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FLAT-PANEL ISSUE

AR-coated STN-LCDs
EL display technology
Other FPDs
Color imaging conference

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Cover: When applied to a supertwisted-nematic liquid-crystal display (STN-LCD), a multilayer antireflection (MLAR) coating not only reduces reflections, it also enhances contrast and makes colors more vivid. Tests were conducted at Compaq Computer's Flat Panel Display Laboratory to see if the improvement is enough to make STNs an acceptable replacement for AMLCDs in general-purpose laptop applications. For the results, see the article beginning on page 10.

Optical Coating Laboratory, Inc.

Next Month in Information Display

SID '95 Preview Issue
- SID '95 Preview
- Field-Sequential Color
- SMAU '94 Report

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editorial

Covering the World

You may have noticed *Information Display*'s steadily increasing coverage of display-related conferences and trade shows. Providing that coverage consumes an appreciable amount of *ID*'s resources, but we felt that making this effort was one way we could be more useful to our readers.

As the year progresses, Contributing Editor Bryan Norris will report on SMAU (Italy), CeBIT (Germany), and Computex (Taiwan). In this issue, I report on the Second Annual Color Imaging Conference (Scottsdale, Arizona). Our April/May issue, which is the SID '95 Show Issue, will also contain my report of the Second Display Manufacturing Technology Conference (Santa Clara, California).

The SID International Symposium, Seminar, and Exhibition, being held this year May 21–26 in Orlando, Florida, is now far too large to be covered in depth by one person. Renée Mello-Robinett and Joe Hallett will join me to provide team coverage.

In October, a team of volunteer Japanese technical experts will work with me to provide coverage of Asia Display '95 (Act City, Hamamatsu, Japan). (The report will appear early in 1996.)

Covering the display world has become a serious commitment at *Information Display*, and we want to make that coverage as useful and as interesting to you as we possibly can. Please let us know which conferences you want to know about the most and if there are any you would like us to add (or drop) from our list.

Telephone communication at an editorial office is generally chaotic. Try reaching us by fax at 203/855-9769, by e-mail at k.werner@ieee.org, or on CompuServe at 73447,2244. We look forward to hearing from you, and we will acknowledge all communications.

– Ken Werner

Official Monthly Publication of the Society for Information Display

INFORMATION DISPLAY

the display continuum

Let's Have Fun with Technology . . .

by Aris Silzars

In the fall of 1980, the editors of "*Playboy*'s Guide to Electronic Entertainment" asked their life-style experts to take a look ahead at the decade of the 80s. Their assignment was to try to predict what changes we would all experience as the "eighties go electronic!"

My curiosity about these predictions and how we see the future was stimulated by a recent lunchtime discussion with several of my esteemed colleagues. As is typical for this group, the day's lunch-table discussion encompassed many important subjects. One of the topics was *Virtual Reality*. How would it likely develop over the next several years? One of the "regulars" of our highly sophisticated and intellectually brilliant group mentioned Woody Allen's 1973 movie, "Sleeper," which was intended as a humorous look ahead to 2173, when robots do all the work, automation is all-pervasive, and the political climate is really ugly. The virtual-reality connection was a pleasure machine that, as we seemed to collectively remember, was called the "Orgasmatron." There was also the "Pleasure Orb," which appeared to have a function one would associate with the high-on-drugs culture of the 70s.

If Woody Allen could predict Virtual Reality way back in 1973, what else did he think would happen? If he or someone else could tell us what our future will be like, then we would know which technologies will succeed, which businesses will grow the fastest, and which investments we should make. And if I could be the first to figure all this out, I would become the richest and most powerful man on earth – even richer and more powerful than Bill Gates!

With this motivation of riches and fame, I rushed down to my local video store, located a copy of "Sleeper" and also, for good measure, a copy of "2001 – A Space Odyssey," released in 1968. Of the two, "2001" is the more serious and visually more spectacular look into the future.

In just a few years, we will be living in the real 2001. Are we likely to see anything like the future predicted for us back in 1968? Not even close! There will be no space station, no moon base, no artificially controlled hibernation, and no manned spaceship bound for Jupiter. But what we *will* see are cockpit displays, flat-panel displays, and computer processing capability startlingly close to that depicted in the movie. We may not quite get to HAL, the human-like spaceship computer named after IBM (minus one), but with neural nets and parallel processing we are getting ever closer. (Pentium-based computers are now playing and winning world-class chess matches.)

Electronics and displays have progressed at nearly the rate predicted in "2001," while mechanical, electromechanical, and biological technologies didn't. We display technologists must be a pretty brilliant lot.

In Woody Allen's movie, in addition to pleasure-giving virtual reality, there are robots with interesting and sometimes dysfunctional personalities, technology that is always breaking down, and a world where politics is as bad (and maybe even worse) than anything we have seen to date. But the overall vision is one that looks very much like 1973. The cultural topics pervading the 70s are the dominant themes of the future as depicted in this movie. While "Sleeper" was obviously not intended as a serious look ahead, it is nevertheless striking

continued on page 36

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Creating Higher-Contrast Color STN-LCDs

Will test results encourage laptop-computer makers to replace AMLCDs with antireflection-coated STNs?

by Mark Parish and Doug Arego

CONTRAST AND BRIGHTNESS are key attributes that drive the selection of one particular liquid-crystal display (LCD) over another. But a color flat-panel display (FPD) is a major cost component of most laptop computers. To save cost, product planners often consider the alternative of using a less-expensive passive color supertwisted-nematic (STN) display over a color active-matrix thin-film transistor (TFT) display. The cost advantage of such a choice is gained at the expense of display contrast and response time. With the advent of active-addressed (AA) STN displays, response time has improved significantly, but little has been done to improve display contrast and brightness. In addition, users generally believe the STN display is more pallid and harder to view from an angle.

