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INFORMATION DISPLAY

October 1995
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FLAT-PANEL ISSUE

Reflective cholesteric displa[ys]
Field-emission displays
Plasma display panels
Computex Taipei '95

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COVER: The friendly clown shown on this Epson 2.5-in.-diagonal "Super-MIM" AMLCD seems to be inviting Information Display*'s readers to explore what is new and exciting in FPD technology. In this issue, you will find articles on field-emission displays, reflective cholesteric displays, and cost considerations for plasma display panels. In addition, there is a report on Computex from the prolific and peripatetic Bryan Norris.*

Credit: Epson America

Next Month in Information Display

Display Manufacturing Issue
- Excimer-laser annealing
- FPD sputtering issues
- FPD fabs
- Shadow-mask suspension

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editorial

Information Products for a Digital World

Today, information is packaged in many different ways to provide many different information products (IPs) for many different audiences. Digital IPs – made possible by technical improvements in computers, dynamic data storage and retrieval, communications, and displays – have begun to supplement print products. The advantages of digital manipulation are inspiring creative communicators and publishers to develop new kinds of IPs. Some of these products will replace traditional print products, but in general these new products will serve new functions. The result will be even more IPs serving even more diverse audiences.

Traditional and Digital IPs

IPs can be classified in several ways. Some products – such as newspapers and weekly news magazines – are ephemeral and meant to be discarded quickly after use. Other products – such as technical journals – are archival. The information they contain is meant to be added to a repository and kept for a long time.

Current print media are monologues in the sense that the end user receives information from the product but does not add information to it in any formal way. In contrast, new IPs using digital formats are interactive and can be conversational, creating a dialogue among the IP users and the IP author.

Articles in technical and other scholarly journals are quasi-conversations in that they undergo a review process in which the author participates in a dialogue with reviewers and editors prior to publication. The dialogue ceases before the article is published, however, so most users of technical information do not participate in the dialogue. Other forms of interaction, such as making notes in the margins, having discussions with colleagues, and writing letters to the journal editor, take place after publication and do not modify the archival version of the article. Subsequent articles may confirm, extend, or invalidate the conclusions of the original article, but this process takes very much longer than the actual interaction times typical of modern science and technology. So the published archival record, which was once the living chronicle of scientific communication and progress, is now often a history incorporating interactions and discoveries that occurred months, and sometimes years, prior to publication. This is a useful and necessary function, but it means that technical journals now have only a secondary role in the advancement of front-line science and technology.

Today's user of print media can make selections by choosing not to read some portions of the text or by skipping ahead to others. Digital media can make these choices easy, but a well-constructed digital IP can go well beyond automating traditional choices. Hyperlinks can take the user outside the document being read or viewed without the expensive duplication of supporting material or the inconvenience of leaving the document and going to a physical or on-line library. If, for example, the references for a technical article are available on the network from which the user has obtained the current IP, then these references are just a mouse click away. Digital media support real dialogues and conversations through private e-mail, electronic forums, and postings to network bulletin boards, thus opening the dialogues to wider participation.

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INFORMATION DISPLAY

the display continuum

Peter Piper Ph.D. Picked a Peck of Picture-Perfect Pixels

by Aris Silzars

One fine day, Peter's recently installed rising-star boss came to him and said, "Peter, I hear so many good things about you. Especially, I hear how you are always coming up with new product ideas that result in major new business opportunities for this company."

"Uh-oh," thought Peter to himself, while giving Boss-person a respectfully pleasant but noncommittal smile.

"In fact, I've been told that in one way or another you are responsible for over half of the most successful products for this division," continued Boss-person.

Peter hadn't exactly kept a tally, but he knew that the products he developed seemed to do quite well in the market. He had also noted that he was well respected in the technical community and that he seemed to have a real talent for understanding new technology directions and which new products were most likely to be appreciated by customers.

Nevertheless, Peter wasn't at all sure he wanted to follow where this conversation seemed to be leading. For the briefest of moments his mind wandered: "Why aren't engineers rewarded more like professional sports stars? If I'm so darn vital to this company, why is my salary the same as that of all the other engineers? If I left, how much time and effort would this company have to spend to replace me? Maybe engineers need agents like professional sports players have."

"Peter ... Did I catch you at a bad time?"

"No, no! Your visit just reminded me of an important upcoming new product review meeting," responded Peter quickly in his most diplomatic tone, hoping that his brief moment of daydreaming hadn't been too noticeable. "Whew! this is as bad as the time I fell asleep in the company's business review meeting," he thought to himself.

"Well, new products are exactly what I wanted to talk to you about. In our last senior-management staff meeting, we decided that what this division really needs is a new highly promotable product line. What we want you to do is design a line of color displays that we can claim are every bit as good as high-quality color photographs. From what I have heard about you, I just know you will come through for us. Well, I've got to run. Oh, by the way, we want to introduce these new products at the next SID Symposium. You know, the one in May ... or is it June? ... of 1996."

As he dashed off down the hall, Peter just barely caught the parting words, "I'll check back with you in a few months to see how you are doing."

"Oh, pook," thought Peter to himself. (Actually, that's not what Peter thought at all, but since this column is rated for General Audience reading, we hope you will overlook this minor inaccuracy.) "What do they mean by ... every bit as good as color photographs? And what am I supposed to do with the projects I am already in the middle of?"

Later that day, trying to get into a more productive frame of mind, Peter decided that he had better try to quantify what he had been asked to do. What does "the quality of color photographs" mean? He had heard some very high

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Reflective Cholesteric Displays

Today's commercial FPD technologies are impressive, but new technologies are needed for major upcoming applications.

by Zvi Yaniv

EVERY DISPLAY-DEPENDENT APPLICATION requires a particular set of display characteristics – a set that is not always available from existing technologies. What display-dependent applications constitute the mother lode for our gold rush of the 1990s? The Sutter's Mill most information-company executives are racing for is multimedia.

Are these executives obeying a basic, well-documented law of the microcosm that dictates the decentralization of power from centralized computer architectures and enormous databases to distributed systems?[1] This is the law that governed the fall of the mainframe in favor of the personal computer. It is the same law, says George Gilder, that will dictate the move from centralized networks and broadcast radio and TV stations to personal media with no center at all.[2] Suddenly it becomes clear that to harvest the fruit of the information revolution, one needs personal media that will be used very differently by each customer. Those media are electronic newspapers and magazines.

Newspapers rely on the intelligence of the reader. We need to create a tool that allows the readers to use whatever information they wish, wherever and whenever they wish to use it. That means we need an electronic display that will be able to replace printed material.[3]

Is such a flat panel available? Can we obtain the resolution of an ink-jet or laser

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Kent State University, Liquid Crystal Institute

Fig. 1: Kent Display Systems, Kent State University, and the University of Stuttgart jointly developed this reflective 8½ × 11-in., 100-dpi, monochrome Ch-LCD. The display requires no backlight and is bistable – it requires power only to write a new image, not to retain it or view it – so its power consumption is 1/50 that of a comparable TN or STN display.

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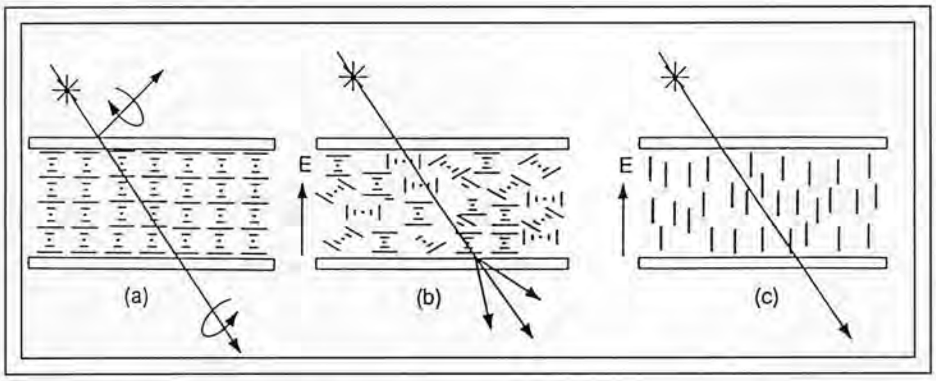

Fig. 2: Ch-LCDs have three possible states or "textures": (a) planar texture, (b) focal conic texture, and (c) homeotropic texture. Each texture has different optical characteristics, and the textures can be selected by the application of appropriate electrical pulses.

printer on a flat-panel display (FPD)? Assuming we can obtain the needed resolution, the key to a newspaper tablet will be portability. The field-emission and active-matrix technologies that were once regarded as possible candidates inherently use too much power to provide the solution. And the higher the resolution, the more power they consume.

Portability, of course, requires limited weight as well as limited power consumption. The large glass substrates that are the basis of FEDs and AMLCDs are heavy, and for the large-media viewer we envision, the weight would be prohibitive. Henry Fung, the author of two books on low-power design, has said that even though subnotebooks and hand-held systems are abandoning AMLCDs in favor of passive LCDs, "the display is [still] the one component that cannot be power managed."[4] We must achieve lower power consumption to allow operation with common dry cells and eventually with solar batteries – or a combination of the two. To achieve these goals we must use plastic substrates, remove the backlight by using the display in reflective mode, eliminate the polarizer for increased brightness in reflective mode, and use bistable (memory) liquid-crystal modes to reduce the power consumption and eliminate flicker.

Reflective Cholesteric Display Technology

With support from ARPA and the National Science Foundation, Kent State University (KSU) developed a unique reflective display technology that does not require a backlight, is bistable, and possesses full gray-scale memory. Subsequently, Kent Display Systems (KDS) was formed in Kent, Ohio, to capitalize on KSU's invention and facilitate the transition from the laboratory to a family of commercial products. The technology, based on cholesteric liquid crystals, uses Bragg reflection to reflect light of preselected color and bandwidth. Techniques were developed for incorporating polymers into the liquid-crystal material and treating cell surfaces (polymer-free) to stabilize the required optical textures without using polymers. Two optical textures – focal conic and planar – are needed for bistable memory in stabilized cholesteric liquid-crystal displays (Ch-LCDs).[5,6] The cholesteric materials have a domain texture that provides gray-scale switching and color control, as well as a broad viewing angle for flat-panel screens. The Ch-LCD technology does not require polarizers or polarized light, which results in high-brightness and high-contrast displays that are viewable under normal room lighting or outdoor conditions.

Of all the FPD technologies developed to date, Ch-LCD technology comes closest to mimicking paper-and-ink readability: it can be read under reflected light, it will hold an image in memory without any refresh power until the image is erased and rewritten, and it can be implemented on lightweight, rugged, and flexible plastic substrates (Fig. 1).[7,8]

Cholesteric liquid crystals in the planar texture [Fig. 2(a)] are unique in that they decompose incident white light into left- and right-hand circular components by reflecting one component and transmitting the other. The wavelength of the reflected component is given by the Bragg formula $\lambda = np$, where n is the average refractive index and p is the pitch length of the cholesteric helix. The spectral bandwidth is $\Delta\lambda = \Delta n\lambda/n$, where Δn is the birefringence of the cholesteric liquid crystal. When λ is in the visible range, the material provides beautiful iridescent colors. The wavelength of the reflected light is easily controlled by adjusting the chemical composition, which changes the chirality of the material and therefore the pitch length p. The reflected wavelength can also be made temperature independent over wide temperature ranges by using suitable chemical mixtures, polymer networks, and/or surface-alignment layers.

When switched to the focal conic texture [Fig. 2(b)], the cholesteric material ceases to Bragg-reflect light and becomes transparent or weakly scattering, depending upon the material composition. The focal conic texture is stable but can be switched back into the planar texture with a voltage pulse of suitable magnitude and shape.

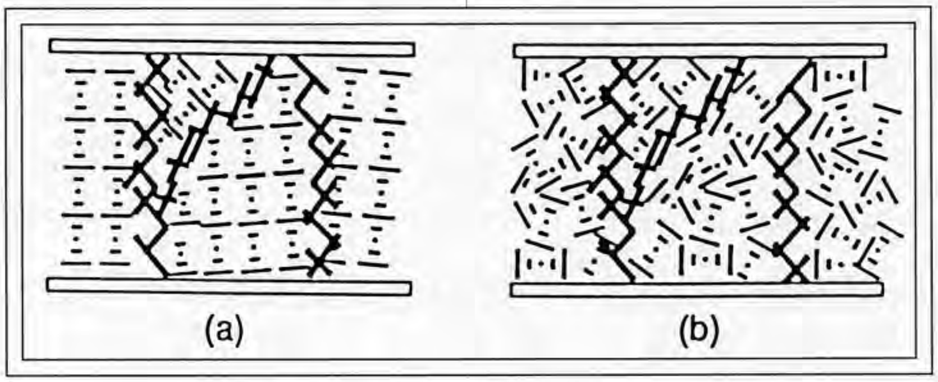

Fig. 3: A polymer network can induce a fine-grained domain structure into a cholesteric liquid-crystal material with focal conic texture.

The addition of polymers or the application of a suitable surface treatment stabilizes the focal conic texture and breaks up the material into a fine-grained domain structure (Fig. 3). This domain structure is important for two reasons: it provides a softer reflected color that does not shift in wavelength over a wide range of viewing angles and it provides a mechanism for gray scale. In the gray-scale mode, the intensity of the reflected light at each pixel is controlled in a continuous way by changing the density of domains in the planar texture. The domain structure is large, and the focal conic texture is transparent or weakly scattering.

The Ch-LCD material can be electrically driven into the planar texture or focal conic texture by applying an electric-field pulse of suitable magnitude. A low-field pulse of about 5 V/μm drives the material into the focal conic texture, while a high-field pulse of about 7 V/μm drives the material into the reflective planar texture. Intermediate levels provide gray-scale response.

The contrast ratio of the Ch-LCD under diffusely front-lit conditions is comparable to an image on paper (Fig. 4). Gray-scale memory can be implemented because there is a voltage range where a pixel can be partially in the planar texture, which produces a reduced reflected intensity. This is possible because the polymer divides a cell into approximately 10-μm-sized domains. The domains switch from the planar to the focal conic texture at different voltage levels, thereby altering the density of domains in the planar texture (Fig. 5).

