the amount of Taiwanese IT-hardware production taking place in mainland China – the People's Republic of China (PRC). Government circles are worried that the transfer could cause a damaging currency drain or an unemployment problem in Taiwan. Thanks largely to Taiwanese companies, a "Made in China" label is on the back of US$25.5 billion worth of IT hardware made in the year 2000, an increase of 38% over 1999. This moved the PRC into third position, ahead of Taiwan for the first time. ("Made in Taiwan" hardware products were worth US$23 billion, a rise of 10% from 1999.)

There were eminent speakers at the press conference – Chin-Peng Huang, President of the China External Trade Development Council; Raff Liu, Chairman of the Taipei Computer Association; and Victor Tsan, Managing Director of Taiwan's Market Intelligence Center (MIC) – pointed out that the possible disadvantages and threats must be balanced by the need to take advantage of China's very low labor rates to remain internationally competitive. In addition, the presence of Taiwanese companies on the mainland makes it easier for Taiwan to tap into the potentially huge Chinese market.

The monitor industry is a prime example of the changes: 60% of monitors produced by Taiwanese companies are currently made in China, with another 21% made in other offshore locations. But how else can suppliers meet the expectations of lower and lower prices? And when they concentrate on the price tag, most non-Chinese consumers do not worry about the "Made in China" label one way or the other.

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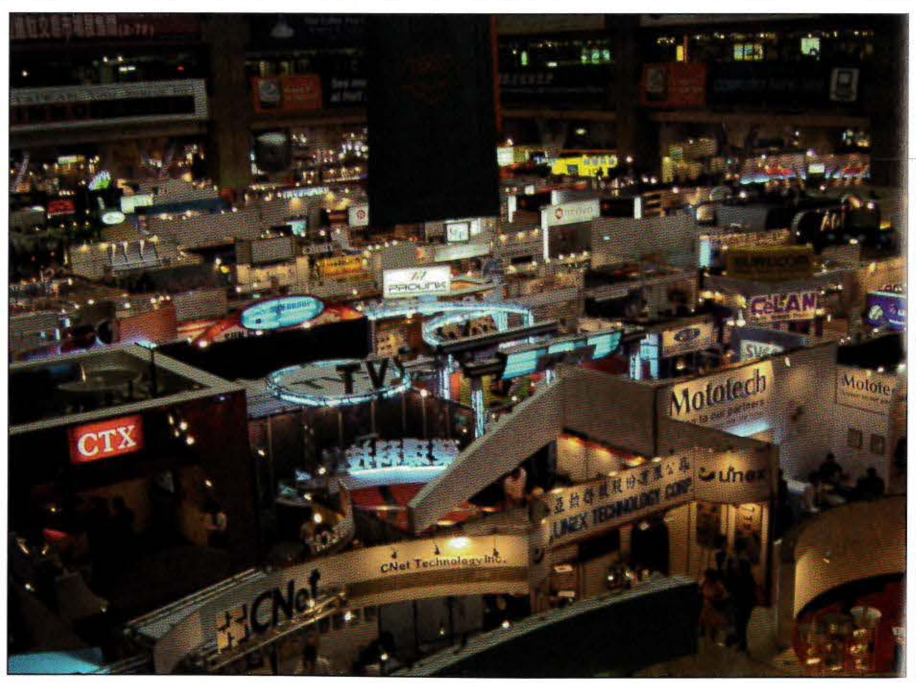

Bryan Norris

Fig. 1: Most of the display exhibitors at Computex Taipei were housed in Hall 1, Section D, of the main exhibition hall of the Taiwan World Trade Center.