The benefits of multilayer antireflection (MLAR) coatings as applied to CRTs are well known, and we wondered if these coatings could make the STN *vs.* TFT tradeoff more attractive. To find out, we set up a comparative test at Compaq Computer's Flat Panel Display Laboratory in Houston, Texas.

The Test

Our test vehicle was a standard commercial color STN-LCD with a standard diffuse antiglare (AG) surface on the linear polarizer. One side of the display was uncoated; the other side was identical except for a thin sheet of coated polyester laminated directly on top of the AG surface (Fig. 1). An MLAR coating had been applied to the exposed surface of the polyester by Optical Coating Laboratory, Inc. The performance of each side of the display was measured, and the contrast, luminance, and reflection differences were documented.

The Cause of Poor Contrast

Many LCD suppliers quote contrast levels that are measured in a dark room. Under such conditions, contrast and brightness are not affected by reflected ambient light. However, displays are normally viewed in daylight or other high-ambient lighting conditions. Here, reflection of the ambient light (noise) from the display surface can impair the viewer's ability to accurately read information displayed on

OCLI

Fig. 1: *As part of a test, an MLAR-coated polyester film was laminated to the AG surface of the polarizer on the left half of this commercially available color STN display.*

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the screen (signal). Analogously, you could look to see if your car head lamps are on at high noon on a bright sunny day. It can be very difficult to observe the light from the head lamps due to the background brightness of the day. However, after the sun goes down, it is very easy to observe the head lamps. The signal-to-noise ratio has improved because the background noise (white light) has been eliminated. This analogy demonstrates that ambient lighting must be considered a critical factor in the evaluation of a display's viewability. FPDs are generally used in an office or outdoor ambient where the light levels are 500 lux or greater. These are the lighting conditions that must be used to realistically evaluate the contrast and brightness of a display.

AG treatments on the triacetate cellulose (TAC) top surface of a linear polarizer are widely employed for laptop computers to reduce the reflection of external light. An AG treatment is typically a textured or roughened surface that is used to reduce specular reflection. All of the unwanted reflected light is still present, but it is scattered rather than specularly reflected. This is why AG surfaces without an MLAR coating can cause hazing or "whiting out," and it is why these surfaces unavoidably downgrade image resolution and contrast. The result is images that are dim and pallid.

Improving the Image with MLAR Coating

The refractive index of a hard-coated polarizer surface is about 1.48, while the index of the surrounding air is 1.00. This difference in refractive index produces a reflection from that surface of about 3.75%. The reflection can be specular or diffuse, depending on whether the surface has a smooth hardcoat (HC) or a textured hardcoat (AG).

There is now a broadband multilayer antireflection (MLAR) coating that can be applied to thin hardcoated plastic substrates – such as LCD linear-polarizer materials – with a low-temperature process. The MLAR coating is designed to produce complete destructive interference of all reflected visible light, causing nearly all incident light energy to pass through the surface instead of being reflected back towards the viewer. Even when applied to an AG-treated surface, the MLAR coating minimizes both diffuse and specular reflected energy, while it increases visible transmittance through the coated surface.

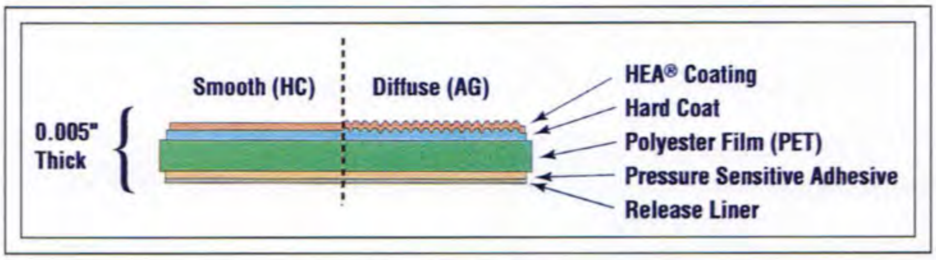

Fig. 2: *OCLI's HEA®2000™, a contrast-enhancing MLAR-coated product, was used in the test because it can be applied to an existing display.*