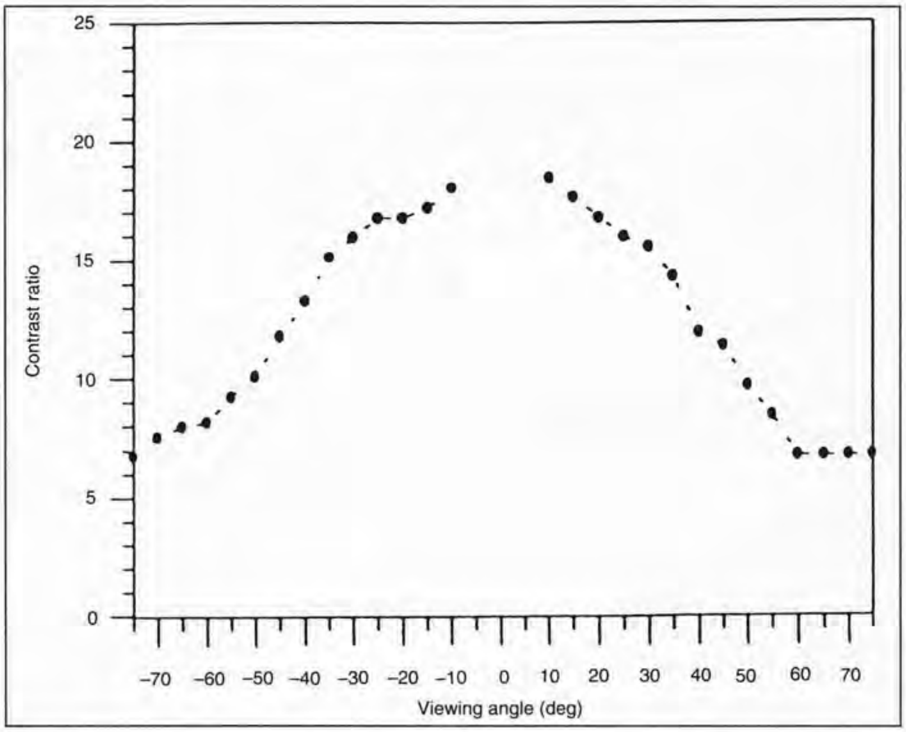

Fig. 4: The contrast ratio of the Ch-LCD under diffusely front-lit conditions is comparable to an image on paper and has a good viewing angle.

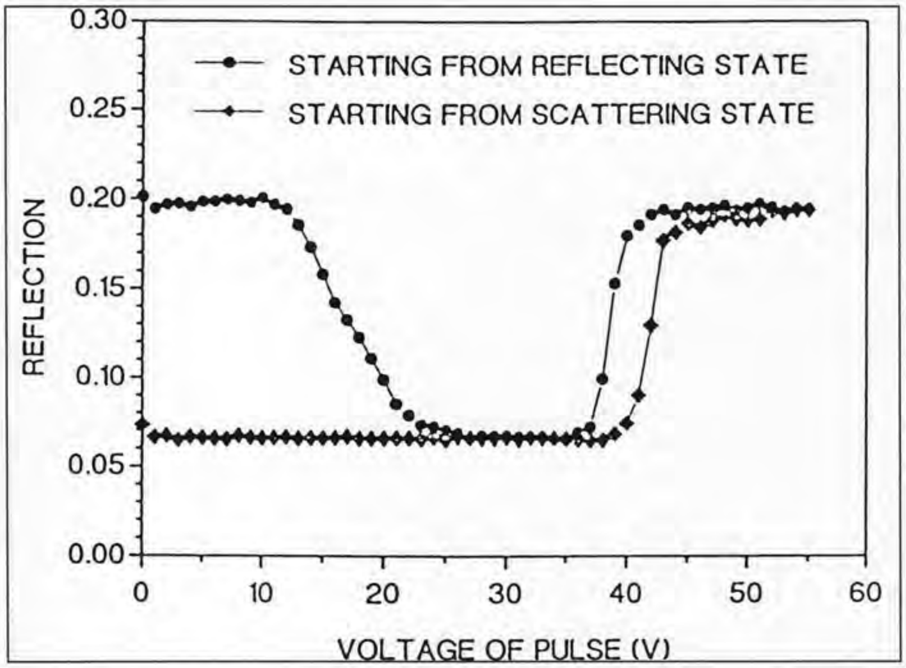

Fig. 5: The reflectivity of a cholesteric display can be changed as a function of the amplitude of an ac voltage pulse. Pulses from 12 to 23 V produce gray-scale reflection.

What's Next?

There is strong demand in the FPD industry for a high-quality reflective display that would eliminate the need for relatively expensive and power-hungry backlights.[9]

A high-quality reflective display should possess the following characteristics:

- Contrast ratio ≥30:1.
- Brighter by a factor of 2–3 than typical TN- or STN-LCDs.
- Operation at TV speed (mouse-compatible).
- Document-like features (bistability).
- High resolution (≥200-dpi capability).
- Black-on-white capability.
- Eight colors and eventually full color.

No FPD to date integrates all of these charac-

Table 1: Comparison of leading reflective LCD technologies.

	TN	STN	FE	AM	PDLC	PDLC/AM	Ch
CR (30:1)	--	--	--	--	-	+-	++
Brightness	--	--	--	--	+-	+	++
TV Speed	+-	+	++	+++	+	+++	---
Plastic substrates	+	-	--	--	+++	--	+++
Bistability	---	---	++	---	+	---	+++
High resolution	--	+-	+++	++	--	++	+++
Flicker	-	--	++	-	-	-	+++
Display size	+	++	+-	+-	++	+-	+++
Viewing angle	--	+	++	++	++	+++	+++
Power	++	++	+++	-	+	+-	+++
Eight color	+-	+	+	+++	+	++	+*
Sun readability	--	--	+-	+-	+	++	+++
Low cost**	+++	++	-	---	++	---	+++

Poor --- -- - OK +- + ++ Excellent +++

*In the laboratory stage at the Liquid Crystal Institute.
**Excluding drivers.
FE — Ferroelectric.
AM — Active matrix.
PDLC — Polymer-dispersed liquid crystal.

teristics at low cost, but the strengths of Ch-LCD technology are already apparent (see Table 1).

As the table indicates, the major drawbacks of the reflective cholesteric technology at this time are its lack of color and TV speed. Recent work at the Liquid Crystal Institute of Kent State University and at Kent Display Systems has produced promising results in both areas. Multicolor reflective cholesteric displays showing the three primary colors were demonstrated using a tunable chiral material whose chirality can be photochemically altered and fixed by exposing the cell to UV light.[10] Any desired color pixel can be implemented by combining selective UV exposure with the usual photolithographic techniques.

The rapid-addressing scheme being developed takes advantage of the rapid transition of the cholesteric liquid crystals from the homeotropic state to the transient planar state. With a proper sequence of pulses – including a preselection preparation pulse – one can choose the optical state of the cholesteric display by using a pulse shorter than 0.5 ms![11] Work is under way at KDS to implement these rapid-addressing schemes so that a large 1000-line display can be rewritten in less than 1 s.

The low-power capabilities of Ch-LCDs are impressive. For a 240 × 160-line display with a resolution of 100 dpi – suitable for high-information-content personal digital assistant (PDA) applications – a Ch-LCD consumes about 1/50 the power of a typical TN-LCD if the display is viewed 100 times per day and each view takes 30 s [Fig. 6(a)]. As the viewing time per frame increases, the advantage of the Ch-LCD technology increases. If the display is viewed 1000 times per day for 60 s, the Ch-LCD consumes about 1/100 the power of the TN or STN types. As screen sizes become larger, average viewing time increases and the Ch-LCD maintains a three-order-of-magnitude power advantage even for 14- and 17-in.-diagonal document viewers [Fig. 6(b)].

We believe that the currently excellent performance of reflective Ch-LCDs, combined with advances in color technology and rapid addressing, will accelerate the introduction of "print quality" electronic displays for exciting new applications, such as high-resolution PDAs, document viewers, and electronic newspapers.

Acknowledgments

Development of the 8.5 × 11-in. 100-dpi prototype was supported by the National Science Foundation (ALCOM Center) and the Advanced Research Projects Agency (ARPA). Research at the University of Stuttgart was sponsored by the Ministry of Science and Technology of Germany. I thank the Liquid Crystal Institute at Kent State University for providing some of the figures.

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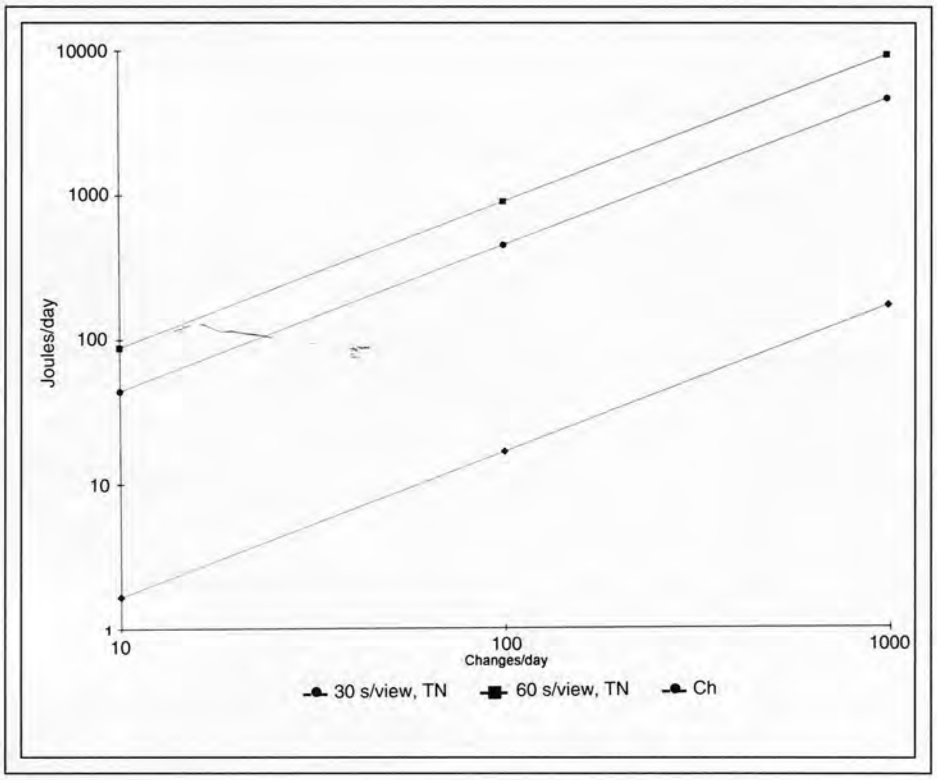
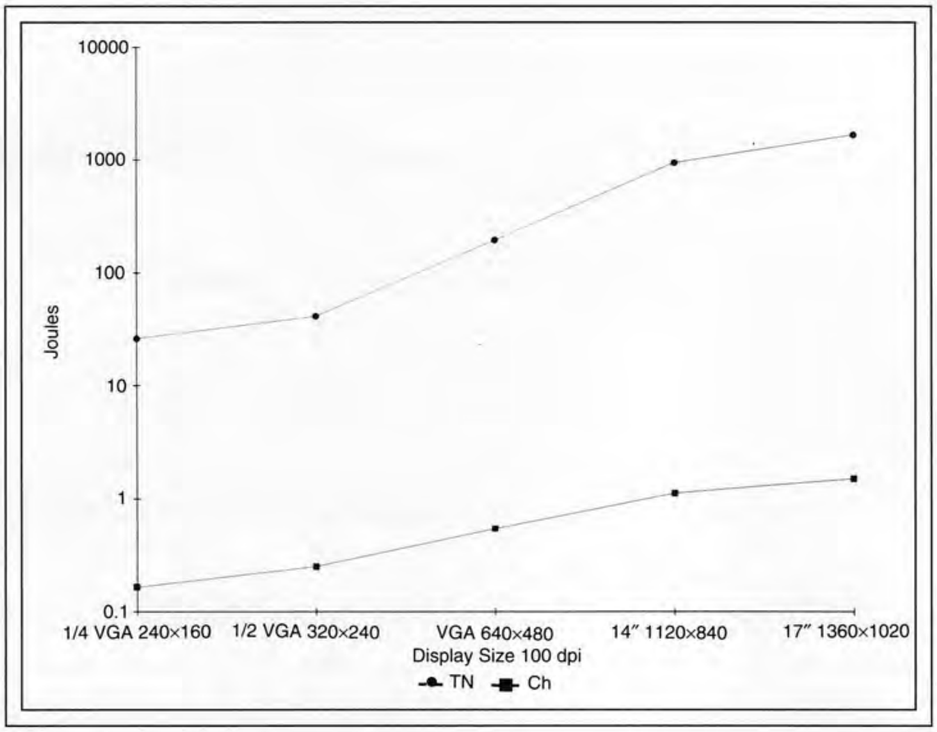


(a)



(b)

Fig. 6: *(a) The energy consumption of a quarter-VGA 100-dpi Ch-LCD is about 1/50 that of a comparable STN display. (b) The advantage is maintained as display size increases.*

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Field-Emission Displays

Following nearly 30 years of painfully slow evolution, FEDs are rapidly being developed for use in the next generation of electronic products.

by David A. Cathey, Jr.

THE LEADING DEVELOPERS of field-emission (or field-emitter) displays (FEDs) are looking forward to a vibrant future. This is not due merely to the natural optimism of humankind. FED developers have become convinced that psychophysics, the Information Age, and trends in display technology are all solidly on their side.

Human beings are capable of perceiving staggering amounts of information through the sense of sight. Therefore, visual displays will continue to be the primary interface for users who require moderate to very large amounts of information from systems and devices. Because of their reduced bulk and weight relative to the venerable cathode-ray tube (CRT) display, flat-panel displays (FPDs) such as active-matrix liquid-crystal displays (AMLCDs) have provided a means of employing displays in devices, locations, and applications where they were never feasible before, such as laptop computers and portable hand-held color television sets.

AMLCD technology is the best current means for producing high-quality portable displays, although they possess significant limitations in the areas of cost, power consumption, angle of view, smearing of fast-moving video images, temperature range, and the environmental concern of employing mercury vapor in the AMLCD's backlight.

The FED is an emissive FPD and operates on very different principles from the AMLCD. It utilizes a cathodoluminescent phosphor coating – similar to that of a CRT – excited by cold-cathode field-emission electrons which bombard the phosphors in a predetermined pattern (Fig. 1). This provides a luminous image that can be seen by a viewer.

The faceplate is separated from a baseplate by a vacuum gap, and outside atmospheric pressure is prevented from collapsing the two plates together by physical stand-offs – or spacers. Electron-emission sites – emitters – are typically sharp cones that produce electron emission in the presence of an intense electric field. In the display shown in Fig. 1, and in most other FEDs, a voltage that is positive relative to the sharp emitters is applied to an extraction grid to provide the intense electric field required for producing cold-cathode electron emission.