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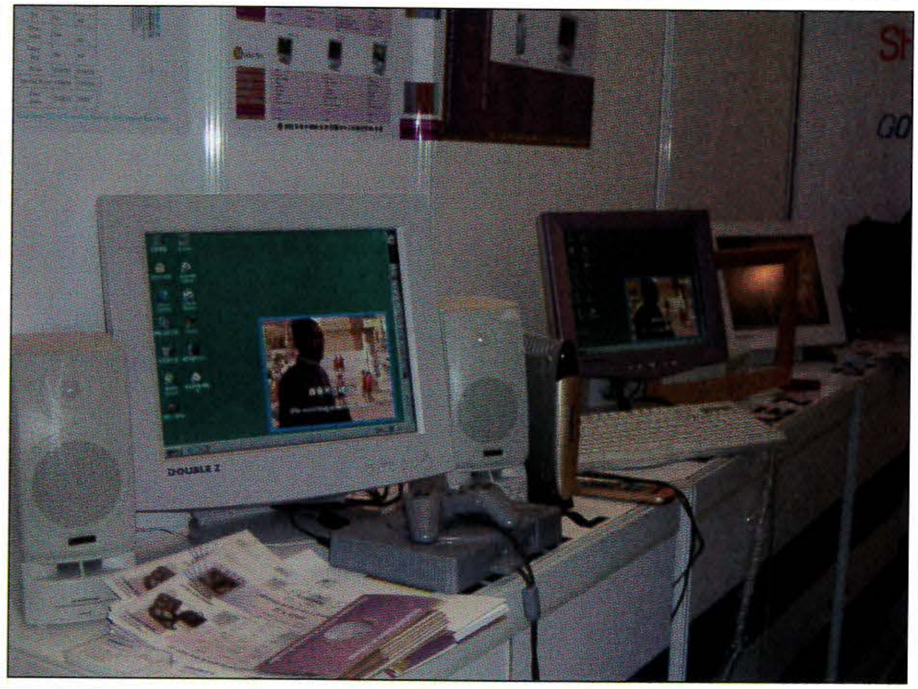
According to MIC, monitor production by Taiwanese companies grew to 62,365,000 units in the year 2000, equating once again to a 58% share of the global production volume. By value, monitor production grew 12% from last year to US$10.4 billion, helped by the significant growth in LCD-monitor shipments to 2.1 million units. Taiwanese CRT-monitor production – just over 60 million in 2000 – continued the trend towards larger screen sizes, with 19-in. models nearly doubling in volume to around 4 million units and 21/22-in. models tripling in volume to over 0.5 million.

But the year 2000 also witnessed the demise of two of Taiwan's major monitor suppliers, ***Royal Electronics*** and ***Kuo Feng Corporation*** (***KFC***). This was one of the reasons why the overall production volume was just over 62 million instead of the 67 million that had been predicted. Royal was primarily an OEM supplier whose most important customer in Europe was ***Maxdata*** for that company's ***Belinea*** brand. KFC was another OEM supplier, but also sold monitors under its own KFC and ***Smile*** brand names (with Smile being particularly successful in France).



Bryan Norris

Fig. 2: *Double 2, a late entrant to the show, was displaying 15.1- and 17.4-in. LCD monitors, both with a choice of 10 different-colored bezels!*

Paying for a Higher Place in the Pecking Order

As usual, most of the display exhibitors were housed in Hall 1, the main exhibition hall of the Taiwan World Trade Center (TWTC), primarily in Section D – the "Display Area" (Fig. 1). However, the more prominent monitor suppliers were again occupying large rooms in the Taipei International Convention Center (TICC). Companies promoting monitors here were ***Compal***, ***Mitac***, ***ProView***, ***Tatung***, ***Teco*** (***Relisys***), and ***Top Victory*** (***AOC***). Less-well-known monitor companies occupying smaller booths on the third floor of the Convention Center included ***Deccaview***, ***Homlan*** (***Viewtec***), and ***Ray System***.

A few overseas companies could be found in the foreign-exhibitors area (Section B) of the TWTC, including ***GTT*** and ***Harsper*** (South Korea), and ***ViewSonic***. And in Exhibition Hall 2, one block away from the TWTC – where most companies were PC assemblers and motherboard makers – some exhibitors, such as ***Aaeon***, ***Bridge***, ***NTK***, and ***Puretek***, were also showing monitors.

But if one really wanted to separate himself from the hoi polloi, then the prestigious suites of the Grand Hyatt Hotel were the place to be. These suites played host to the latest offerings of some very important OEM monitor suppliers to Europe and the U.S.A., in particular, ***AmTRAN***, (***Pro***)***Arch***, ***GVision***, and ***TopVision***. Local panel producer ***Hannstar*** and Korean all-rounder ***KDS*** also had suites there.

A War on the LCD Front

This year, almost all the monitor suppliers were concentrating on the promotion of LCD monitors. More than 70 of the booths were listed in the show catalogue as housing "Liquid-Crystal Displays," although the products in a few of these booths were niche items such as point-of-sale terminals or touch-screen models. But the bottom line is that CRT monitors are now definitely taking a back seat! Only 33 Taiwanese companies were listed in the show catalogue as supplying color CRT monitors, compared with 44 last year. (Surprisingly, nine companies were still promoting monochrome CRT models.) Seven suppliers were showing plasma screens, and four were listed as having electroluminescent displays.

Those Plummeting Prices

The dramatic fall in the price of LCD monitors over the preceding 5 months was a frequent topic of conversation. Taiwanese suppliers were commonly quoting FOB "buy" prices of US$340–360 for a 15-in. LCD and US$550–600 for a 17-in LCD. These were typical opening offers. But if one was prepared to do some serious negotiating, particularly if buying appreciable volumes, then the price for a 15-in. unit could be brought down to as low as US$300 – or even less!