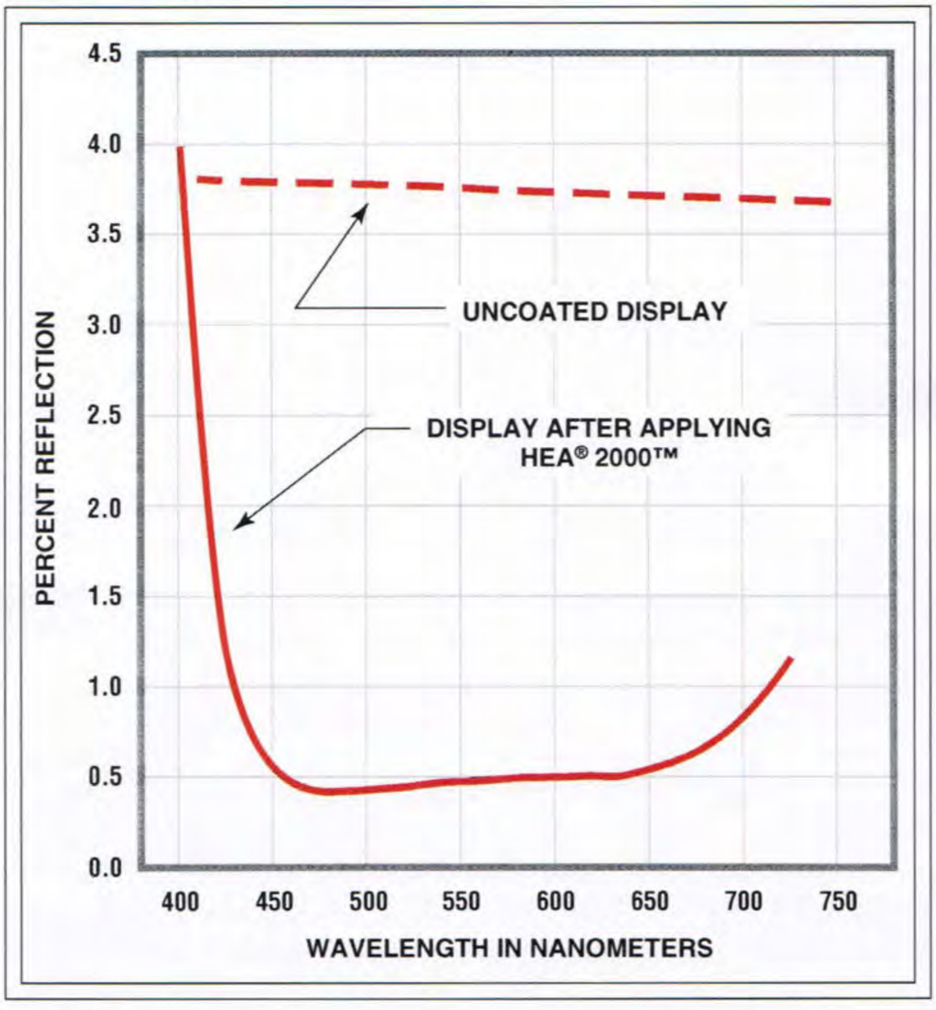

Fig. 3: *Applying HEA®2000™ to the outer surface of an LCD's polarizer reduces total reflection by nearly a factor of 10.*

There are two ways of applying an MLAR coating onto a color STN display. The preferred method from the standpoints of performance and cost is to directly coat the exposed polarizer surface before it is applied to the display. In fact, OCLI has a strategic alliance with Nitto Denko, the world's leading manufacturer of polarizers and retardation films for LCDs, to produce coated polarizers in exactly this way. (OCLI applies its HEA® coating to Nitto's linear polarizer to produce what has become a very well-accepted product.)

But the same MLAR coating can also be applied to an existing display. To accomplish this, OCLI has developed a product called HEA®2000™ that is applied to the existing LCD using an index-matching adhesive (Fig. 2). HEA®2000™ consists of an adhesive-backed polyester film that incorporates an MLAR coating on the exposed surface. It can be supplied with either an HC or AG hardcoat.

HEA®2000™ was selected for these tests because it could be easily applied to an existing display. We used the version with an AG hardcoat for direct comparison with the standard display, which also has an AG hardcoat.

Applying HEA®2000™ to the linear polarizer's exposed AG surface substantially reduces the total integrated reflectance (Fig. 3). The 0.50% photopic reflectance – integrated visible reflectance as seen by the human eye – of the coated display represents a substantial reduction over the 3.75% of the uncoated display. However, this reduced reflectance level is about 0.3% higher than that obtained by applying an MLAR coating directly to the polarizer prior to panel assembly (Fig. 4). The additional 0.3% reflection is caused by an internal refractive-index mismatch between the AG hardcoat and the polyester (PET). This mismatch is not present on the directly coated linear polarizer because the AG hardcoat's refractive index closely matches that of TAC (the polarizer's outer material).

The photopic reflectance of the directly coated surface measures 0.20% across the visible spectrum, slightly less than one-twentieth the reflectance of the uncoated display, and less than half that provided by the HEA®2000™ used in this test.

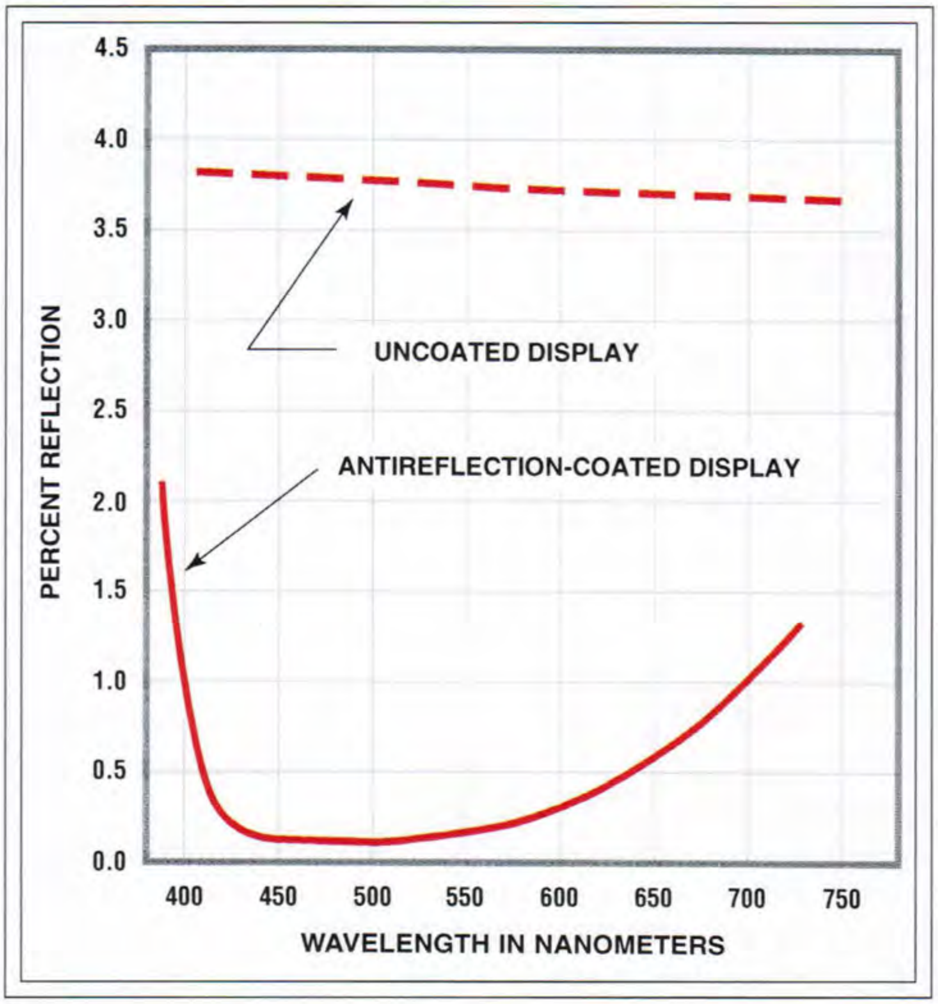

Fig. 4: Applying an MLAR coating directly to the linear polarizer prior to panel assembly reduces display reflection by nearly a factor of 20.