Schottky's approximate theories describing cold-cathode emission[1] were replaced and advanced by those of R. H. Fowler and L. W. Nordheim,[2] the fathers of the Fowler–Nordheim equation, which describes the emission process when a field is applied to one of the emitters (see Fig. 1) by generating a voltage differential between the extraction grid and the emitter tip.

The concept of a video-capable color FED was first presented by M. E. Crost, Kenneth Shoulders, and Mortimer Zinn in a U.S. patent applied for in 1967.[3] Following the work of Crost, Shoulders, and Zinn, recent developmental efforts have produced the world's first color video FEDs. LETI/Pixel (now PixTech) in France has demonstrated sequential-color FED prototypes, and Micron Display Technology (MDT) has demonstrated spatial-color FED prototypes in the United States.

How FEDs Work

The baseplate of an FED incorporates arrays of emission sites and a means of addressing and generating electron beams from those sites. Many techniques are available for creating the emissions, addressing the emission arrays, and activating the emission sites. There must also be a way to achieve variations in display brightness – gray scale – when the sites are activated.

Increasing the total electron charge delivered by an emission array to the phosphor of an individual pixel within a frame[4] increases the brightness of that pixel. In many cases, the brightness change will be nearly proportional to the increase in the delivered charge.

Cathodoluminescent phosphors have a property known as persistence: the phosphors continue to emit photons even after electron excitation has stopped. The duration of the persistence can be controlled by selecting different phosphor materials and varying the way the phosphors are synthesized. Persistence allows designers to choose how they will implement charge variation, and makes it relatively easy to produce a bright, high-quality image without having to activate a pixel during the entire frame time, as one must do for an AMLCD. Two techniques for varying the charge delivered by an emission array in a given frame are to vary either the time period

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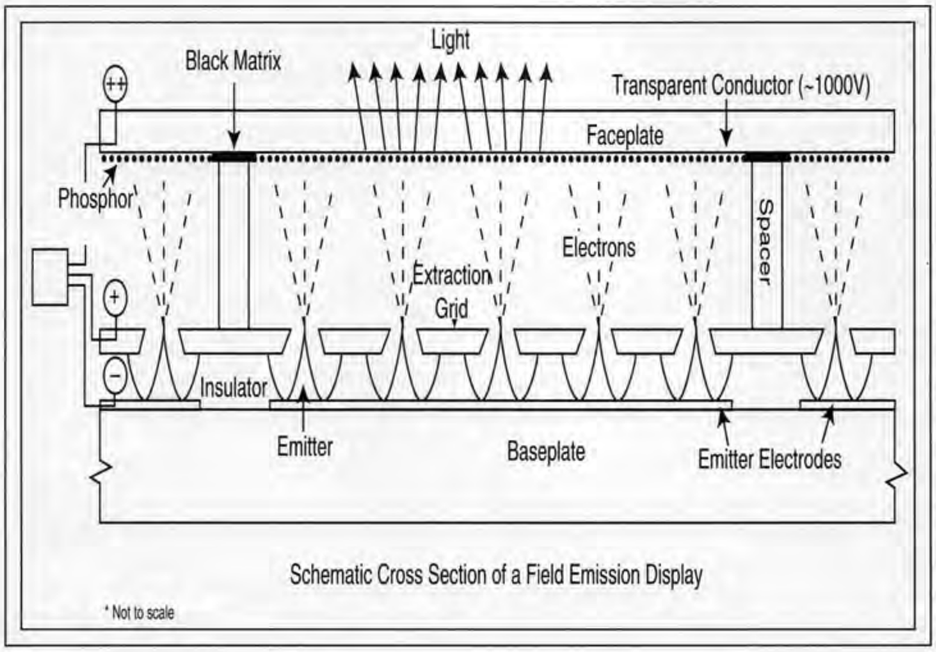
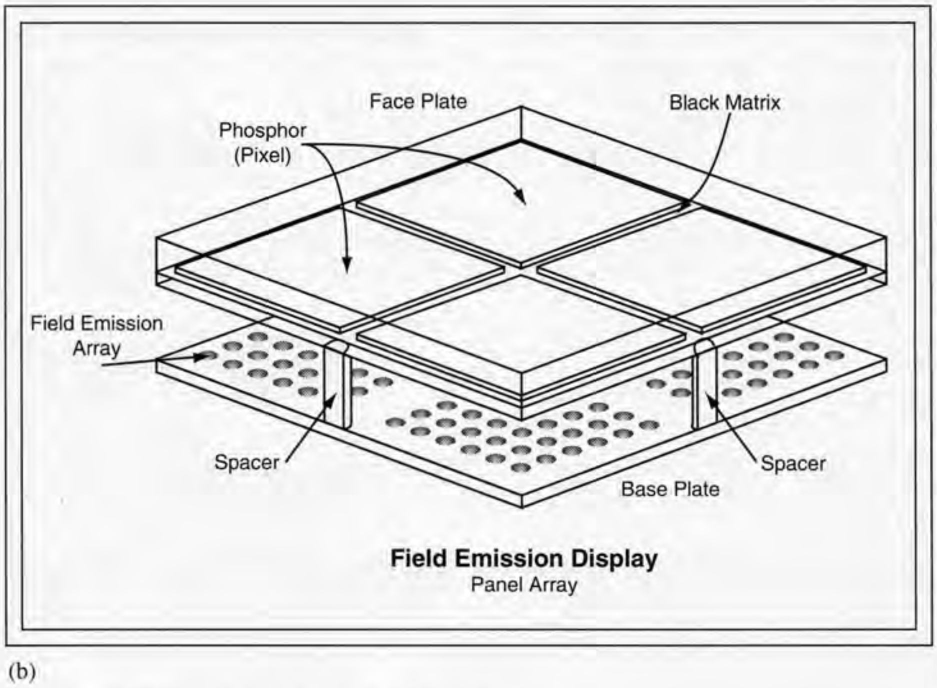


(a)



(b)

Fig. 1: *(a) FED cross section and (b) FED panel array.*

within the frame at the activated site or to vary the emission current produced during activation.

One means of addressing field-emission arrays for video-display applications is to use rows of emitters that are electrically connected and placed parallel to other rows of emitters.[3] The extraction grids associated with the emitters are electrically connected in parallel columns which are orthogonal to the emitter rows. The emitter array associated with each pixel is uniquely defined by the intersection point of a specific emitter row and a specific extraction grid column.[5] Electrically addressing a row while simultaneously addressing a column selects a specific pixel in the frame.

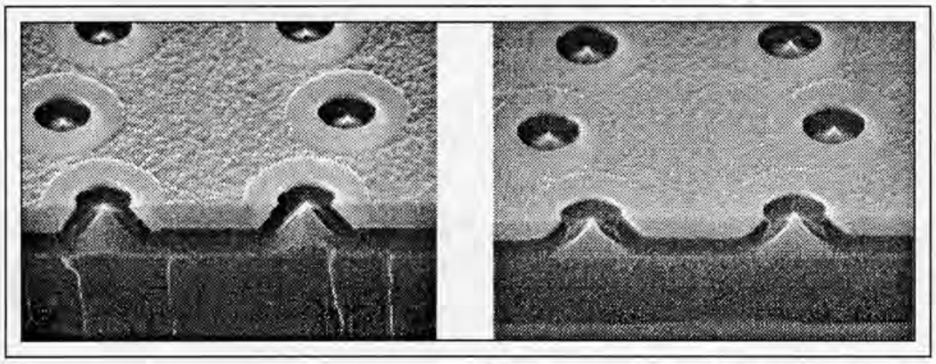
Design of the emission structures is a critical technology that has consumed much of the R&D work carried out on FEDs to date. Two pioneers in the area who are still active today are Dr. Cap Spindt of SRI and Dr. Henry Gray of the Naval Research Laboratory. In the late 1960s, prior to the dramatic advances in micro-machining and thin-film processing techniques that have been driven by the semiconductor and flat-panel industries, an enabling procedure was developed by Spindt and SRI for the fabrication of gated emitters.[6]

The Spindt technique uses high-resolution lithography and etching to create micron-sized openings in a metal–dielectric sandwich. A subsequent directional molybdenum deposition reduces and finally closes off the openings, which produces pointed molybdenum cones that are self-aligned to the openings in the original metal–dielectric sandwich. The molybdenum is selectively removed with an electro-chemical etchback, providing emitters with self-aligned extraction grids. The resultant structures are "Spindt emitters."

The classic Spindt technique has been a vehicle for advancing FED developments for many years and is still used today. Henry Gray and others have investigated a number of alternative techniques for self-aligned emitter processes involving plasma etchback planarization, lift-off processing, and fiber growth.

Alignment of the extraction grid to the emission site is a key factor. If alignment is not achieved, emitted electrons that would ordinarily be accelerated towards the faceplate and collected by it would be collected by the grid electrode instead. Collection of a large amount of emission current by the grid electrode would result in power inefficiency, image degradation, and an increase in the probability of failures.

Another approach, which Micron is using to fabricate precisely formed extraction grids that are self-aligned to the emitters, uses a combination of deposition, polishing, and wet etching (Fig. 2). The structure produces an emission I–V curve, which in the case of an FED means the field-emission current is a function of the voltage differential between



(a) (b) Micron Display Technology, Inc.

Fig. 2: SEMs of self-aligned emission structures fabricated at Micron. (a) Center of 6-in. substrate; (b) edge of 6-in. substrate.

the extraction grid and the emitter tip. The anode voltage relative to the substrate during these measurements was 1000 V.

Micron selected the polishing process for device fabrication because it is self-aligning, has a wide process window, defines the grid diameter by deposition (not lithography), avoids using a thick deposition of angularly evaporated molybdenum, and is compatible with MDT's large-area tip-formation process.[7]

Again, Again, and Yet Again

Emitters on the same substrate – and even within the same array – can produce significantly different emission currents even though the same voltage differential is being applied to their respective extraction grids. These differences are the result of small variations in tip diameter and surface structure which affect the electrical field. Small variations in the atomic make-up of the surface can change the work function, which also generates significant differences in emission current.[2,6]

Variations in emission current affect image quality. The image variations are reduced by using large numbers of emitters operating in parallel at each pixel site.

Further improvements in uniformity can be achieved through electrical compensation. The emitters are operated with a grid voltage capable of producing an electron emission current greater than the current desired and limiting the electron current supplied to the emitters. In addition to enhancing uniformity, regulated operation prevents very-high-performance emitters in an array from destroying themselves by generating very large currents.

One straightforward way of achieving current limiting is to use a series electrical resistance both to individual emitters and arrays of emitters. An approach developed by NASA in the early 1970s uses microscopic discrete resistors integrated with each emitter tip.[8] Another approach, pioneered at the Georgia Institute of Technology, is described in a Ph.D. thesis by Dr. Kon Jiun Lee that is an excellent document for training engineers in the area of field emission.[9] The thesis presents a technique – subsequently used in prototypes produced by the French team at LETI – in which a resistive layer is deposited to limit current through the field-emission cathodes (Fig. 4).

Almost Like a CRT Screen

The phosphor screen of an FED produces light by cathodoluminescence, as does a conventional CRT. As in a CRT, a color image can be obtained by using either a frame-sequential or spatial-color approach.[10,11] Nearly all commercially successful displays today – including those in home television sets, desktop computer monitors, laptop computers, and color-camcorder viewfinders – use spatial integration to provide a color image to the viewer.

Although the qualitative physics of an FED faceplate is very similar to that of a CRT faceplate, there are significant quantitative and engineering differences. FEDs do not tolerate particle shedding from the faceplate as well as CRTs, so excellent phosphor adhesion is required. The FED cathodes, which are very close to the faceplate, are also sensitive to the deposition of electronegative chemicals that can increase the value of the emitter work function. Therefore, some phosphor materials that are suitable for CRTs – notably sulfides of cadmium and zinc – are not recommended for use in FEDs.

The processes used to pattern the phosphors on the faceplate, bind the phosphors to the faceplate, and prepare the phosphor materials prior to application are critical to the fabrication of FEDs. These processes produce a thin, non-luminescent coating on the phosphor called the dead layer. High-voltage CRTs can tolerate a significant dead layer because the electrons are accelerated to high energies and

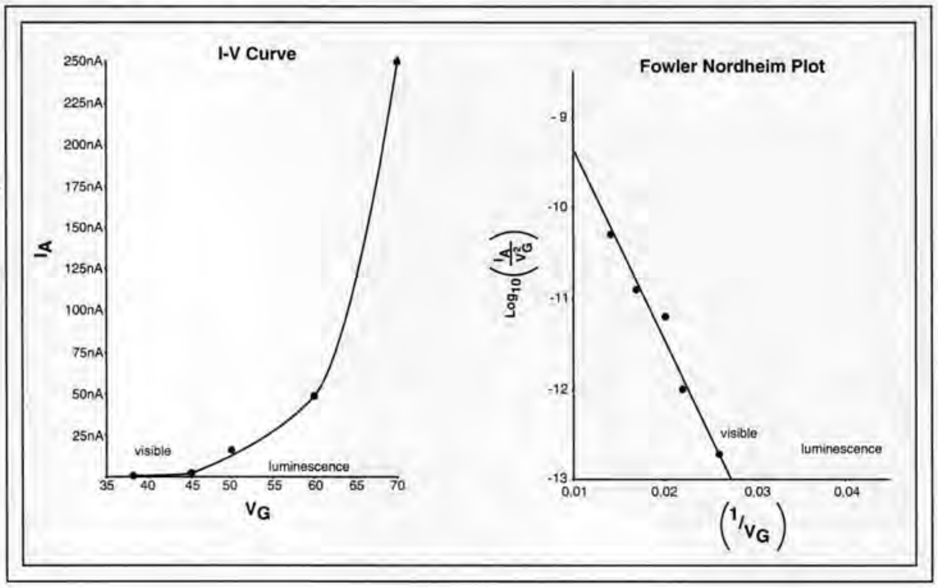


Fig. 3: Field-emission I–V curve and Fowler–Nordheim plot.