Just prior to the show, some LCD-panel producers, including ***Chi Mei*** and ***Chunghwa Picture Tubes*** (***CPT***), had reported that panel prices would rise by 10–20% in Q3 '01. But during the week, nobody appeared confident enough to insist that monitor prices would definitely rise.

The main reason prices have dropped is because most of the Taiwanese monitor manufacturers can now use LCD panels from local suppliers, primarily for their 15- and 17-in. models. Significant panel quantities are now provided by ***AU Optoelectronics*** (the merger company of ***Acer Display Technology*** and ***Unipac Optoelectronics***), ***CPT***, and ***Hannstar*** – with Hannstar holding off its launch of a 17-in. panel until it sees which way the price wind is blowing. When it comes to panels for larger monitors, the Japanese and Korean

Bryan Norris

Fig. 3: 2001 Technology showed its unique "Massimo" dual-display – two adjustable 15-in. LCD monitors back to back – which is intended to be connected to two PCs, a multimedia unit, or a LAN.

makers, notably ***LG*** and ***Samsung***, are still dominant.

So a company such as (Pro)Arch was employing a variety of panels from its sister company Chi Mei, but for its 17-in. LCD monitor (with speakers) and new 20.1-in. monitor it uses LG's panels. ***Fujitsu***'s excellent panels were being used in all the 17.4- and 23.1-in. models on display, and Fujitsu units were also incorporated in some of the 18- and 19-in. models. In the interests of economy, ***TopVision*** was using the same casing and stand for both its 18- and 19-in. models.

As usual, ***AmTran*** was bucking this trend by offering LCD monitors that contain panels from a variety of foreign suppliers, and only rarely using panels from Taiwanese makers. In its range this year, the company was showing production versions of a 20.1- and a 23.1-in. model. These large-screen units could also be seen in their end-user state – with ViewSonic badges – on the ViewSonic stand.

New Players – and a Few New Ideas

As well as the more familiar LCD suppliers, from ***Acer*** through ***ViewSonic***, several more general computer and computer-peripherals companies were including 15-in. stand-alone LCD monitors in their portfolio. Three new names offering LCD monitors at this year's show were ***Double 2 Electronics, Inc.***, ***Pora Corp.***, and ***2001 Technology, Inc.*** Double 2 is an interesting example. It was established in 1986 as a manufacturer of hi-fi systems, mice, desktop PCs, sound cards, and notebook bags. A late entrant to the show, it was displaying its 15.1- and 17.4-in. LCD monitors, both offered with bezels in 10 different colors (Fig. 2).

The proliferation of suppliers reflects the fact that assembling LCD parts to create monitors is now a fairly straightforward business. And the introduction of "smart" LCD panels is making the process even easier. Furthermore, models using these new "smart" or "EZ" panels are particularly eye-catching, with small neat bezels and thin housings. Among the units benefiting from these panels are Acer's FP581 – only 4 cm thick – and a 15-in. model from (Pro)Arch.

One new supplier that cannot be accused of jumping on the LCD bandwagon with just any old product is 2001 Technology, which has been supplying mobile-equipment accessories to corporate customers worldwide for some time – and has done particularly well selling these products in the U.K. As an alternative to offering just another LCD monitor, the company was offering the unique "Massimo" dual-display, comprising two adjustable 15-in. LCD monitors back to back (Fig. 3). These monitors can be connected to two PCs, to a multimedia unit, or to a LAN. The company was also exhibiting more conventional offerings.

Another solution to ensuring that one's LCD monitor stands out from the crowd is to design it oneself and produce an outstanding and trendy product for niche markets. One Taiwanese company which has implemented this approach is ***neovo***. The company has recently introduced a 17.4-in. version to accompany its smart black 15-in. models, which are already selling well in Germany and the U.K. (see "On Monitor Safari at CeBIT 2001," *Information Display*, August 2001).

Most of neovo's units have a tough glass overlay to protect the LCD. The company's hi-tech 15-in. models sell for around US$1000, but an alternative model was introduced at the show that keeps the same stylish appearance without the protective glass. This F15 model is intended for volume sales and thus priced at only $500 to the consumer. AG neovo is the brand name of Associated Industries China, Inc., part of the world's fifth-largest maritime-transport group. The transfer of container production to China has left more than enough space at the Chung-Li factory (near Taipei's international airport) for the newly constructed cleanrooms that are used to produce the neovo monitors (Fig. 4). Production of 150 units a day is doubling in the second half of the year to meet a target of around 75,000 monitors in 2001, and is expected to rise again – to 200,000 units in 2002.