Test Conditions

HEA®2000™ was applied to one-half of a commercially available color STN with an AG linear polarizer surface, as shown in Fig. 1. The exposed surface of the HEA®2000™ had an AG treatment like that of the linear polarizer and was secured to the linear polarizer with an index-matching pressure-sensitive adhesive. Contrast measurements were taken from each half of the display.

Equipment. Pritchard 1980B Photometer; SL-20 lens, ND-filter, 3° spot. (A 3° spot integrates an area of approximately 1.2 in. in diameter at the surface of the display.)

Setup. Viewing angle: X (horizontal) = 0° (normal incidence), Y (vertical) = 15° below normal incidence. When lights were on, illuminance at the display is about 500 lux. When lights were off, the room was dark. (There were no windows in the room, but there was a very low light level from a small desk lamp. The lamp was located about 10 ft. from the display and the measurement equipment, and was directed away from them.) Measurements were taken at 5-nm intervals over the wavelength range 370–720 nm.

Display. Color STN-LCD with backlight power of 3.14 W to the inverter.

Results and Discussion

By comparing the tabulated data (Table 1) from Tests 1 and 2 (lights off), we see that the MLAR coating has reduced the background (black) signal, while the luminance of white, red, blue, and green have been increased. The contrast of the display is improved because black areas appear "blacker," while white and colored areas appear brighter. The measured increase in luminance shown in Test 2 is due to the increased transmission of the coated LCD surface. The MLAR coating actually increases perceived display brightness, while making colors appear less pallid and more vivid, as shown by the increase in contrast for each color. Note that after application of the MLAR coating, there is virtually no change in the CIE color coordinates.

A comparison of Tests 1 (lights off) and Test 3 (lights on) shows that the luminance from a black area of the display has increased

Table 1: Test results show that MLAR coatings can be used to improve STN displays when viewed under lightning conditions of a typical office environment

Test #1: Lights off, no MLAR

	Black	White	Red	Blue	Green
Luminance (cd/m^2)	11.4	75.0	25.1	26.0	49.1
CIE/UCS 1976: u'	0.1947	0.1920	0.3001	0.1669	0.1509
CIE/UCS 1976: v'	0.3996	0.4775	0.4912	0.3834	0.5330
Contrast = W, R, B, G/Black		6.58	2.20	2.28	4.31

Test #2: Lights off, HEA®2000™

	Black	White	Red	Blue	Green
Luminance (cd/m^2)	10.5	79.0	25.8	27.2	51.2
CIE/UCS 1976: u'	0.1957	0.1914	0.3072	0.1653	0.1498
CIE/UCS 1976: v'	0.4673	0.4823	0.4971	0.3902	0.5372
Contrast = W, R, B, G/Black		7.52	2.46	2.59	4.88
% Contrast Improvement		14.4	11.6	13.6	13.2
% Increase in Luminance with HEA®2000™		5.3	2.8	4.6	4.3

Test #3: Lights on, no MLAR

	Black	White	Red	Blue	Green
Luminance (cd/m^2)	120.3	184.5	135.1	135.2	158.4
CIE/UCS 1976: u'	2.2685	0.2404	0.2813	0.2495	0.2382
CIE/UCS 1976: v'	0.5233	0.4775	0.5227	0.4949	0.5310
Contrast = W, R, B, G/Black		1.53	1.12	1.12	1.32

Test #4: Lights on, HEA®2000™

	Black	White	Red	Blue	Green
Luminance (cd/m^2)	59.2	127.1	74.5	76.2	99.8
CIE/UCS 1976: u'	0.2685	0.2265	0.2927	0.2345	0.2177
CIE/UCS 1976: v'	0.5146	0.4993	0.5158	0.4699	0.5316
Contrast = W, R, B, G/Black		2.15	1.26	1.29	1.69
% Contrast Improvement with HEA®2000™		40.1	12.2	14.7	28.1

from 11.4 to 120.3 cd/m^2. This increase is due to the reflection of ambient light (noise) from the front of the display. In a comparison of Test 2 and Test 4, on the other hand, the coated display exhibits a luminance increase from 10.5 to 59.2 cd/m^2 – an increase of only 48.7 cd/m^2. The substantially smaller noise increase when the lights are turned on is due to the effect of the MLAR coating. Similarly, when white or colored areas of the display are compared, we also find that a significant performance improvement is provided by the MLAR coating. Note that as ambient lighting is increased, the luminance of the displayed image is not actually increased; rather, it is the light reflected from the front of the display that is increased. The photometer responds to each source of light without favoritism, so the data indicates increased luminance from the display when the lights are turned on.

When contrast is low – say, for a contrast value less than 3 – increases in contrast on the order of 5% are apparent to the eye.[1] Improvements in the range of 12–40%, as reported here, are substantial. Although contrast at various viewing angles was not measured in this test, contrast improvements provided by MLAR coating are known to remain essentially constant over a viewing angle up to ±30° from normal incidence. It was reported earlier[2] that MLAR coatings contribute to the viewability of active-matrix TFT displays used outdoors if a low-reflection black-matrix coating is also used to suppress the display's internal reflections. The construction of a color STN display does not produce as much internal reflection as is found in a typical active-matrix TFT, so an externally applied MLAR coating is all that is needed to significantly improve the performance of an STN display.