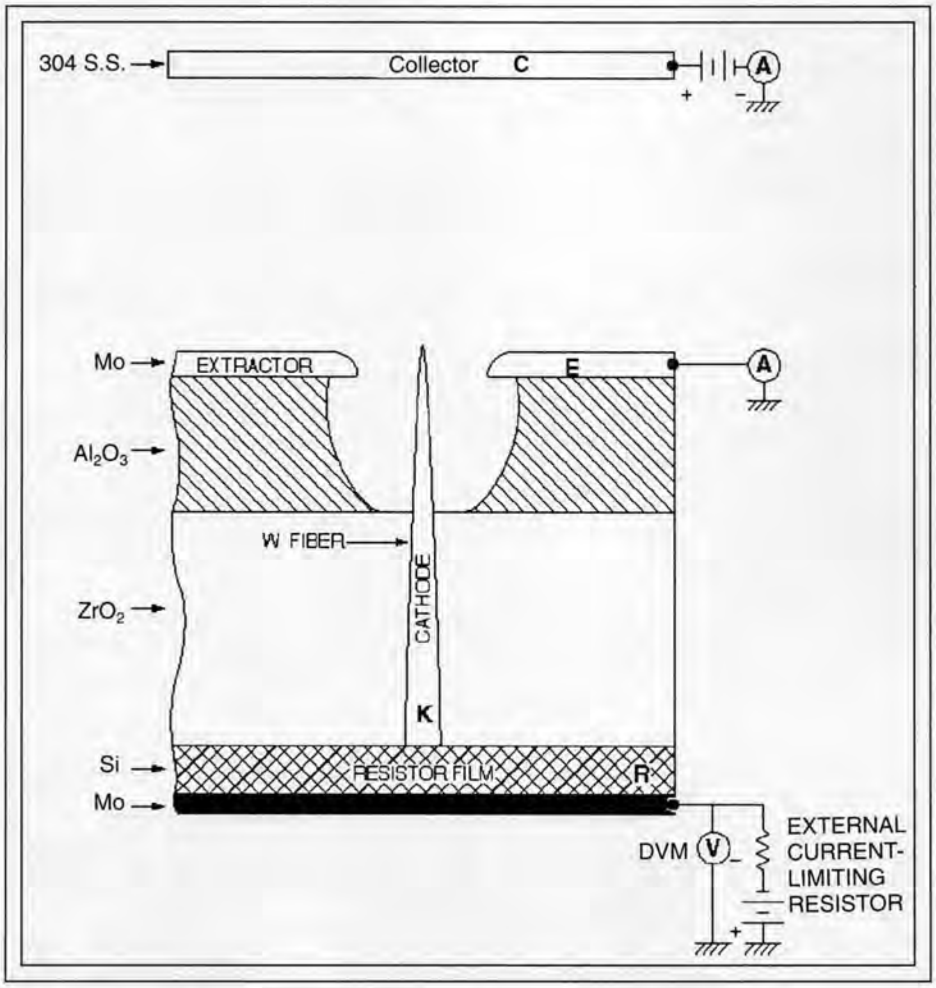


Fig. 4: A current-limited field-emitter array and emission test circuitry (see Ref. 9).

can easily pass through the dead layer to excite the phosphor. Because FEDs employ lower anode voltages, the phosphor screening and binding processes must be tightly controlled to minimize the dead layer. Significant advances in materials science, materials handling, and processing have occurred since the last major industrial push in phosphor synthesis, which was driven by the development of color television. These advances are being employed in the production of quality phosphors optimized for use in FEDs, and we are also seeing a resurgence of phosphor research.

Spacer Story

As shown in Fig. 1, FEDs use spacers between the faceplate and the baseplate to support the plates against atmospheric pressure. In medium- and large-size FEDs, the spacers must be distributed across the active region of the display so thin, lightweight faceplates and baseplates can be used. (The black-matrix regions of the display – used to absorb ambient light and thus improve the display's contrast – provide an excellent place to put spacers so they are invisible to the user.)

The materials used for FED spacers must not outgas and contaminate the high vacuum between the plates, and the materials must be able to withstand some stray electron bombardment without suffering from flashover, degradation, or generation of secondary electrons. Spacer architectures employing a series of individual posts provide the greatest protection against local pressure build-up, which can result in destructive arcing. But this type of structure requires spacer materials with high compressive strengths.

Researchers have tried a variety of spacer approaches. SRI has had some success with patterned, deposited polyimide layers. LETI has used glass spheres – a simple and low-cost approach – for prototype displays.[12] An advantage of spheres and other spacers with curved sides is that they yield a higher voltage stand-off than spacers with straight sides. Low-resolution FEDs can readily accommodate spherical spacers because the relatively large spacing between phosphor patterns is large enough to hide them.

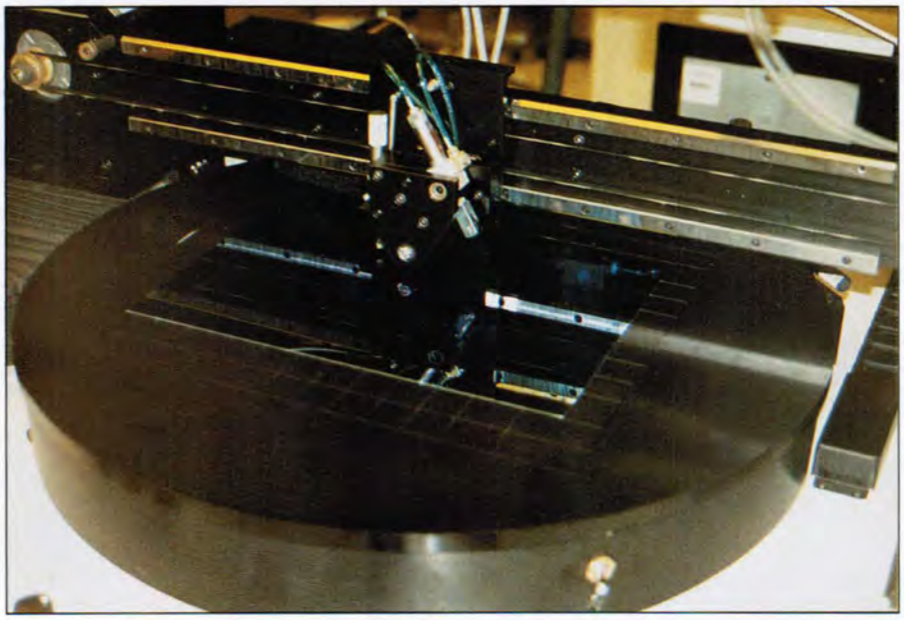
High-resolution FEDs will provide very little distance between phosphor patterns to accommodate spacers. Smaller-diameter spheres could be used, of course, but they would make it difficult to provide a practical working distance between the faceplate and the baseplate.

The issue of working distance is critical because it impacts the important issue of phosphor lifetime. The smaller the working distance, the smaller the maximum anode voltage. The light output from many phosphors is power-dependent, so increased current can compensate for reduced anode voltage. But most phosphor lifetimes are largely determined by the total accumulated charge delivered per unit area through the life of the display. This coulombic aging of the phosphor can be reduced through faceplate and phosphor-materials considerations, but can be impacted most dramatically by increasing the stand-off capability of the spacers so the required light output can be obtained with less current.

Micron is pursuing a post-spacer architecture in its 14-in. prototype line (Fig. 5). Micron's current design rule is to maintain a reliable stand-off voltage of 1000 V. Micron's spacer technology (patent pending) produces freestanding support pillars 25 μm wide and 250 μm tall. Voltage flashover measurements taken along spacer stalks 250 μm long and 25 μm in diameter range from 1400 to 2200 V, depending on process conditions. The surfaces of the stalks have outgassing characteristics equivalent to those of the materials of the display envelope from 25 to 450°C.

Recent Results

MDT has recently produced several video-rate spatial-color FED prototypes for use in military HMDs, weapon-siting devices, and camcorder viewfinders (Fig. 6). Prototype dis-



Micron Display Technology, Inc.

Fig. 5: A 14-in. FED panel in process at Micron's facility in Boise, Idaho.

plays have been installed in fully functional RCA PR0845 camcorders for demonstration purposes. Testing of the prototype displays in the camcorders has shown a complete absence of image smear, even during rapid panning in camera mode, which conventional AMLCD viewfinders cannot do.

Conventional camcorder viewfinders typically operate at a luminance of about 15 fL. The power consumption of the FED viewfinder at this luminance is approximately 25% that of a backlit AMLCD viewfinder. The baseplates for these displays were fabricated on 6-in. substrates at Micron. The viewing angle during direct observation of the display is over 160°.

Acknowledgments

Munsey Crost, Ken Shoulders, Mortimer Zinn, Cap Spindt, and Henry Gray had the foresight and fortitude to pioneer FED technology during a period in which only a small fraternity recognized the technology's potential.

I thank ARPA for supporting our work, and I appreciate the many valuable discussions I had with Bill Rowe, Phyllis Libman, and Heinz Busta. Finally, I thank my colleagues at Micron for the hard and innovative work that has made Micron's FED development possible.

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[5]The term "pixel" has been used to mean one discrete light-emitting element or dot.
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Micron Display Technology, Inc.

Fig. 6: This NTSC color video image was photographed on Micron's spatial-color 0.7-in.-diagonal 240 × 420 FED prototype. The prototypes have an active viewing area of 0.42 × 0.56 in. and total outer bezel dimensions of 0.95 × 0.80 in.

Are Plasma Display Panels a Low-Cost Technology?

At high volumes, materials costs and plant capitalization determine the base cost of a display.

by Peter S. Friedman

PLASMA DISPLAY PANELS (PDPs) are widely considered to be the only current technology that is practical for large direct-view color displays. But the current pricing of about $400 per diagonal inch makes a 21-in. panel cost about $8000, and the 42-in. panels that may reach commercial production next year would cost about $17,000 – clearly too much for even high-end home-theater applications. Fujitsu, however, is predicting that PDP prices will tumble to ¥10,000 (US$125) per diagonal inch, which would bring the price of a high-end system within the range of the "early adopters" market segment.

Is this projection fanciful? If not, can the price of PDPs fall farther – even far enough to allow PDPs to compete with CRTs for mainstream data and television applications? The answer to the latter question is yes. An analysis of the cost of ownership of the manufacturing equipment and of the cost of materials indicates that PDP technology should be a low-cost way of fabricating large-area direct-view FPDs once PDPs become a mature, high-volume manufacturing business – one in which the facility investment does not dominate the manufacturing cost. This high-volume manufacturing model, which describes the cost structure for CRTs, predicts that the manufacturing cost should be determined primarily by the total materials cost.

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PDPs in General

Monochrome PDPs have been available for over 20 years and have found significant markets in computer, medical, commercial, and military applications. While the basic construction and processing of monochrome PDPs has evolved very little, there have been significant advancements in PDP color structure, materials, fabrication processes, electronics, and packaging. Since the late 1980s, a number of companies have made important contributions toward the development of full-

Photonics Imaging

Fig. 1: *The finest pixel pitch currently available in a full-color (8-bit-gray-scale) plasma display is the 0.33 mm found in Photonics' 21-in. 1280 × 1024 AC-PDP video monitor. (This display was developed with ARPA funding.)*

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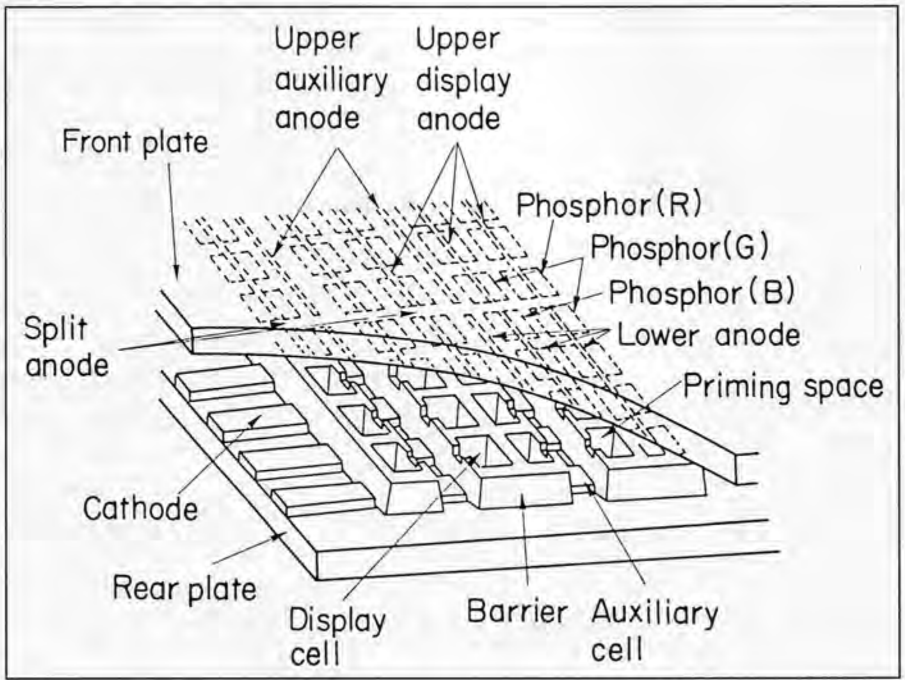


Fig. 2: The pulse-memory-drive structure for DC-PDPs was first developed by NHK in 1982. The illustration shows the implementation of this structure in NHK's 40-in.-diagonal developmental color display.

color high-definition PDPs that operate at full video rates with high luminance, high efficiency, true gray scale, and large area.

To date, the finest RGB-group pixel pitch for a full-color plasma display is 0.33 mm (Photonics' 21-in. AC-PDP 1280 × 1024, see Fig. 1). This compares with 0.28 mm for a typical 15-in. SVGA CRT computer monitor and 0.35 mm for Sony's 28-in. (viewable), 16:9, 1920 × 1080 CRT monitor. The largest full-color FPD fabricated to date is a 40-in.-diagonal DC-PDP developed by NHK.

At last count, there were approximately 20 major color-PDP research and development efforts worldwide – most of them in Japan – aimed at commercializing this technology. Large-area full-color PDPs are available from Fujitsu, Photonics Imaging, Plasmaco, and Thomson, with Fujitsu in volume production. However, of those companies focusing on picture-on-the-wall HDTV, NHK has probably done the most to publicize the materials and process issues related to fabrication of large PDPs. As high-volume commercialization of color PDP technology comes rapidly closer, the focus has changed from improving device performance to manufacturing and materials issues. Because PDPs use predominately thick-film construction and non-semiconductor fabrication procedures, they offer relatively low capitalization, materials, and process costs.

Device Structure

Many different types of structures have been reported, including ac, dc, and ac-dc hybrid devices. One of these structures, the Townsend-Discharge dc-memory display, set a record for luminous efficacy at 1.6 lm/W for white that has not been surpassed to this day. But the once huge diversity of device structures has given way to just three current configurations: the pulse-memory-drive DC-PDP, the surface-discharge AC-PDP, and the double-substrate AC-PDP. The reason for this coalescence is economics. Now that color PDPs are emerging from R&D labs, it is manufacturing cost that distinguishes practical structures from laboratory curiosities.