What's in a Name?

Once they have produced their products, most Taiwanese monitor makers would, ideally, like to sell the units under their own brand name in Europe or the U.S.A. However, they realize that the cost of setting up a distribution chain and supporting a brand, both pre- and post-sale, is prohibitive. Therefore, the primary route to Western markets for most of the suppliers is by selling their products OEM. This applies particularly in countries such as

Bryan Norris

Fig. 4: *neovo monitors are made by Associated Industries China, Inc., part of the world's fifth-largest maritime-transport group. The transfer of container production to China has left plenty of space at a factory near Taipei's international airport for the newly constructed cleanrooms used to produce the monitors at a rate that will rise to 300 per day in the second half of this year.*

Germany, where there are a number of large local PC assemblers, distributors, and retailers who want to buy significant quantities of OEM product to sell under their own brand names. German companies that fall into this category include Actebis (Peacock and Targa), Ingram Macrotron (VideoSeven), Maxdata (Belinea), Medion (Medion), Natcomp, and Wortmann (MaGIC).

So Taiwanese suppliers such as AmTRAN, Compal, Delta, GVision, (Pro)Arch, and Vicom currently sell all their monitors to OEMs. In fact, Delta feels so confident in its current OEM customers that it does not feel the need to promote its monitors at Computex Taipei. (The company claims to have the capacity to make over 10 million units per year, and it actually made 3.6 million CRT units in 2000.)

Manufacturers such as Jean, Lite-On, ProView, Sampo, and TopVision primarily sell OEM monitors. But they also manage to find channels for their branded products in certain markets. Lite-On and ProView sell branded products most successfully in Eastern European markets, but also appear in some Western European markets – ProView sells strongly in Spain, for example.

Sampo also sells branded products successfully in certain Eastern European markets, but has important OEM customers in Western Europe. Notably, the company is the major volume supplier of VideoSeven monitors to Ingram Macrotron. And TopVision sells its branded products through Gandalf in the Nordic countries.

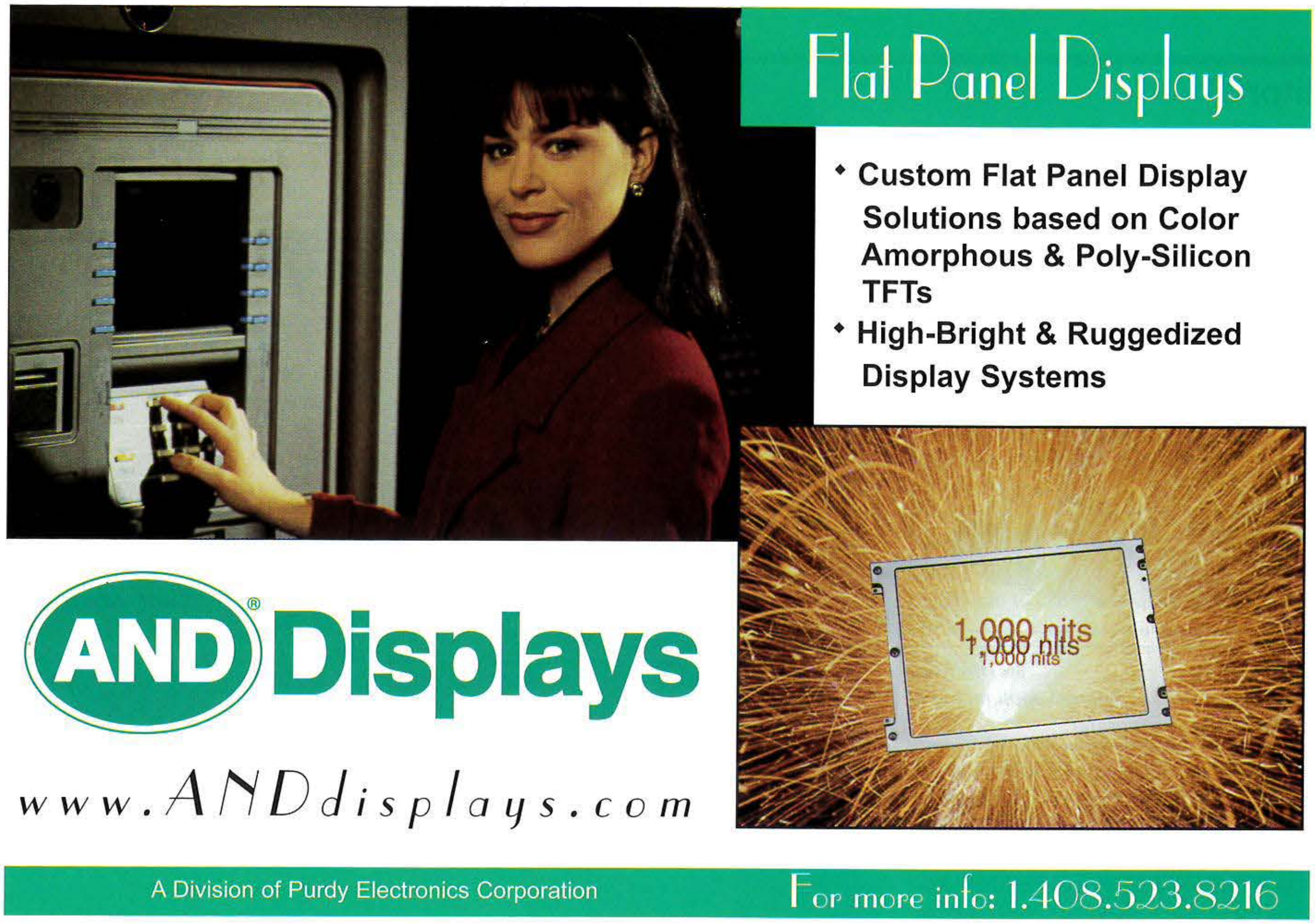
Of course, some of the large Taiwanese players rely on selling both OEM and branded monitors. Companies such as Top Victory Electronics (AOC brand in Europe, and Envision in the U.S.A.), ADI, and TECO (Relisys) have important OEM customers, but also sell strongly under their own brand names.