Conclusion

These measurements show that MLAR coatings can be used to improve the contrast, brightness, and color vividness of STN displays when the displays are viewed under the type of lighting conditions found in a typical office environment. Performance of a coated display continues to improve relative to that of an uncoated display as the ambient light is increased. This feature makes the AASTN passive color display a more viable and cost-effective alternative when choosing between it and the more expensive active-matrix TFT. When the MLAR coating is deposited directly on the linear polarizer, instead of on an intermediate plastic film, even greater improvement will be achieved than is indicated by the data presented above because less light will be reflected from the display.

Notes

[1]R. L. Martin, D. E. Evanicky, and S. Lu, "Antireflection System for LCDs and Pen-Based Computer Tablets," *SID Intl. Symp. Digest Tech. Papers*, 673 (1993).

[2]H. Yoshida *et al.*, "Development of LCD Modules for Automobiles," *SID Intl. Symp. Digest Tech. Papers, Applications Volume*, 27 (1994). ■

The Other Flat-Panel Displays

If Europe and North America want an appreciable piece of the FPD pie, it is not likely to be with LCDs but with one of the other FPD technologies.

by Steve Berry and Randall Sherman

FLAT-PANEL DISPLAYS (FPDs) have been capturing the attention of electronics-industry participants, suppliers, OEMs, users, the press, and the public at large for many years now. These displays represent a market that still holds much promise for additional growth. It is a market that is constantly in the making – and one that is evolving toward the "hang-on-the wall" TV.

More than a decade ago, the Japanese recognized FPDs as an important part of the electronics industry and set about developing core technologies, principally for the manufacture of liquid-crystal displays (LCDs). Today, after investing nearly $5 billion, Japanese companies dominate the FPD industry from consumer-electronics products to large-screen projection systems.

Innovations are forthcoming from North American and European manufacturers, but most can hope to compete only in niche-market areas or with leading-edge technologies. These leading-edge technologies are plasma, electroluminescent (EL), and field-emission displays (FEDs). This article examines the markets for these technologies.

***Steve Berry**, President of Electronic Trend Publications (ETP) of San Jose, California, prepared this article, which was excerpted from the much larger report entitled,* The Worldwide Flat Panel Display Market, *published by ETP. **Randall Sherman**, senior analyst for ETP, wrote the complete report. ETP is located at 1975 Hamilton Ave., Suite 6, San Jose, CA 95124; 408/369-7000, fax -8021.*

Gas Plasma

Plasma FPD technology is one of the more interesting niche technologies because it has the potential to produce large-area displays cost-effectively. Companies like Fujitsu and Photonics have demonstrated large-geometry (20-in.) full-color high-resolution FPDs at around $5000 per unit. The forecast is that costs will come down in general and that the cost of larger-size displays will scale linearly with screen diagonal – instead of exponentially, as is the case with LCD and other technologies. But in medium sizes, plasma displays have been unable to displace LCD technology except in the niche segments where plasma's superior shock resistance, performance under extreme temperatures, and long life are of value. Plasma technology may be one of the answers to the hang-on-the-wall TV concept of the future, but much development work is needed to make this a reality.

Plasma-display panels (PDPs), while showing only moderate market success and penetration over the last few years, are expected to become prominent during the forecast period for large-geometry color-display applications. PDPs have significant potential for large-size display screens (up to several meters), and the large size can be coupled with high luminance and contrast. These displays are also inherently immune to electromagnetic interference (EMI) and are therefore well-suited to applications such as aluminum and steel mills, electrical control rooms, and magnetic-resonance-imaging medical equipment.

PDPs are a unique form of display technology because these displays rely on the emission of photons from a gas when it is ionized by the application of a significant voltage. The PDP consists of two glass substrates, each containing an array of electrodes, separated by a 0.1-mm gap. In monochrome PDPs, the space between the substrates is hermetically sealed and filled with neon gas. A discharge between the electrodes occurs when 100–200 V is applied, causing the neon gas to emit the panel's characteristic red-orange light.

PDPs come in dc and ac types. In the dc type, the electrodes are exposed to the working gas; in the ac type, the electrodes are covered with protective insulating layers. The DC-PDP can operate with a lower driving voltage, but its luminance will diminish over time because it lacks an insulating layer to prevent electrode deterioration. Furthermore, its luminance decreases markedly as the number of horizontal scan lines increases.

In AC-PDPs, a protective magnesium oxide layer insulates the electrodes and prevents deterioration. The panel's memory function stores the electric charge and allows addressed pixels to stay on, even while another line is being modified. Therefore, an increased number of lines can display a greater volume of data with uniform intensity without sacrificing panel brightness. Recently, manufacturers have started adding memory functions to DC-PDPs as well.

PDP technology enjoys a simple basic structure and an abrupt voltage-breakdown characteristic for light emission. The emitted light can be visible or ultraviolet (UV). The visible light can be used directly, which is the case with the familiar red-orange plasma displays. If significant UV is emitted, it can be used to excite phosphors, which makes it possible to design a full-color display by patterning a surface with appropriate phosphors.

PDP displays have two major disadvantages. First, there must be enough gas to produce adequate brightness, since the light output of a PDP pixel is a linear function of the number of gas atoms present. This requirement defines the minimum size of a pixel and of a PDP screen having a given number of pixels. Second, the display's three-dimensional structure produces light that is emitted in all directions, leading to crosstalk between pixels. Obtaining a high dynamic range in luminance is a continuing problem, since "off" pixels can glow from the ionization in an adjacent active pixel.

The pricing of PDP technology is nearly twice that of LCD technology. It is almost as much as the pricing of EL displays in the smaller sizes – approximately $25 per square inch. Although prices have come down over the past several years with improvements in technology, it is forecast that costs for plasma displays can still be significantly reduced – particularly for large-size screens – over the next several years. Improvements in production and technology should permit the manufacture of displays for $10–$20 per square inch for screens of 25–50 in. as economies of scale are realized and commercial applications become more feasible.