From a materials and fabrication point of view, the three basic color-PDP structures are much more alike than they are different. All three devices employ the same substrate glass and gas mixtures, and the same phosphor, barrier, black-matrix, and seal materials. They even have similar driver chips and gray-scale memory chips, and energy-recovery and power-supply circuitry. The manufacturing processes and the equipment required to produce all three devices are also very similar.

Pulse-Memory-Drive DC-PDP

Worldwide, a number of companies are working to develop color DC-PDPs for commercial application. Virtually all of these efforts use some form of the pulse-memory drive structure first developed by NHK in 1982 (Fig. 2). Modifications to the basic structure involve the possible use of a resistor in each cell, white reflective dielectric layers, an anti-reflective black matrix, and a contrast-enhancing RGB internal color filter. (All of these modifications have been implemented via screen-printing technology.)

Surface-Discharge AC-PDP

There are more than a dozen AC-PDP efforts worldwide, most involving surface-discharge structures (SD-PDP). The first color SD-PDP device was reported by Fujitsu in 1981. The forerunner to the modern three-electrode configuration – utilizing transparent ITO electrodes on the cover substrate, screen-printed dielectric ribs on the rear substrate, and no electrode crossovers – was first demonstrated by AT&T Bell Labs in 1985. In 1993 Fujitsu was the first to market a high-information-content color SD device: a 21-in. 640 × 480-pixel, 8-bit-gray-scale, full-color AC-PDP video monitor (Fig. 3). This display has an area luminance for white of 200 cd/m^2 with a luminous efficacy of 0.7 lm/W. Many companies are investigating different variations of the Fujitsu SD structure, but most of today's efforts are on improving the manufacturing process for lower cost and higher resolution. As with DC-PDPs, the production process is predominantly thick-film, with many of the same fabrication techniques and materials.

Double-Substrate AC-PDP

The conventional double-substrate AC-PDP has been investigated since the early 1970s for use in color devices. The structure's two major advantages are higher spatial resolution and simplicity of fabrication. Today's highest-resolution full-color FPD video monitor –

Photonics' 21-in. 1280 × 1024 unit – uses this structure. The double-substrate AC-PDP is manufactured with materials that are almost identical to those used in the other two structures, and is made with similar fabrication techniques.

PDP Materials: Substrate Glass

Because all three basic PDP configurations utilize similar manufacturing processes and materials, we can use a generic PDP structure and process to consider PDP cost issues.

The maximum process temperature for PDP devices is determined by the thick-film firing temperature of the screen-printed electrodes or dielectric – whichever is higher. Since this temperature is generally less than 625°C, fabricators can use soda-lime silicate float glass. This glass is low in cost and has excellent surface flatness and finish, but its low softening point of 722°C can result in changes in dimension during processing. (Whether the glass expands or contracts depends on the thick-film firing profile being used.) This lack of dimensional stability during processing complicates subsequent barrier and phosphor-dot alignment. We can either compensate for the substrate's dimensional instability by learning to adjust subsequent fabrication process steps or we can develop a new glass with a higher softening point. A new glass formulation would involve a significant increase in materials cost. On the other hand, manufacturing yields will suffer if dimensional instability can not be adequately controlled. Most companies are trying to learn to live with the properties of conventional float glass, although new formulations are being investigated.

PDP Materials: Electrodes

While many types of electrode materials have been tried in PDP devices, the obvious trend has been toward low-cost electrode materials that are compatible with low-cost deposition processes. The two most common thick-film electrode materials for the rear substrate are screen-printed nickel and silver. For the front substrate, the tendency is to use a low-cost transparent conductor with a narrow, screen-printed metal bus-bar. Except when gold is used, the materials cost far less than the processing to fabricate the electrode. As a result, most of the research in this area has been focused on low-cost process technology. High-resolution thick-film printing processes are the subject of much of this research, including techniques such as ink-jet printing and new formulations of photosensitive inks and pastes. For high spatial resolutions, though, conventional thin-film deposition of metal films followed by photolithographic patterning is still the most common technique.

PDP Materials: Barriers and Dielectric

All full-color PDPs require subpixel barrier structures to physically isolate the R, G, and B cells from optical crosstalk. Without such isolation, xenon VUV photons generated from one cell can stimulate adjacent cells. This causes photoluminescence of non-selected phosphors, which produces color desaturation and loss of pixel definition. The barrier geometry, in conjunction with the gas composition and pressure, affects not only pixel saturation and definition, but also the luminance, luminous efficacy, phosphor lifetime, and fabrication cost.

The subpixel barrier structure also isolates the subpixels electrically. The importance of this second function was not appreciated by early PDP developers, who were familiar only with the open structures of monochrome PDPs. This led to the erroneous conclusion in the 1970s and early 1980s that the electrical crosstalk between adjacent cells would make color PDPs with high spatial resolution impossible. But such displays are being made today because barrier structures, in conjunction with new gas mixtures, have sharply reduced electrical-crosstalk effects.

The optimum height for a barrier structure depends upon several factors, but the most important is pixel spatial resolution. The barriers in a color PDP also maintain the proper gap, which eliminates the need for the spacers used in monochrome PDPs. Typical barrier heights range from 100 to 200 μm in current color devices.

These cell structures require thick-film fabrication. The most impressive results have been achieved by screen printing – particularly as implemented by Noritake (Fig. 4), whose panels have been used extensively by Fujitsu. The barrier-rib width in these panels is 55 μm; the fluctuation in both rib width and height is ±10–15%. Making a rib three times as high as it is wide requires the application of five different thick-film pastes. And fabricating 55-μm-wide ribs across a 21-in.-diagonal

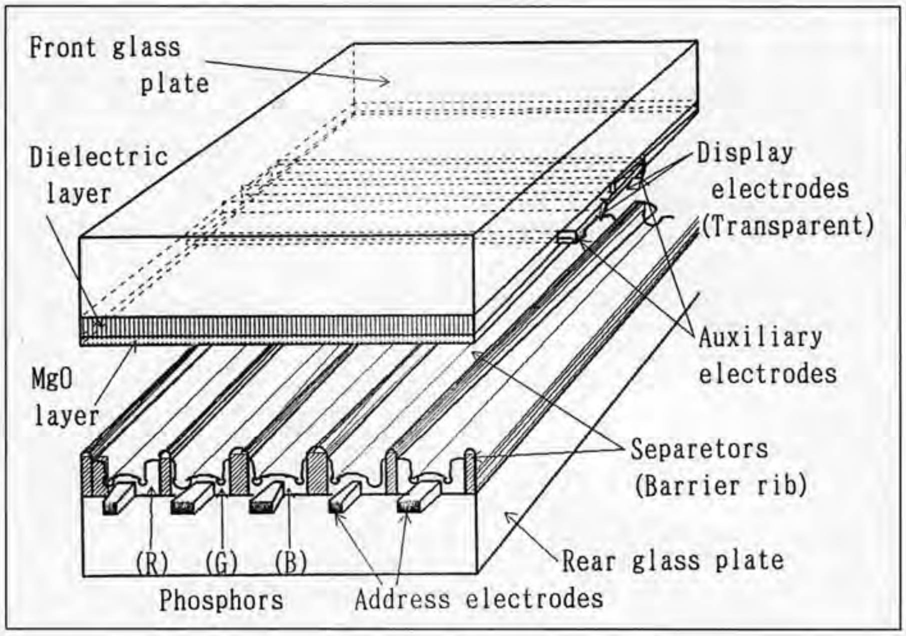
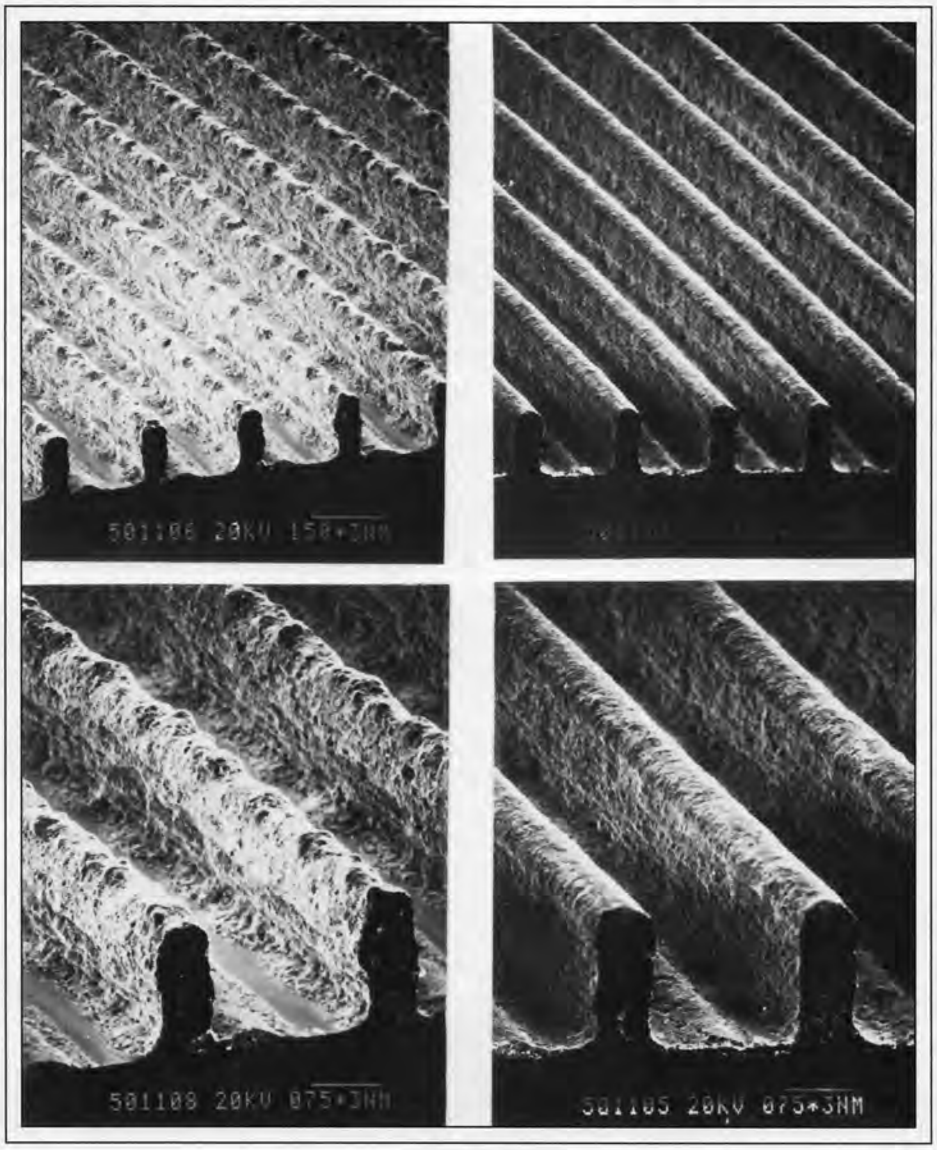


Fig. 3: *In 1993 Fujitsu marketed the first high-information-content, color surface-discharge AC-PDP – a 21-in. 640 × 480-pixel, 8-bit-gray-scale, full-color AC-PDP video monitor with an area luminance for white of 150 cd/m² and a luminous efficacy of 0.7 lm/W. The structure is illustrated.*



Noritake

Fig. 4: Noritake's barrier-rib structure is used in the Fujitsu and Plasmaco 21-in. color displays.

panel represents a significant advance in the state of the art for high-resolution screen printing.

Fujitsu and Plasmaco successfully use Noritake's technology in their 21-in. 640 × 480-pixel displays. For greater pixel densities, new technologies are being developed. Among these are hybrid screen printing and photolithographic techniques using photosensitive pastes or novel removal schemes such as sandblasting done with machines having very precise frit and flow control.

In addition to the barrier-rib dielectric and a black-matrix dielectric that coats the barrier ribs on the viewing side, AC-PDPs also employ a thick-film dielectric that is screen-printed over the sustain electrodes. This material capacitively stores the pixel wall charge. If this dielectric is on the front substrate, it must be transparent. When on the rear substrate it can be clear, white (to improve internal reflection), or black (to increase contrast). In most cases, the thick-film material is a lead borosilicate with a dielectric constant of 10–15 and a coefficient of thermal expansion close to that of the substrate glass ($85–90 \times 10^{-7}/°C$).

All AC-PDP devices, color and monochrome, require a low-work-function, thin-film dielectric coating for high secondary electron emission. This dielectric is typically magnesium oxide (MgO), which has high electron emissivity, low cost, and high resistance to sputtering. The MgO surface effectively becomes the ac electrode and is responsible in large part for the long life of these devices. Deposition of MgO is most often done by electron-beam evaporation, although researchers at Hiroshima University are developing a thick-film MgO paste that looks very interesting.

PDP Materials: Phosphors and Gas Mixtures

There are two fundamental ways to achieve color in PDP devices – through the inherent color of the gas discharge itself or through an appropriate phosphor excited by the gas discharge. Virtually all commercial monochrome PDPs utilize the visible emission from a neon-gas discharge, which is inherently orange-red in color. Other gas mixtures can produce different colors, but this is not a practical approach for a full-color PDP with saturated colors. For this, it seems we must use a single gas mixture in conjunction with photoluminescent phosphors.

Color PDPs are theoretically more efficient than monochrome PDPs; recently, this theoretical advantage has been realized in practical full-color devices. Fujitsu's commercial 21-in. VGA panel has a luminous efficacy of 0.7 lm/W, and Plasmaco showed a higher-luminance 21-in. VGA prototype at SID '95 with an efficacy of 1 lm/W.

The deposition of RGB phosphors in a PDP is generally more difficult than in a CRT because the phosphors must be placed within the confines of a three-dimensional barrier structure. Several effective thick-film deposition techniques have been developed, including pattern screen printing, and researchers are working on new hybrid photolithographic techniques for displays requiring greater pixel densities.

There is room for improving the properties of the phosphors themselves. In the U.S., a government/university consortium – the Phosphor Technology Center of Excellence

(PTCOE) – has been established at the Georgia Institute of Technology in Atlanta to pursue long-term research aimed at improving the basic properties of phosphor materials. Photoluminescent phosphors have excellent color saturation with good stability, but most of the work on these materials has been oriented toward the needs of the fluorescent-lamp industry, which has different requirements than do PDP manufacturers. About a year ago, the PTCOE began a photoluminescent phosphor-synthesis program to produce materials optimized for PDP stability and efficiency.