Computex the Showcase

Whether a Taiwanese player is selling OEM or under its own name, Computex Taipei remains the most important showcase for its products. And this year, more than 50 Taiwanese companies took advantage of the show to exhibit their stand-alone LCD monitors.

Across the board, the show continued to attract the bulk of the IT industry in this part of the world. The organizers of Computex Taipei 2001 – CETRA (China External Trade Development Council) and TCA (Taipei Computer Association) – were once again pleased to report a record number of exhibitors and visitors. And out of the 1071 exhibitors (compared with 1030 last year), 125 were from overseas, including 25 from the U.S.A. The attendance of overseas visitors also rose by 2% to 23,306, with the Japanese again forming the largest contingent of foreign buyers, followed by visitors from the U.S.A., Korea, Hong Kong, and Singapore.

So all appears to bode well for next year's show, to be held June 3–7, 2002. The only small cloud on the horizon is possible competition from the new Comdex IT exhibition being set up in China for the first time this August. However, production is one activity, while designing, selling, and negotiating are something quite different! For the moment, Taiwan is still the marketplace where one plans one's products and sets out a stall. ■



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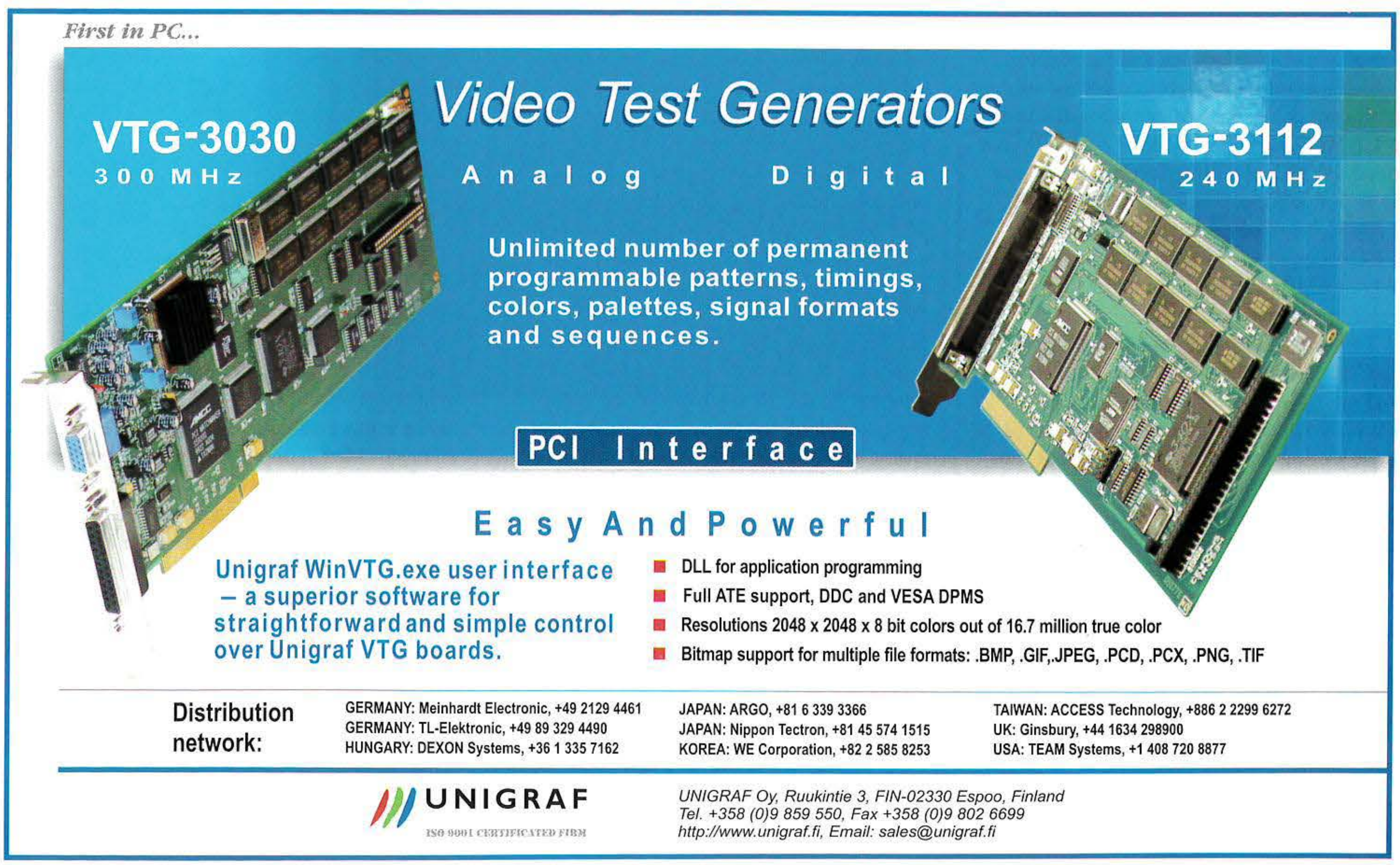