Exhibit 1. Summary Market Forecast for Flat-Panel Displays by Technology, 1993–1998 ($M)

	1993	1994	1995	1996	1997	1998	CAGR* (%)
Plasma							
Computers	46	56	67	75	81	84	13.0
Consumer	0	0	0	0	0	0	0
Commercial	17	18	18	19	19	19	3.0
Industrial	19	36	58	82	101	106	40.8
Military	38	76	115	152	175	184	36.9
Total	120	186	258	328	376	393	26.8
EL							
Computers	40	47	53	59	64	70	11.9
Consumer	4	4	5	5	6	6	8.2
Commercial	20	22	23	25	26	27	6.2
Industrial	6	7	7	8	8	8	5.6
Military	10	10	11	11	12	12	5.3
Total	80	90	99	108	116	123	9.2
FED							
Computers	0.0	0.0	0.0	0.0	0.0	0.0	---
Consumer	0.4	0.7	1.3	2.2	3.2	4.2	60.1
Commercial	0.2	0.5	1.0	2.2	4.4	8.8	113.0
Industrial	0.2	0.3	0.5	1.1	2.8	7.5	106.4
Military	1.2	3.4	8.0	18.1	37.9	72.8	115.8
Total	2.0	4.9	10.8	23.6	48.3	93.3	115.6

*Compound annual growth rate.

Electroluminescent Displays

EL is an attractive solid-state FPD technology that will probably never be a general-purpose display solution. EL has found acceptance despite its high cost – which is similar to PDPs – because of its bright emissive color and wide-angle viewability. This technology is a favorite among users in hospital and industrial environments, where its performance features are superior. Still, this is a color-limited power-hungry technology that is ill-suited to those product applications in which LCDs have proved cost-effective. EL technology will remain a niche FPD solution throughout this study's forecast period despite advances in cost and performance and the imminent introduction of a commercial full-color EL display in quarter-VGA size.

The EL glass panel is a solid-state device with a thin-film luminescent layer sandwiched between transparent layers and a matrix of row and column electrodes. The row electrodes (in back) are aluminum; the column electrodes (in front) are transparent. The entire thin-film device is deposited on a single glass substrate. A circuit board containing the control and drive electronics is connected to the back of the glass panel using conductive silicone rubber technology. Components are mounted on the circuit board within the same area as the glass panels. The result is a display device that is flat, compact, reliable, and rugged.

EL technology creates light from the excitation of phosphor dots. Since the phosphor material is deposited and patterned in pixel format, each pixel can be electrically addressed. As a voltage is applied across the dot, the phosphor "breaks down" electrically and becomes conductive. The resulting "hot" electrons in this breakdown current excite the phosphor, which is controlled solely by the electric current. The close spacing makes the EL structure highly capacitive, making a fast refresh rate difficult and expensive.

Up to eight colors can be produced with EL using filtering techniques similar to those used for PDPs. EL panels can achieve finer resolution than PDPs – 20 *vs.* 50 mm.

Efficiency problems with the blue phosphor in EL color displays have prevented their widespread commercial success to date. Recently, Sharp announced that it is abandoning research efforts to develop a blue phosphor and is instead concentrating on producing a white phosphor. Planar, on the other hand, has developed a more efficient blue phosphor and a clever architecture that partly compensates for the fact that this phosphor is still less efficient than the company's red and green phosphors. Planar is introducing the world's first commercial full-color EL display during the first quarter of 1995. The small size of Planar's color display and Sharp's decision to try to get to color without a blue phosphor reflect the difficulties in fabricating full-color EL displays.

Pricing for EL technology is admittedly expensive. Since there are only two major suppliers to the marketplace today – Planar and Sharp – production is limited and is focused on niche areas. Cost for a typical 6 × 8-in. panel is approximately $25 per square inch, more than twice that of comparable LCD technology. As a result, EL technology is relegated to those applications that are relatively price-insensitive and where its performance and space advantages are paramount. These include medical environments and certain industrial process-control and military applications.

FEDs

Field-emission, or field-emitter, display (FED) technology is an extremely exciting and promising FPD technology, and it could have a substantial impact on the FPD market. FED uses a micro-emitter approach that produces bright full-range color and high-resolution displays. It has great potential as a viable alternative to LCDs in the full range of display sizes and product applications. The major drawback of FED technology is that it is still 5–10 years away from mass-market commercialization, with many products still in the prototype stage.

Field-emitter arrays (FEAs) work by applying voltage between the field-emitter point and the extraction gate. Electrons quantum-mechanically tunnel out of the emitter and are drawn to a phosphor screen. The field-emission current-voltage curve is nonlinear, which permits direct x-y addressing without the need for a transistor at each pixel. FEA cells can operate in parallel, providing inherent redundancy and low electronic noise. Their structures also exhibit low capacitance, which allows FEDs to achieve high screen-refresh rates.

The main problem with FEAs is that fabrication uses expensive and complex micromachining technology. The field-emitter tips are astoundingly small – about 40 atoms wide – and must be made uniformly over the entire screen area. Much R&D is needed to develop new phosphors, which are needed so reliable and economical large-area FEAs can be produced.

Several designs for FEDs have been demonstrated. The French Government laboratory, LETI, in Grenoble, France, has already demonstrated the first FED to work at TV rates. PIXEL, a French start-up company in Aix-en-Provence, France, is commercializing vertical metal field-emitter technology in collaboration with LETI. Another start-up company, FED Corp. out of Hopewell Junction, New York, is concentrating on silicon field-emitter technology for application-specific products. Honeywell, in Bloomington, Minnesota, is pursuing field emitters fabricated from the edges of very thin conducting films. Texas Instruments and Raytheon are licensees of PIXEL's technology.