The radiative lifetime of a phosphor must be fast enough so that it does not induce motion "smear" in video-rate images. Of the three primary-color phosphors, only the Zn_2SiO_4:Mn commonly used for green has a decay time that is too long (25–30 ms) for moving images at 72 fps. Fortunately, modifications of this phosphor have demonstrated decay times of 5 ms or faster, and other materials also look promising.

The excitation gas used in most color PDPs is a Penning mixture of xenon and at least one other component, with xenon as the minority constituent. He-Xe and Ne-Xe are the most common two-component mixtures. Because of the variety of color PDP device structures being developed, device designers have not reached a consensus on optimum gas composition or gas pressure. Everything else being the same, the higher the concentration of xenon, the higher the luminous output and operating voltage. The higher the gas fill pressure, the greater the luminous output and the higher the operating voltage.

Driver ICs

The first generation of driver integrated circuits (ICs) specifically developed for color large-area 8-bit-gray-scale AC- and DC-PDPs has now been fabricated and is being designed into the next generation of color-PDP products. These drivers have been developed by a Photonics–Supertex team in the U.S. (under ARPA funding) and by an NHK–Texas Instruments team in Japan. The development is significant because for 1000-line color FPDs, driver chips constitute the single largest component cost. The new generation of driver ICs should reduce the electronics cost by half. Later in this decade, we should see advances in the fabrication of high-voltage ICs using dielectric isolation technology. These advances should cut the driver cost by half again, which would make plasma drivers cost-competitive with LCD drivers.

The Bottom Line

Large-area color PDPs exhibit inherently low costs from both the materials and manufacturing points of view. Most of the production processes are thick-film, which are typically high in yield and low in capitalization. Thus, once PDPs are produced in high volume, their costs should be competitive with large-area high-resolution CRTs for both the desktop-computer and home-entertainment markets. ■

editorial

continued from page 2

The new digital information media will allow conversations to replace monologues – both where it makes sense and where it does not. Paper-like electronic displays are expected to appear in the marketplace as early as next year. These new document readers, some of which will be lightweight and portable, will support a new spectrum of IPs. Some of these IPs will be electronic periodicals that are both multimedia and interactive. When the document reader is also designed to be interactive, it can serve not only as a rendering engine for the information but also as a means for altering the database.

In the era of digital information, new flat-screen display technology will continue to stimulate the development of many new information products. We're seeing a lot, but we ain't seen nothin' yet.

– Jim Larimer and Ken Werner

__Jim Larimer__ is Principal Scientist, Computational Human Engineering Research Office, at the U.S. National Aeronautics and Space Administration's Ames Research Center. __Ken Werner__ is Editor of Information Display.

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show report

Computex Taipei '95

Taiwanese companies will ship nearly 30 million monitors in 1995 – and most of them seemed to be on display at Computex.

by Bryan Norris

SOUTHEAST ASIA's largest computer show, held June 5–9, 1995, in Taipei, Taiwan, set new records. Computex Taipei '95, expanded from one hall to two twin halls in the Taipei World Trade Center, boosted exhibition space by 12% to 30,000 square meters and boosted exhibitors by 15% to 637 from 553 in 1994.

Over half of the 73 overseas exhibitors were from the USA, while others came from Japan, Singapore, Hong Kong, Germany, the UK, Australia, Malaysia, South Africa, and Thailand. This year, the show also included nine of Taiwan's top information-technology (IT) exporters: Chicony, Chuntex (CTX), Clevo, Compal, Datatech, Elitegroup, GVC, Mitac, and Tatung. They were housed in grand suites of the new "Rising Stars Hall" at the over-the-road Taipei International Convention Center. A few companies, such as AOC and newcomer AmTRAN, had their wares laid out in luxury suites of the nearby Grand Hyatt Hotel. In addition, the show organizers, the China External Trade Development Council (CEDTRA) and the Taipei Computer Association, increased the number of keynote speeches and seminars by 40% to a total of 56.

No Stopping the IT Industry

In 1994 Taiwan was the fourth-largest IT producer, with a combined local production value of US$11.6 billion – up 19.5% over 1993 – plus a staggering further US$3 billion of offshore production by Taiwanese companies. Taiwan therefore became the world's leading producer of main boards, mice, and keyboards (80% market share in each category), image scanners (61%), monitors (56%), and, more recently, notebook computers (28%). And in 1995, Taiwan's production of IT hardware is predicted to grow nearly 20% to US$17.3 billion, with domestic output up 13.5% to $13.1 billion and offshore production up 42% to $4.2 billion! Furthermore, Taiwanese industry, already very active in CRT production, aims to increase its investment in the key core-components sector, notably by ramping up its output of DRAMs, CPUs, chip sets, and LCDs. Thus, in 1995, Taiwan is expecting to overtake Germany and become the world's third-largest IT products supplier – after the USA and Japan.

The Rich Get Richer

According to articles in the local press, the well-respected Market Intelligence Center (MIC), a division of Taiwan's Institute of Information Industry (III), reported that Taiwanese suppliers manufactured over 24 million monitors in 1994, up over 34% from 1993 and worth nearly US$5.3 billion or 30% of Taiwan's total IT revenues. More surprising, 40% of Taiwan's monitors are now made offshore, primarily in Thailand and China. In the first quarter of 1995, Taiwan's monitor output grew to nearly 7.5 million units (up 31% over the same period in 1994), with nearly 4.2 million being produced in Taiwan itself (up 7.5%) and nearly 3.8 million being produced at offshore locations (up 84%!). For this first quarter, Europe overtook the USA as the largest recipient – taking over 40% of the 7.5 million monitors – while the U.S. share dropped below 39%. Of the second quarter's predicted output of over 8 million monitors, nearly half will be made offshore.

For the full year 1995, combined monitor production is expected to reach between 27.5 and 30 million units! Interestingly, there is a clear indication that most of the major producers are getting larger, both by volume output and share of total Taiwanese production. In 1993 the top 20 suppliers by volume accounted for just over 89.5% of the total output. In 1994 their share rose to nearly 92%, and in the first quarter of 1995 it was over 95.5%.

Offshore plants making large volumes of predominantly 14-in. monitors play a significant role in this trend. Acer, Philips, ADI, Lite-On, MAG, Tatung, and CTX – all leading members of the top 20 in terms of units produced in 1994 – had a good year. Each of them is now making well over a million units a year. Although lower down the list, Delta, TVM, KFC, Shamrock, Teco, Bridge, AOC, and Jean (Wen) also had good years. Royal, Compal, and Capetronic, on the other hand, did not do as well as in 1993.

Some companies, such as Intra, went out of business. Others were bought by large multi-product companies. Elitegroup took over the Da Vinci brand from Chenbro group and renamed the monitor range Vertos. Other firms, including Clevo and Chien Hou/Datas, withdrew completely from the monitor marketplace.

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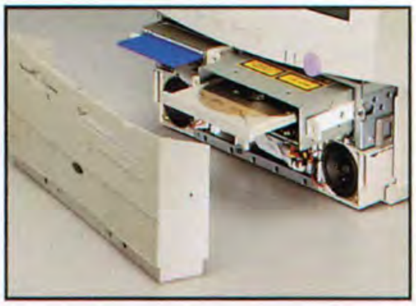
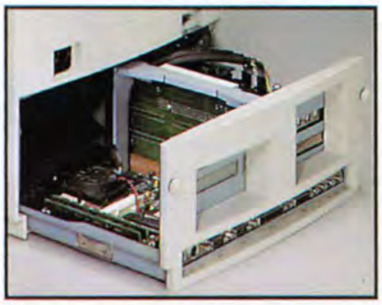




	Model	Sphinx 442	Sphinx 554
PC	CPU	486SX/DX/DX2/DX4	Petium P54C
	DRAM	4MB-68MB	8MB-128MB
	Cache	128KB-256KB	256KB-512KB
	Flash ROM	•	•
	Expansion Slot	2 PCI, 1 ISA/1PCI, 2 ISA	2 PCI, 1 ISA/1PCI, 2 ISA
	Driver Bay	3	3
	Serial/Parallel Port	2/1	2/1
	Game (MIDI) Port	1	1
	HDD Interface	Enhance IDE	Enhance IDE
	CD-ROM Interface	IDE/ATAPI	IDE/ATAPI
	CD-ROM Drive	Double Speed	Quard Speed
VGA	VGA Bus	PCI	PCI
	Window Accelerator	•	•
	Video Memory	1MB-2MB	1MB-2MB
	Resolution	1280x1024 256 colors	1280x1024 256 colors
	MPEG	Add on Card	Software
Display	CRT	14", 0.28mm	15", 0.28mm
	Scan Frequency	30-50KHz	30-64KHz
	Power Management	DPMS	DPMS
	Over Scan	•	•
	Control Pannel	Digital	Digital
	External VGA input	•	•
Audio	Sound Card	16 bit on board	16 bit/Wave Table on board
	Amplifier	3W	3W
	Speaker System	Internal Bass Refex	Internal Bass Refex
	Headphone Jack	1	1
	Microphone Jack	1	1
	Internal Microphone	•	•
	Volume Control	Digital	Digital
	Mute Switch	•	•
System	AC Power	90-264V AC	90-264V AC
	Power Management	•	•
	Tilt & Swivel	Option	Option
	IR (Remote Control)	Option	Option
	Dimension (WxHxD)	360x433x428(mm) 14"x17"x17"	360x433x428(mm) 14"x17"x17"
	NET-Weight	26kg (57.27lb)	27kg (59.47lb)
Others	Fax/Modem/Voice	Option	Option
	TV Tuner	Option	Option

Elitegroup/Vertos

Fig. 1: *An old idea revived by today's multimedia needs, the moniputer is an all-purpose all-in-one product integrating a PC, monitor, speakers, CD-ROM, and a variety of optional features. The market for these products has really taken off in Japan – 650,000 units sold in 1994 – and a dozen companies showed moniputers at Computex. The Elitegroup/Vertos Sphinx 554 (pictured) contains a digitally controlled 15-in. CRT display with 0.28-mm dot pitch and a horizontal scan frequency of 30–64 kHz.*

For the smaller firms to continue to manufacture monitors, provided they can still get tubes of course, they must become niche-market suppliers or search out special small-volume needs that the larger companies have no wish to service. For example, ThreeSOMA boasts a couple of "quality" 14-in. monochrome monitors, which it sells OEM in quite reasonable quantities to Tatung and OEMs and under its own brand name in Europe, particularly in Poland.

Chun Yun Electronics has withdrawn from providing 14-in. color and concentrates on 17-in. and large-screen models, notably those that are video-compatible and have 28-, 29-, 33-, and 37-in. CRTs. At the other end of the screen-size table, Action, ETC, TVS, and Wen (Jean) have all built up a reputation for supplying the relatively small but growing market for 9/10-in. monitors, monochrome and color.

The Magnificent Seven

Acer Peripherals, by virtue of its new volume-production factory in Malaysia, almost doubled its 1993 output to reach nearly 2.6 million monitors and to top the 1994 list. With nearly 900,000 monitors produced in the first quarter of 1995, Acer is well on course to supplying 4 million units in 1995 – over 3 million from Malaysia – and 6.7 million a year by the end of 1996. (Three more production lines will be added to the Malaysian plant.) API's new monitor plant near Taoyuan, Taiwan, will be ready in the third quarter of 1995 and will double the company's capacity in Taiwan. API has also started construction on a new monitor factory at Suzhou, China, and another plant is being considered in South America or Mexico.

Dutch company Philips Taiwan also had a very successful year in Taiwan, both in monitor and CRT production. Having also produced nearly 2.6 million monitors in 1994 and around 750,000 in the first quarter of 1995, it is also well on target in its ambitious 1995 goal to produce over 5.5 million monitors in its Taiwanese, Mexican, and Hungarian plants.

ADI made just over 1.9 million monitors in 1994 and, now working to capacity to meet its commitments, has signed contracts with firms in Malaysia and China to sub-contract production. A large part of the output of ADI's two Taiwanese factories, currently making about 120,000 units a month, is devoted to supplying its major OEM client, Compaq. The three production lines in ADI's Thailand plant are producing 65,000 units a month, and the Thai and Chinese operations are being expanded to provide 80,000 units a month. In 1994, ADI, one of the largest Taiwanese monitor-only producers, had profits of US$16 million on revenues of US$424 million. This profit margin of only 3.7% is not atypical for Taiwanese monitor makers.

Founded in 1918, Tatung is one of the old established Taiwanese companies, and one of the largest, with 1993 sales revenues of US$2.6 billion. It employs 30,000 people and manufactures a wide variety of electronic and electrical goods in factories all over the world. As well as making monitors in Taiwan, Tatung assembles monitors in Thailand and at Telford in the UK. Asian production reached nearly 1.9 million monitors in 1994, and Tatung is expanding production significantly. An integral part of Tatung's operation is its CRT production division, Chunghwa Picture Tube (CPT), which is one of the world's largest manufacturers of 14-in. tubes.

Lite-On doubled its monitor output in 1994 to 1.75 million units and has very ambitious plans to continue to expand production at this rate. At its two plants on the Keelung, Taiwan, site there is a monthly capacity to make 85,000 monitors, and the Penang, Malaysia, factories have a combined capacity of 220,000 units a month. With Lite-On's new plant in China coming on-stream in 1995 and the Mexican plant in 1996, capacity in 1996 will rise to 470,000 monitors a month. A European plant is planned for 1997, which will bring the total capacity up to 600,000 units a month.

CTX (Chuntex) and its nearly 14,000 employees produced 1.45 million monitors in 1994. Chuntex expects revenues to reach US$750 million in 1995, primarily from the planned production of 2.5 million color monitors – 1 million in the Chuntex-owned Ann-Dong plant at Chung-Li, Taiwan, another million in the new Thailand factory, 450,000 in the older Thai factory, and 50,000 in the new Hong Kong plant. The 15-, 17-, and 20/21-in. models made by CTX in its Chung-Li factory are noted for their up-to-date specifications. Chuntex is also very active in the stand-alone LCD monitor field. One of the world's largest suppliers of these products, CTX is being forced to look for larger premises for its LCD assembly operation currently located at the Science-Based Industrial Park Hsinchu.

MAG, considered to be a high-end monitor maker, produced around 1.2 million monitors in 1994, 45% of these being 17- and 21-in. models. In the first quarter of 1995, MAG supplied over 410,000 units, and with full-scale production of 14- and 15-in. monitors beginning at the Indonesia factory in August, 1995, MAG aims to increase its 1995 total to 1.8 million units.