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Sony Electronics

Fig. 1: Sony's eVilla™ Internet appliance is a network entertainment center.

works at all, and amazing that it works well. The module will output PowerPoint presentations at XGA and, with MARGI software, will output anything appearing on the Visor screen at VGA. This could be a very attractive combination for people who do sales presentations for a living – and two-pound projectors are coming.

Somewhat older, said MARGI's Ricardo Valle (rvalle@margi.com), is the 4-megabyte Display-to-Go™ CardBus display adapter, which was introduced about eight months ago. This card comes with your choice of standard VGA, DVI, or DFP connector cable. If your notebook PC won't interface with your new DVI projector, or if it has an anemic video system like mine does and won't produce SXGA output with 24-bit color, it's cheaper to buy one of MARGI's $245 cards than to replace your computer.

Ben Joy, business line manager for small and medium conference-room projectors for ***InFocus Corp.***, told *ID* in an interesting exclusive interview that the company will have its first home-theater product out later this year. An intermediate goal for front projectors for consumer television is 1000 lumens at less than $2000. Joy is "guessing" that this combination will be available by Q2 '02 (for SVGA format). Look for such projectors at INFOCOMM next year, he said. At that point, front projectors for home HDTV use become feasible.

One of the new products Joy was touting was the InFocus LP130, a three-pound single-DMD projector with 1100 lumens of output and DVI interface. Joy said that 1000 lumens is the practical minimum for any bargain-basement projector. "It has become very hard to sell an 800-lumen projector," he said.

Joy said that InFocus will match PLUS's two-pound projector – eventually. "The three-pound projector is an important product, but it's not the magic bullet the industry thought it would be." The company is working closely with TI, which is driving DLP™ projector technology smaller, with smaller engines and smaller devices. TI is also looking at scrolling color, Joy said. Wireless connectivity will be another important projector technology.

"What about LCoS," *ID* asked. "We're looking at it," said Joy. The LCoS people have been touting their technology for the "value" end of the projector range, but the price is not yet low enough, and the image quality is not as good as polysilicon's. Polysilicon XGA imagers with 0.7-in. diameters are good now, and will soon go to 0.5 in. with good performance. But, with all the development activity in Taiwan and elsewhere, Joy is sure that LCoS will eventually get to where it needs to be.

Sony was showing its eVilla™ network entertainment center with a 15-in. flat-screen CRT display in 800 × 1024 portrait mode (to better match the orientation of Web pages) (Fig. 1). This is a well-thought-out Internet appliance. The front panel has an on-off button, Memory Stick™ slot, Web button, e-mail button, ± volume buttons, and that's it. The unit uses the BeOS with integrated Opera browser and a proprietary e-mail client. Both a V.90 modem and an Ethernet card are included. Particularly for those with only a dial-up connection, the unit will dial and connect to selected sites at night to download media for local access in the morning. The bundled EarthLink Internet service is currently required, but the service can be used with a second computer at no extra cost.