Interest in FED technology is growing throughout the world. Almost all of the major electronics companies in Japan have ongoing R&D programs in vacuum microelectronics directed toward FEDs. At least two national Japanese consortia of 20–30 institutions each meet several times a year. Moreover, Japan's MITI is sponsoring in-house research and development, which has already produced simple prototype FED devices in collaboration with commercial firms.

FEDs may turn out to be the best choice for computer monitors and HDTV screens in the future, assuming cost and production problems can be overcome. Currently, FED technology in the U.S. is being applied to helmet-mounted displays, radar screens, cockpit and dashboard displays for airplanes and automobiles, and virtual-reality eyepieces for electronic cameras. FED technology promises the benefits of FPDs (thinness, light weight, high resolution, and low emissions) combined with the advantages of CRT technology (luminance, long life, and, eventually, low cost).

Market Projections

The market for PDPs, EL displays, and FEDs is shown in Exhibit 1. While these numbers are small compared with today's multibillion-dollar market for LCDs, the growth rates are attractive. Plasma displays begin from a substantial base of $120 million (in 1993) and should grow at a 26.8% compound annual rate. The rugged nature and bright emissive quality of gas-plasma displays should propel industrial and military use of this technology.

EL displays begin from a smaller base of about $80 million/year (in 1993) and are expected to grow at a 9.2% compound annual rate. The computer market for larger EL displays will lead the growth of this technology.

It is more difficult to project shipments of FEDs. At about $2 million, the base is very small, but growth should proceed at a compound annual rate exceeding 100%. Military uses are predicted to dominate revenue from this technology over the period. Although there is rich potential for this technology in non-military areas, these other markets will not underwrite the required development efforts when much lower-cost LCDs are available. Thus, military spending (or other directed funding) on this technology is necessary for its growth to 1998, and even beyond.

In summary, these "other" FPD technologies appear to have a solid future. But compared with LCDs, they will remain niche players for the foreseeable future. ■

More Contrast and Luminance for EL

A revised internal structure improves the image without external filters.

by Jerry Vieira

WORLDWIDE SALES of electroluminescent (EL) displays were $100 million in 1993. That's modest compared with the sales of CRTs and LCDs – the two biggest-selling technologies – but there's another side to the story. EL sales have been growing strongly, and Stanford Resources projects that EL will grow at an annual rate of more than 20% over the next 5 years, which would make it the single fastest-growing display technology. This suggests that end users of display-based equipment in the non-consumer sectors of the market, where most EL sales are, increasingly perceive real benefits in EL technology – and are letting their original equipment manufacturers (OEMs) know it.

EL has found solid acceptance in medical, industrial-control, test-and-measurement, defense, transportation, and communications markets, where the need for ruggedness, wide temperature range, wide vertical and horizontal viewing angles, long life, fast response times, and good contrast and luminance are critical. Growth in the medical market alone exceeded 50% per year over the last 3 years as care providers came down hard on equipment manufacturers to improve display image quality and provide the largest possible viewing angles. Some manufacturers of critical-patient-monitoring equipment now have product mixes that are as high as 90% EL and only 10% LCD in product lines that give end users the option to select their display. The growth rate is also exceeding 50% in the industrial market as manufacturers of operator interfaces and industrial computers increasingly shift from CRTs to EL.

But for some of the most demanding applications in these markets, additional luminance and contrast were required. Now, a new manufacturing process called Integral Contrast Enhancement (ICE™), along with some new drive schemes, has doubled the contrast and luminance of EL displays and made their pixel crispness better than ever by virtually eliminating blooming. (Blooming is the growth in spot size when luminance is increased to high levels.) With blooming minimized, it is now possible to implement a new pixel drive scheme that more than doubles the refresh rate. Since the luminance of EL displays is proportional to the refresh rate, luminance is also doubled.

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What is ICE™?

ICE™ is an enhancement to the fabrication process for monochrome EL flat-panel displays (FPDs) that:

- Increases display contrast by more than 100%.
- Improves display luminance by more than 100%.
- Improves crispness of display characters by eliminating blooming.
- Lowers overall cost to display users by eliminating the need for a separate contrast-enhancing polarizing filter (which can contribute from $25 to $100 to the total system cost).

The technique incorporates a new light-absorbing layer in the EL display's thin-film structure that significantly reduces reflections of ambient and internal light from the display's back electrode (Fig. 1). This light-absorbing layer is deposited between the dielectric layer and the aluminum row electrodes. The layer is a thin film with a graded optical index. At the surface, the film exhibits optical characteristics similar to those of the EL structure. As we progress through the film, the optical constants slowly change so that they are similar to those of the aluminum electrodes. This graded-index transition eliminates reflections from the metallic electrode structure that degrade contrast and crispness in conventional EL structures.

At the pixel level, the process enhances the contrast ratio of adjacent lit and unlit pixels by preventing light emitted by a lit pixel from being reflected and exiting at an adjacent unlit pixel (Fig. 2).

The ICE Plus™ family of displays adds a special display drive scheme that increases the refresh rate of the display lines, thus producing an average brightness of 65 cd/m^2.

Contrast in More Detail

FPD images lose some of their contrast when stray light from lit pixels in the display or ambient room light remains unabsorbed and free to reflect back to the viewer. The two light sources are reflected light (RL) and light emitted (LE) from the addressed pixels.