On View at Computex Taipei '95

Over and above any other show, Computex is a paradise for anybody interested in monitors! The exhibition halls were crammed with over 50 monitor suppliers, nearly all with impressive booths.

The move toward monitors with larger screens – and thus higher profit margins – continues. Some of the smaller-volume producers without low-cost overseas plants, such as Topfly and Chun Yun, have withdrawn completely from supplying 14-in. models. Most of the larger companies have slimmed down their 14-in. range, standardized on one or maybe two chassis, and often have dispensed with the high-end model now being challenged by 15-in. models. Examples include ADI, Bridge, CTX, and Parco (Pei Chou).

The main emphases by the Taiwanese suppliers are on 15-in. and, especially, 17-in. monitors. Most of the products have maximum horizontal scan frequencies in the 64–70-kHz range, giving a flicker-free 1024 × 768 at around 75 Hz. However, in addition, there were nearly 40 80–85-kHz 17-in. models on offer which are capable of running a flicker-free 1280 × 1024 at around 75 Hz. At the other end of the scale, seven 15-in. and seven 17-in. 48–50-kHz models were to be seen. Half of the 17s had 0.42–0.39-mm dot-pitch tubes aimed at the consumer/multimedia market.

An interesting 17-in. unit on the ADI stand was a rotatable model allowing the screen to be in either the "landscape" or "portrait" position. AmTRAN, whose President, Alpa Wu, is the ex-CEO of MAG, was exhibiting its very impressive 17- and prototype 21-in. monitors alongside the much larger, heavier, and less-featured MAG models in a Grand Hyatt suite.

This year there were quite a few 20- and 21-in. monitors on offer by some of the larger or more able monitor producers. It must be noted that some of these monitors are still to be announced, and others come under the category of "We will make these if you wish to order enough." However, some manufacturers, such as Cheer, had decided that it was just not economical to offer still another 20-in. monitor.

Despite ongoing demand by a significant number of end users – especially in southern and eastern Europe and in developing countries – this year is likely to see the last of the 14-in. monitors with a 0.39-mm dot-pitch tube. Companies such as Addonics, ADI, Cheer, Lite-On, Parco, Proton, Regent, and VDO have already stopped making this product, and others are only hanging on "while stocks of CDTs last, to the end of 1995, perhaps."

Shortages and Price Hikes

It was tube shortages and price rises that were the major talking points in Taipei. At the moment, there is shortfall of color display tubes (CDTs) of all screen sizes. But as CRT manufacturers work 24 hours a day, 7 days a week, and rush to bring extra capacity on-stream, the deficit between demand and supply is confidently predicted by most tube suppliers to disappear by the end of 1995, or even earlier. Thus, this year's worldwide CDT demand, variously estimated to be between 47 and 50 million units, should be satisfied eventually, but empty supply times could take a while to fill. It appears that only the monitor makers who have high-volume demand on their side, or who got orders in and accepted early, will have their requirements satisfied before the fourth quarter.

In times of shortage, producers can increase prices, especially if profit margins have fallen below economically viable levels. CDT profit margins fell to as low as 4–5% in 1994, and we have seen price rises of 12–15% since October, 1994, to improve these margins, as well as to keep up with spiraling costs for steel, copper, and plastics, and to keep up with dollar–yen exchange-rate depreciation. Current CDT prices are around US$90 for a color 14 in., US$110–130 for a 15 in., and US$220 for a 17 in. But percentages are still well below the profit levels of other components, so further increases are in the pipeline. This means that monitor prices will at least stay constant – if not increase – for the rest of 1995.

The Moniputer

There was considerable razzmatazz about "the final integration" – the "moniputer" (Fig. 1). An old idea revived by today's multimedia needs, the moniputer is an all-purpose all-in-one product integrating the PC in the monitor and adding sound card, speakers, and CD-ROM, plus as many other features as the end user considers necessary and is willing to pay for. (Unlike earlier efforts in this genre, the current generation is expandable, with accessible card slots, drive bays, and memory sockets.) The market for these products has really taken off in Japan. In 1994 around 650,000 moniputers were sold there. The major suppliers were NEC, IBM, Compaq, Fujitsu, and Matsushita/Panasonic. In 1995 sales of these units are expected to reach one and a quarter million!

At CeBIT '95, Lite-On showed its 14/15-in.-screen model. And at Computex there were moniputers in all status positions, from "you like it – we'll make it" prototypes to units actually being delivered. Companies that had a moniputer to show included Compal, Elitegroup/Vertos, FIC/Leo, Forefront, GVC, KFC, Mitac, Philips, Tatung, TVM, and Waffer/High Ability Computers. Apparently, President also has a model. Most had a 14-in. screen with a 15-in. option. Forefront has a 12-in. unit and Compal is planning a 17-in. model.

Elitegroup Computer Systems – a major motherboard maker with Umax as its parent company – promoted its Vertos moniputers, which are representative of what is being offered. As shown in the exhibit, these have a 0.28-mm dot-pitch (30–50-kHz) 14-in. monitor (Sphinx 442) or (30–64-kHz) 15-in. monitor (Sphinx 554) with two integrated stereo 3-W speakers, built-in double- or quad-speed CD-ROM drive, and a 16-bit sound card. The PC itself is a 486SX/DX/DX2/DX4 (442) or Pentium P54C (554) with 4–68 to 8–128 MB of RAM. Five assorted expansion slots are standard. Options include MPEG video card or software, fax/modem/voice facility, TV tuner card, and remote control. Some suppliers even offer karaoke kits.

Taiwan's Monitor Makers Go for IT

This year's Computex again served to endorse the commanding presence that Taiwanese monitor manufacturers have in the world. It is not just a case of sheer volume – which is staggering. But the quality and variety of the products and the innovations already being incorporated in them are also extremely impressive.

Suppliers such as Abco, AOC, Bridge, Compal, Delta, MAG, Philips, Royal, Sampo, Shamrock, Tatung, TVM, VDO, and ViewSonic now offer some models with the option of (DDC1/2B) "Plug & Play."

On the "green" theme, most Taiwanese monitors have the MPR-II option, and a number have TCO '92, which incorporates NUTEK's stringent power-save levels. Notable manufacturers in this camp are Acer, ADI, Compal, MAG, and Sampo.

CTX has a new 17-in. model that incorporates the new 17-in. Diamondtron® aperture-grill tube from Mitsubishi and a line of state-of-the-art stand-alone LCD monitors. The company promises bigger screen sizes and high-resolution flat-panel models soon. AOC now offers a 3-year guarantee, partly to redress the troubles AOC had last year. Newcomer AmTRAN has a very neat, simple-to-operate, one-knob, on-screen-display system on its sophisticated 17-in. monitor. And Action, GVC, Optiquest, Philips Taiwan, Sampo, and Tystar all have models with housings in "your newest color" blue-grey plastic. A number of companies, in addition to CTX, were demonstrating LCD stand-alones.

Computex Taipei again provided a rewarding opportunity to learn just how important and up-to-date are the monitors from the Taiwanese industry. The industry's volume output, innovation, and quality are already extremely impressive – and the industry's competitiveness virtually assures that in 1995 it will be even more impressive! ■

Edited by JOAN GORMAN

Multi-format hi-res monitor

EDL Displays, Inc., Dayton, Ohio, has announced the MasterSync 6128, a 16:9 high-resolution color monitor utilizing a 28-in.-diagonal CRT with a dot pitch of 0.35 mm. The 6128 provides sharp images at resolutions up to 1920 × 1080 non-interlaced, and will automatically sync and display any RGB format from 15 to 90 kHz without a scan converter. The MasterSync 6128 is built in a modular fashion and all electronics are accessible via rear-panel plug-in modules.

Information: Michael J. McArdle, EDL Displays, Inc., 1300 Research Park Drive, Dayton, OH 45432. 513/429-7423, fax 513/429-6985.

Circle no. 1

High-definition floating images

Dimensional Media Associates (DMA), New York, New York, has introduced a high-definition volumetric display (HDVD™) for interactive touch-screen kiosks that projects full-motion 3-D animation and video images into free space. The principle of the suspended-image system involves the collection of light rays from either single or multiple sources, including a CD-ROM, laser disc, video recorder, or HDTV broadcast signal, and reassembly and projection of the aggregate light rays into a 3-D aerial image. The projected image can vary from inches to as much as 20 ft. across, and the horizontal and vertical fields of view may extend to as much as 360°. The display hardware and the screen surface are filtered out to display the 3-D computer rendering or full-motion video image in "thin air," thus eliminating the physical boundaries of a monitor. The images can be viewed in natural light as well in darkness or under controlled lighting conditions. In addition to use in point-of-sale kiosks, the technology is also relevant to gaming, entertainment, medical, military, and navigational applications.

Information: Dimensional Media Associates, 675 Avenue of the Americas, New York, NY 10010. 212/620-4100, fax 212/620-7771, e-mail: dma@3dmedia.com.

Circle no. 2

Tabletop projection TVs

Matsushita Consumer Electronics Company, Secaucus, New Jersey, has announced the Panasonic PT-51G20 and the step-up PT-51G30, two new 51-in.-diagonal tabletop projection TVs that double the viewing area of a 35-in. direct-view set. Their slim profiles, just 23.6 in. deep, facilitate in-wall installation, where remote controls can command the TVs through the screen. Both sets can reproduce 750 lines of horizontal resolution. The PT-51G20 features a comb filter which helps remove "dot-crawl" distortion, while the PT-51G30 employs a new 3-D luminance/chrominance comb filter for even greater picture integrity. User-activated artificial-intelligence sound, which detects and compensates for sudden and drastic volume changes, protects viewers from the auditory jolts that usually accompany TV commercials, and equalizes volume levels among different TV channels. The suggested retail price for the PT-51G20 is $2499.95 and $2699.95 for the PT-51G30.

Information: Matsushita Consumer Electronics Co., One Panasonic Way, Secaucus, NJ 07094.

Circle no. 3

Projection-panel upgrade

Proxima Corp., San Diego, California, has introduced Version 2.0 of its Ovation+® 920, the first fully workstation-compatible active-matrix LCD projection panel capable of displaying 1280 × 1024 images. With a data rate of 135 MHz, the panel offers the highest bandwidth compatibility of any LCD projection panel, and can interface with the highest-speed workstations directly at their highest-resolution mode. Ovation+ 920 features include the ability to pan freely around the entire screen area to display full pixel resolution, and zoom capability to blow up a 640 × 480 image to fill the entire screen. In addition, the panel incorporates an innovative LightBoard™ feature that lets users highlight information directly on the projected image, regardless of application, and it's the only product in its class to offer complete remote control of software through Proxima's Cyclops® cordless mouse. The Proxima Ovation+ 920 lists for $14,795 and is available through value-added resellers and workstation distribution channels.

Information: Proxima Corp., 9440 Carroll Park Drive, San Diego, CA 92121-2298. 619/457-5500, fax 619/457-9647.

Circle no. 4

Adjustable magnetic shield

Magnetic Shield Corp., Bensenville, Illinois, has announced SHIELDWRAP™, a spiral-wound EMI magnetic shield that adjusts to protect sensitive electronic components ranging from 1.25 to 4.00 in. in diameter. The shield is also easily formed to fit irregular cross sections, and has the capacity to adjust the level of attenuation by varying the degree of overlap. Reusable SHIELDWRAP provides the high levels of attenuation associated with concentric shields. It is manufactured from high-permeability CO-NETIC AA alloy and produced in 60-in. lengths at a price of $50.00 each from stock. Custom lengths supplied on special order. Contact factory for data sheet SW-1.

Information: Magnetic Shield Corp., 740 North Thomas Drive, Bensenville, IL 60106. 708/766-7800, fax 708/766-2813.

Circle no. 5

Circle no. 29

Fast photoresist stripper

Silicon Valley Chemlabs, Inc., Santa Clara, California, has introduced the PR_X™ Positive Photoresist Stripper, a non-corrosive stripping solution that removes post-etch hardened polymers and polymer residue from semiconductor wafers. The solution is formulated specifically for modern sub-half-micron IC processes, and dissolves hard-to-remove high-dose ion-implanted, hard-baked, and plasma-etched polymers 2–3 times faster than conventional solvent-based strippers at low temperatures between 25 and 60°C. The PR_X stripper is water soluble, biodegradable, non-flammable, non-toxic, and non-corrosive. Soft metals such as copper and aluminum are not attacked because the formula is free of amines and NMP, chemicals present in other stripper formulations.

Information: Shawn Sahbari, Silicon Valley ChemLabs, Inc., 3446 De La Cruz Blvd., Santa Clara, CA 95054. 408/970-0656, fax 408/970-0659.

Circle no. 6

Stand-alone frame grabber

VideoLabs, Inc., Minneapolis, Minnesota, has announced the VideoShot, a palm-size stand-alone frame grabber for notebooks and PCs that plugs directly into a parallel port, operates on three AAA batteries, and can capture 500 true-color frames when working with notebooks. VideoShot can capture an image at 640 × 480 resolution in 16 million colors in 1/30th of a second, works with all available image-processing software, including PhotoStudio, Photoshop, and Corel Draw, and is TWAIN-compatible. Video input is accomplished using VideoLabs' FlexCam®, a camcorder, a VCR, or any other video source. Depending upon the capabilities of the user's computer, a preview rate of 8–12 frames/s is possible. The VideoShot frame grabber is listed at $229.

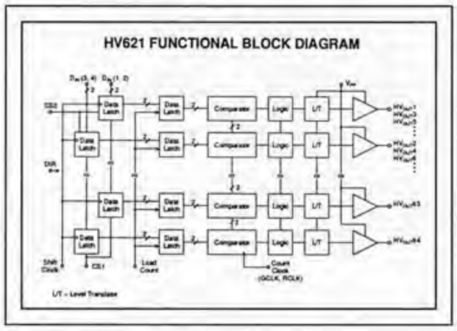
Information: VideoLabs, Inc., 10925 Bren Road East, Minneapolis, MN 55343. 612/988-0055, fax 612/988-0066.

Circle no. 7

64-channel column driver IC

Supertex, Inc., Sunnyvale, California, has introduced the HV62106, a 64-channel column driver IC designed for gray-shade flat-panel displays capable of achieving 16 gray shades on each of the 64 outputs. The HV62106 has a breakdown voltage of 60 V and a source and sink current capability of 12 mA minimum. The logic section of the chip, which operates at 5 V, has two sets of 2-bit data-input pins that receive data at a 14-MHz rate, with an effective data throughput rate of 28 MHz. Other features include a direction pin to allow for either clockwise or counter-clockwise output sequencing, as well as a chip select pin that enables the next device in the chain of ICs. Available in die form, the HV62106 has a pad layout that is mechanically balanced for use in flip-chip-on-glass (FCOG) mounting. Applications include driving electroluminescent, plasma, vacuum fluorescent, and other flat-panel displays. The price for the HV62106 in 1000-piece quantities is $12.74. Lead time for production quantities is 4–6 weeks ARO.