The eVilla is intended as an easy Internet device with a simple GUI, or as a second device in homes where there is excessive demand for the single household PC. The product was to start shipping the week after PC Expo. If any $499 (MSRP) Internet appliance can attract the public's attention, the eVilla is a likely choice. But the big question remains: Is ease of use and a tidy all-in-one package enough to seduce buyers when the same money can buy a fully functional computer with a 15-in. monitor?

Sony also showed its substantial line of flat-screen CRT monitors with Digital Multiscan™. Among them was the 24-in. GDM-FW900 with wide aspect ratio, 2304 × 1440 pixels (max.), and dual inputs for multiple-PC usage. Another was the GDM-F520 21-in. with 0.22-mm aperture-grille pitch – "the tightest grille pitch available" – and up to 2048 × 1536, with dual inputs.

Sony was also showing TFT monitors up to 18.1 in., including the 16.0-in. SDM-M61 with dual digital and analog inputs.

ViewSonic was showing a range of TFT monitors, including the newly introduced 23.1-in. VP230mb, which has a DVI interface, 1600 × 1200-pixel format, and a 30-msec optical response. No video – just still images – was being shown on the screen, which might make some buyers nervous when the MSRP is $6699.

OKI may not have been pulling out all the stops to promote its work-group LED color printers with single-pass processing, but it was pulling out a lot of them, including a Tuesday evening reception featuring digital photos of the guests taken with former New York basketball great Earl "The Pearl" Monroe – and printed on an OKI printer, of course.

OKI made much of the fact that its four different-color toner cartridges were changed individually and separately from their respective drums, and also separately from the belt for transferring the paper and from the fuser unit. The fuser and belt are good for 80,000 pages, each toner cartridge for 15,000 pages, and each drum for 39,000 pages. The colors of sample pages were intense, and perhaps over-saturated.

Agaté Technologies was not exhibiting, but was making appointments to show its "Q" USB hard drive. The Q looks like a roughly cylindrical plastic key fob, complete with hole to slip into a standard key ring. Inside is flash memory (16, 32, or 64 MB) and a controller; part of the outside is a USB connector. Plug it into a USB port on your computer, and you're ready to read or write data. Well, not quite. You do need a driver, but driverless versions will be available in a few weeks, said John Madigan, president and COO (jmadigan@agatetech.com). There are a variety of attractive applications for this technology, including image transfer and the enabling of a patient to keep complex medical records at all times. Agaté may be hoeing the high-quality end of the USB hard-drive row, but others are hoeing

Ken Werner

Fig. 2: KD Net's "WebTel" Web pay telephones feature full-color TFT-LCD screens.

the "value" end. ***J.M.Tek***, the U.S. distributor for Jung Myung Telecom of Korea, is selling USB flash hard drives up to 1 GB – no internal controller, but 60 MB is only $60. A driver is currently needed for the "Flash USB-Drive," but, as with Agaté, driverless versions should be available in a few weeks. J.M.Tek is encouraging potential customers to put their PowerPoint presentations on a USBDrive and to leave their computers at home.

Finally, in the Korean Pavilion, ***KD Net*** of Seoul, Korea, was showing several models of slick Web pay telephones (Fig. 2). The phones all incorporate a full-color TFT-LCD screen that displays advertising when the phone is not being used for other purposes. When a user inserts a credit card or other means of payment, telephone, e-mail, and Internet services become available. In at least one model, inserting the credit card releases a slide-out keyboard with trackball for full Internet-terminal functionality. The "Web-Tels" have been installed at a major Korean airport, and KD Net is looking for substantial North American customers. As KD Net's Harris Han (hshan@kdnetwork.co.kr) said with great enthusiasm, "Why carry a heavy PC when you can check your e-mail so quickly and easily?"

With SpringBoard video modules, USB drives, and Web pay phones – not to mention purveyors of folding Palm Pilot keyboards, PDA-enhancing software and wireless services, and new PDAs themselves – there were quite a few exhibitors at PC Expo encouraging people to leave their notebook PCs at home. That's an interesting message in what, for the PC industry, is an "off" year.

– 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).

a view from the hilltop

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Clearly, some Are we there yet? situations are more easily identified than others. If I need to be in Washington D.C. tomorrow for a business meeting, then it's fairly easy to establish if I have accomplished that. On the other hand, many activities in our lives have outcomes that are more difficult to measure. When have we achieved "success"? Is our career progressing the way we would like? "Are we having fun yet?" As I think back over some of the high and low points of my still-developing career, I see much of that history very differently from the way I did at the time I experienced it. Now it seems that all those "learning experiences" – some of which I most certainly did not enjoy – have had a beneficial effect. Life's journey turns out to be more of a continuum, a blending and overlapping of a multitude of activities, than a predefined destination. There are certain times when changes and learning experiences are more intense and focused than others. In between, we get to rebuild our energy and enthusiasm – perhaps to coast a bit if we so choose.