Information: Supertex, Inc., 1350 Bordeaux Drive, Sunnyvale, CA 94089. 408/744-0100, fax 408/734-5247.



Circle no. 8

Broadband polarization rotator

Displaytech, Inc., Boulder, Colorado, has introduced the Achromatic Rotator, a high-speed liquid-crystal light valve that transmits broadband light waves for more even color transmission. The device, which serves as a broadband polarization rotator, is able to improve the broadband spectral response by sacrificing contrast. The Achromatic Rotator combines a single ferroelectric liquid-crystal cell with a static birefringent element, and is designed and assembled so that the retardance is a half-wave in the green, blue, and red. The rotator can be designed and built to accommodate both the visible-light spectrum and near-infrared. Typical spectral responses are an 85% transmission for single wavelengths and 92% for the integrated spectrum. Contrast ratios are 100:1 between parallel polarizers and 200:1 between crossed polarizers. The device can be used in applications such as single-camera 3-D video capture.

Information: Haviland Wright, Displaytech, Inc., 2200 Central Ave., Boulder, CO 80301. 303/449-8933, fax 303/449-8934.
Circle no. 9

Super-bright LCD projectors

Polaroid Electronic Imaging Systems, Cambridge, Massachusetts, has announced the

Polaview line of super-bright LCD projectors. The lead product in Polaroid's new lineup is the Polaview 105 polysilicon projector that produces sharp images in up to 16.7 million colors. Its optimized 300-ANSI-lumen optical system includes a metal halide lamp that delivers exceptionally bright images even in fully lit meeting rooms. The Polaview 105's motorized 1.6:1 zoom lens with focus control can be adjusted with a remote control or keypad located on the projector. With a focal distance from 1 m to infinity, the Polaview 105 can display images more than 30 ft. in size, measured diagonally. Multiple computer and video inputs allow dual presentations. The Polaview 105 supports most worldwide video standards and has a suggested list price of $9495.

Information: Michael J. Spataro, Polaroid Electronic Imaging Systems, 565 Technology Square, Cambridge, MA 02139. 617/386-3573.

Circle no. 10 ■

Please send new product releases or news items to Joan Gorman, Departments Editor, Information Display, c/o Palisades Institute for Research Services, Inc., 201 Varick Street, New York, NY 10014.

Please send new contributions or noteworthy news items to Aris Silzars, Contributing Editor, Information Display, c/o Palisades Institute for Research Services, Inc., 201 Varick Street, New York, NY 10014.

Circle no. 30

Circle no. 31

continued from page 4

digitization numbers for color film – on the order of 20 megapixels – and had even read one article, the source of which he now could not remember, that quoted a figure of 60 megapixels. If this is what they had in mind, maybe he would put in a few hours updating his résumé instead of working on such a ridiculous project. Besides, his daydream about the million-dollar salary hadn't completely left him yet.

Peter decided that he obviously needed to talk to someone well versed in color photography; in particular, someone who knew something about the capabilities of current films and cameras. Serendipity was at work. Peter had a friend who had done some interesting product photographs for his company, and who also just happened to write a column for a display magazine. It was time to make a visit.

"Peter! Welcome. It's nice to see you in person. Isn't your e-mail working?"

Peter apologized for having been so busy and for resorting to electronics as his only way of keeping in touch. He promised to try not to forget an occasional human interaction in the future. Then, after throwing out a few rather pointed opinions about management in general and his company's in particular, he explained the purpose of his visit.

"OK, Peter, let's give you a tutorial on what's really possible with the current crop of color films when used in real-life shooting situations. And what I am about to tell you is going to be quite different from the technical literature that makes those wonderful claims for 20-megapixel capabilities or more for photographs. I haven't tried it personally, but I think the only way one could possibly realize that level of resolution from typical films would be to expose them using a sub-micron silicon-wafer stepper instead of a camera.

"Let's begin by looking at all the factors that contribute to the quality of the final image that we see in a photograph. The resolution and color capabilities of the film are certainly of high importance. Then, we have the resolving capabilities and distortions introduced by the camera lens which, by the way, reduce image quality significantly more in the corners than in the center of the image. But, in order to realize what the lens can do, we must make sure that it is optimally focused on the most important part of the subject. On top of that, there are various sources of vibration, such as the mirror movement in a single-reflex camera, camera movement from shaky hands or a flimsy tripod, and the vibration of the typical focal-plane shutter while the exposure is being made. Then, of course, once we have captured the image on film, we still need to go through a printing process before we have a picture to hold in our hands or hang on the wall.

"Typically, when you read articles about films or lenses, the tests are done under carefully controlled laboratory-type conditions. For example, a lens will be tested with the mirror locked-up, the shutter open, and the exposure made using a switched external light source. The exposure is carefully controlled and the film specially processed to give optimum resolution results. Results obtained in this way are nice to know, but I'm sure you will agree they don't represent what you are likely to get taking a photograph under normal circumstances.

"So, let's get down to some practical results that may help you decide if you want to take on this project or go home and work on your résumé. Let's pick a few high-quality, 100–200 ISO-speed, color negative films and take a look at some test patterns that were made using several 35mm and 2-1/4-in.-format cameras and see what we can conclude."

As they took turns looking through the microscope and doing a few quick calculations, Peter's face started to brighten, and his friend could see the dawning of an actual smile. "Now, you're really not fooling me?" questioned Peter, as if to confirm one final time what they were observing. "You're sure that 40 to 50 lines per millimeter is the upper end of performance for a 35mm camera sitting on a tripod and carefully focused on the subject? And you're sure that you can only use 0.9 in. of the negative in an enlargement? But that means that the best 35mm photographs are only comparable to a display of **1000 × 1500** pixels!" concluded Peter incredulously. "What about the 3000 lines of resolution I've been told about? What about the 20 megapixels?" Clearly, Peter needed some additional reassurance.

It was easy for his friend to provide it. "Peter, actually, the 1000 × 1500 pixels is even better than you need. If you remember when we were looking at the negatives, we were measuring barely resolvable line pairs near the center of the image. If your pixels are nice and crisp and you can address them properly, you can probably match the best 35mm photograph with even less resolution. By the way, can you tell me why some HDTV systems have selected a 9:16 format when the format of 35mm photographs is 2:3? And I don't think movies are 9:16 either." Peter had to admit that he had never thought about this. He decided that later he would ask some of his colleagues to see if anyone had a logical answer to this question.

"Now, Peter, before you decide that your project is so easy that you can just loaf for the next 9 months, let's look at the larger film formats and estimate what they can do. If we run the same tests on 2-1/4-in.-format cameras, we will end up with a range of resolutions from about **1600 × 2000** pixels, for the 645 format, up to **2000 × 2500** for the 6 × 7 format. That is why, typically, 35mm enlargements are only good up to about 8 × 10 in. and the 2-1/4-in. format looks so crisp in 16 × 20-in. hang-on-the-wall photos.

"Now, if you really want a challenge, let's use 4 × 5-in. negatives in a view camera, and then we can begin to approach the 20 megapixels that you were so worried about. But from what you told me about your Boss-person, I don't think you have to be one bit concerned that 4 × 5 is what he or the senior-management group had in mind. By the way, have you noticed that I have not said anything about the printing paper or the enlarger that, of course, one must use to make the print?" asked his friend, as if to test Peter's new understanding. "Well, I'm sure that it has an effect, but with all that you've shown me today, I'm not even going to try to guess how much," replied Peter.

"It's not really such a tough question at all. As you can see, paper has nearly the same resolution as film, and since the image is enlarged at least four times, the degradation is not significant. Also, good-quality enlarging lenses are optimized for a certain range of magnifications and aperture openings and, for that reason, they typically outperform camera lenses. So, again, we're on pretty safe ground if we neglect their effects. However, I would not necessarily draw the same conclusion about the typical drugstore mini-lab. But for your project's success, all these additional effects that reduce film performance will just make you look all that much better. I would suggest that if you can develop a color display that can produce somewhere between 2 and 4 megapixels, your company should give you a million-dollar bonus. You will have surpassed 99.9% of all photographs, and I promise not to say anything to your Boss-person about the other 0.1% – I guarantee your Boss-person will never know."

On the drive back to his company, Peter didn't even notice the people in the other cars giving him puzzled looks and wondering why this engineer-looking person had such a big grin on his face. But Peter knew. With some of the new design ideas he had already been exploring, the next 9 months at work were going to be ever so much more fun than he could have possibly imagined.

In this month's industry-news segment, there are indications that a number of companies are making good progress – and maybe even having fun while doing it.

Tektronix, Inc., Beaverton, Oregon, has made five significant management changes designed to increase the competitiveness of its measurement business unit, which represents approximately 50% of the company's overall revenues. The changes include three internal moves. **Dave Coreson** has been named the measurement business vice president of manufacturing operations. **Richie Faubert** has

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been named general manager of the newly combined television/communications test business unit. **Rick Wills** has been promoted to general manager of the instruments business unit. The internal changes are complemented by two new hires. **Al Miksch** has joined Tektronix as general manager of the tools business unit and **Kermit Yensen** has been added as director of marketing, filling the vacancy left by Rick Wills. Al Miksch comes to Tektronix from Hewlett-Packard, where he was most recently marketing manager for HP's InkJet Supplies Business Unit, a business nearly the size of Tektronix, Inc. Kermit Yensen was formerly with Pi Systems and also with Hewlett-Packard.

Silicon Video Corporation, San Jose, California, has installed a new management team. **Harry Marshall** has become Chairman, President, and Chief Executive Officer. **Robert Pressley**, formerly President and co-founder of SVC, will continue as a board member and work with SVC as a technology consultant. **Robert Duboc** remains Executive Vice President in charge of day-to-day operations. **Ted Fahlen** remains Vice President of Research and Development. **David Bergeron** has recently joined as Vice President of Manufacturing Technology. Mr. Bergeron comes to SVC from IBM's semiconductor sector. To achieve a faster rate of learning and to accelerate taking its Thin CRT technology from the lab into production, Silicon Video is implementing an aggressive concurrent manufacturing engineering strategy. In January, 1995, the company began running cathode, faceplate, and back-end assembly development lines in its pre-production facilities in San Jose and Cupertino, California. In July, the company consolidated its headquarters in the San Jose facility. SVC is in the final engineering phase of fabricating prototype test devices and expects to have some initial demos during the latter part of 1995.

Planar Systems, Beaverton, Oregon, announced the completion of the sale of 2,979,920 shares of Planar common stock held by Metra Corporation, headquartered in Helsinki, Finland, and the State Farm Companies Foundation. Metra continues to own 306,942 shares of Planar common stock. State Farm Companies Foundation sold all of its holdings. The offering price of the shares was $19.25.

Sony Corporation, Tokyo, Japan, has developed a flat-panel display for large-screen use based on Plasma Addressed Liquid Crystal (PALC) technology jointly developed with Tektronix, Inc. Sony plans to introduce the display, which has tentatively been named PLASMATRON, sometime in 1996 in Japan. The display is an active-matrix system which uses plasma as an electronic switch that separately addresses each pixel of the liquid crystal, allowing for a full range of colors, high contrast, and smooth replay of moving images. A key Sony development is a high-precision screen-printing technology which can be produced in low-grade clean rooms rather than semiconductor facilities, resulting in a manufacturing process that is simpler, affords higher yields, and thus lowers costs. It is expected that with these developments, it will be possible to produce consumer-use wall-hanging TVs in sizes ranging from 20 to 50 in. Sony also expects that further development of this technology will result in space-saving multimedia terminals and computer displays.

Optical Imaging Systems (OIS), Northville, Michigan, is qualifying its new $100-million AMLCD factory based on commercial accounting and quality standards. **Chuck Wilson**, chief financial officer, states that the company has decided to define their operation as a commercial business rather than as a defense contractor. OIS estimates that about 85% of their production volume will be for commercial products. Therefore, even though half of the money to build OIS's facility came from the U.S. Advanced Research Projects Agency, to achieve the goals of establishing a viable U.S. commercial manufacturing base for flat-panel displays, a non-military accounting method had to be adopted. By driving down the cost of production and by becoming ISO 9001-certified, OIS also expects to meet the needs of the U.S. Government for a reliable domestic flat-panel-display manufacturer.

SI Diamond Technology, Inc., Houston, Texas, and **Philips Components B.V.**, Eindhoven, The Netherlands, have signed a technology cooperation agreement under which Philips will provide $10 million of development support over the next 2 years to accelerate commercialization of SIDT's Diamond Field Emission Displays (DFED). Under the terms of the agreement, Philips and SIDT have each committed at least $5 million per year applicable to the joint effort. At the point in development that mass production of DFEDs is anticipated, non-exclusive licenses can be granted. The agreement includes an ongoing broad-based program of technical collaboration. The joint inventions resulting from this program can be used by either company. Philips and SIDT have also agreed to look jointly at future business developments in this area.

In a separate action, **C. R. Kline, Jr.**, was named to the position of Chief Operating Officer by the Board of Directors of **SI Diamond Technologies, Inc.** Since June of 1994 Kline has served as vice president of SIDT, with responsibility for business development. Prior to joining SIDT, Kline was president of Horizon Battery Technologies, Inc., a joint venture of BDM International and Electrosource, Inc. This new appointment is expected to emphasize SI Diamond's transition from a research-and-development company to one more focused on managing and sustaining business growth.

Sloan Technology, Santa Barbara, California, a subsidiary of Veeco Instruments, Inc., has announced two new appointments. **Alan Martin** has been appointed to the position of Director of Sales and Marketing. He will direct the overall marketing and sales efforts of the Dektak line of surface-measurement equipment, serving the flat-panel-display and semiconductor industries. Prior to his appointment at Sloan Technology, Mr. Martin was Director of Sales and Marketing with Hine Design, Inc., providing wafer-handling systems to the semiconductor industry. **Jerome Wiedmann** has been appointed to the position of AFM (Atomic Force Microscope) Marketing and Sales Manager. His responsibilities will include overseeing the marketing of the Dektak SXM, Critical Dimension AFM, based on the Nobel prizewinning technology developed at IBM. Prior to his appointment, Mr. Wiedmann was International Marketing Director with Digital Instruments, Inc.

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