For companies and organizations such as SID, the process is similar. In the journey of growing a new company, it is appropriate to ask, "Are we there yet?" And just as appropriately, the answer often is, "That depends." It depends on what you want the next objectives to be and what the various participants think is possible. I have been in several situations in which investors had expectations of the next "destination" that were, at least from my experience base, unrealistic. Yet, since each was a new situation with new technologies or new products, there was no ready comparison for me to use to conclusively prove that. The typical behavior in these situations is for investors to force a series of management changes until it becomes clear that no one can accomplish the wished-for results. The most clever players in this game are those executives who can anticipate the investors' "learning curve" and who take on the top position(s) at the time when the investors are finally willing to accept reality. (So far, I have not been very good at this game, but at least I now understand some of the rules.)

What about the Society for Information Display? Are we there yet? By most measures we certainly seem to be doing well. But can we do better? Fortunately, we do not have to contend with investors who have unrealistic expectations. But we also have to appreciate that the world is a competitive place and that challenges are being offered up to us on a regular basis.

In the last year, the membership has increased from the 4,826 total reported by Tony Lowe at last year's annual business meeting to 6,409 – a healthy 30% increase. This year's SID International Symposium, Seminar, and Exhibition was held June 3–8 in San Jose. The technical conference consisted of more than 300 peer-reviewed technical papers, and the exhibition had 523 exhibitor booths as compared with 432 last year. The attendance at the technical sessions increased from about 1,700 last year to over 1,800. The overall Symposium attendance exceeded 7,900 – an increase of about 20% over last year. Paul Drzaic as the general chair and Frank Libsch as the technical-program chair, as well as the entire program committee, clearly are to be congratulated for making key contributions to this success.

The next major conference event will be the combination of the International Display Workshops (IDW) and the International Display Research Conference (Asia Display), to be held this year in Nagoya, Japan, from October 16 to 19. The technical program in Nagoya will be similar in scope and size to the one in San Jose.

Conferences, not only at the international level, but also at the regional and chapter levels, are a vital part of the Society's activities. Over the coming years, we will continue to identify new topics and venues, and we will continue to support the activities that encourage the exchange of the latest technical information.

The SID publications are also continuing to improve. *Information Display* magazine has been on a "continuous improvement" plan for several years now – one that will never end. The major challenge this year was to get the Society's archival technical publication, the *Journal of the SID*, on a regular quarterly publication schedule. Editor Andy Lakatos has just about completed this objective. Tony Lowe has continued to champion our efforts to introduce important books on various topics of interest to the display community. The most recent contributions are by Ernst Lueder, *Liquid Crystal Displays*, and Shin-Tson Wu and Deng-Ke Yang, *Reflective Liquid-Crystal Displays*.

This year, major improvements were made to the SID Web site (www.sid.org) as its utilization and popularity continue to grow. An indicator of the growing importance of "sid.org" is that this year most of you registered for the Symposium using the Web site. The Web site is becoming a source of technical information and industry news and is a way to network with display experts anywhere in the world. It also contains what we believe is the most extensive and up-to-date conference calendar for display-related events in the world.

Local chapter activities continue to expand, allowing for the local and regional exchange of technical information and for networking with colleagues. The opportunity to meet others and to be able to discuss technical and industry trends is becoming ever more important as the display community grows. Two

a view from the hilltop

new chapters were added this year, one in India and the other in Singapore/Malaysia. SID is today very much an international organization. It owes its success to the many volunteers who give freely of their time and expertise. We maintain only a small office in San Jose, competently staffed by Dee Dumont and Jenny Needham.

Should you wish to increase your participation or if you have some ideas about how to further enhance SID's success, I would be very pleased to hear from you. One area that I will be emphasizing during this coming year is education. Can we as a society be more effective and have a greater ongoing presence in display-related education? Today, we do various seminars in connection with our conferences. I think we can do more.

So, "Are we there yet?" I think by now you can guess my answer. Do we need to make a quick stop for a stretch-break or to recharge our batteries? Would you like to get on board as we drive on to the next exciting interim destination? I would be pleased if you would share your thoughts on this topic and others. You can reach my by e-mail at president@sid.org or silzars@attglobal.net, by phone at 425/557-8850, by fax at 425/557-8983, or by mail at 22513 S.E. 47th Place, Sammamish, WA 98075. ■

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