The contrast ratio of an EL display can be represented by the following formula:

Display Contrast Ratio =

$$\frac{\text{Light Emitted (LE)} + \text{Reflected Light (RL)}}{\text{Reflected Light (RL)}}$$

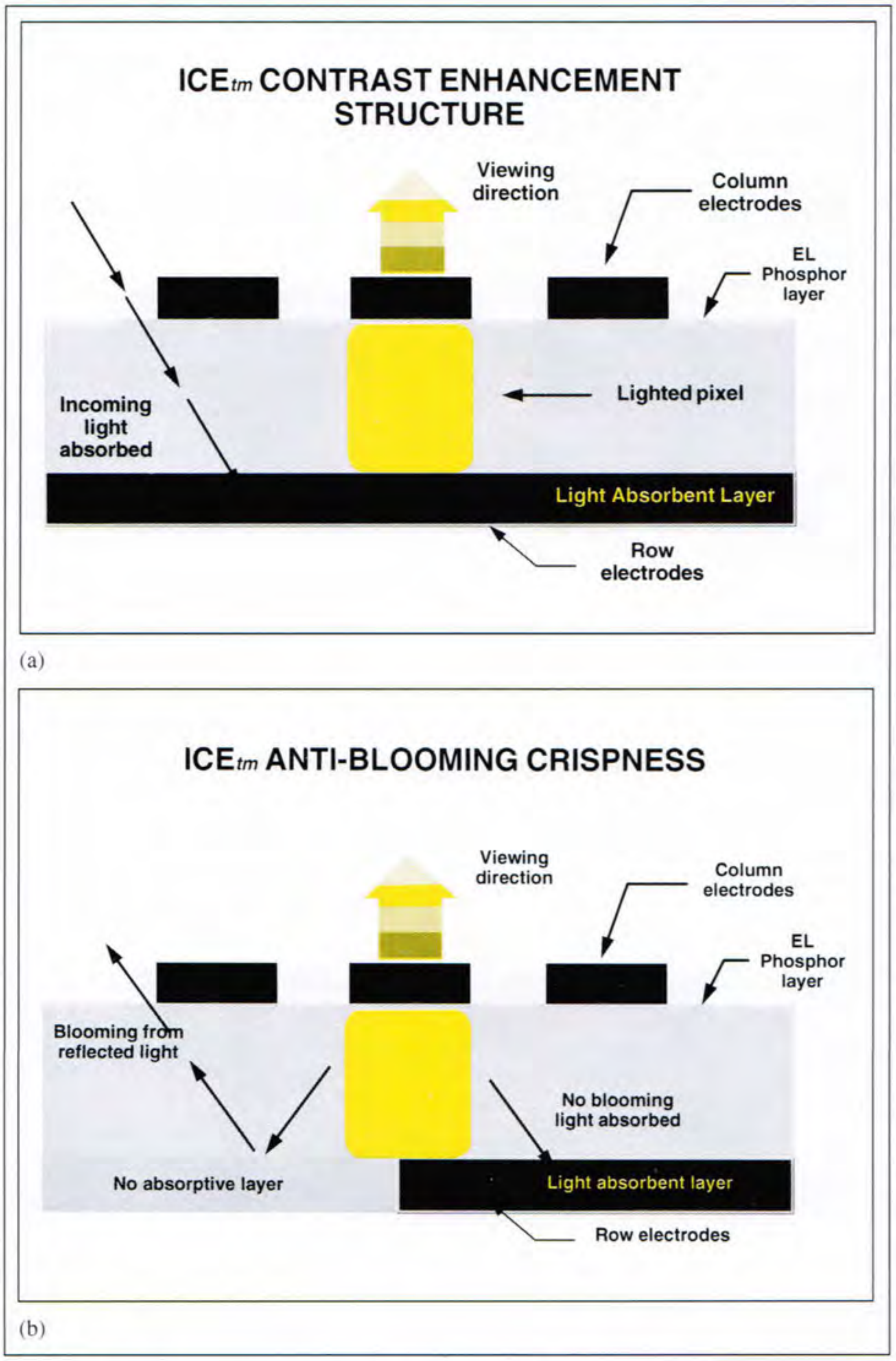


Fig. 1: The light-absorbing gradient-index thin-film layer in Planar's ICE™ EL displays (a) improves contrast by absorbing ambient light and (b) reduces blooming by absorbing light from lit pixels.

The higher the contrast ratio, the better the display appearance and the easier it is to read. The primary source of RL is the ambient light that enters the front of a display. The brighter the ambient light, the lower the contrast ratio and the poorer the image quality of the display. ICE™ technology dramatically reduces the reflected light that reaches the viewer by absorbing nearly 90% of incident ambient light in the internal ICE™ layer.

Typically, indoor light ambient ranges from 250 to 500 lux (ISO 9241, Part 3). A Planar ICE™ display will provide the user with twice the contrast of a non-ICE™ display in a typical indoor application. Because so much of the incident illumination is absorbed, ICE™ displays can be operated in an ambient that is 5–10 times greater than that for traditional EL displays, while maintaining the same contrast.

Taking the Bloom off the Rose

Blooming is wonderful for roses but incompatible with display quality. The ICE™ layer enhances the crispness of display characters by eliminating blooming, which is the fuzzy appearance (or halo) that is sometimes characteristic of a bright pixel. The perception of crispness in a display is determined by the abruptness of the brightness transition from a lit pixel to an adjacent unlit pixel. If a significant amount of light from the lit pixel "leaks" out to an adjacent unlit pixel, characters and lines take on a hazy look. This problem becomes more exaggerated as customers demand brighter and brighter displays – unless the unwanted light is absorbed before it can exit the display.

With a conventional display, light leaks from the lit pixels to adjacent unlit pixels by reflecting off the back electrode surface, resulting in a moderate but distinguishable blooming effect in the written image (see Fig. 2). In an ICE™ display, this light is absorbed in the thin-film ICE™ layer, which inhibits the multiple internal reflections.

Adding Increased Luminance to Increased Contrast

In ICE Plus™ displays, the luminance is doubled compared to normal ICE™ displays, while the contrast-enhancing structure is retained. These displays have exhibited contrast of better than 50:1 at 1000 lux. The drive technique that is used to increase the luminance, which increases the display refresh rate, can be operated in an optional low-power mode. The reduced contrast and luminance in this mode is equivalent to that of ICE™ displays, and the power consumption is about half.

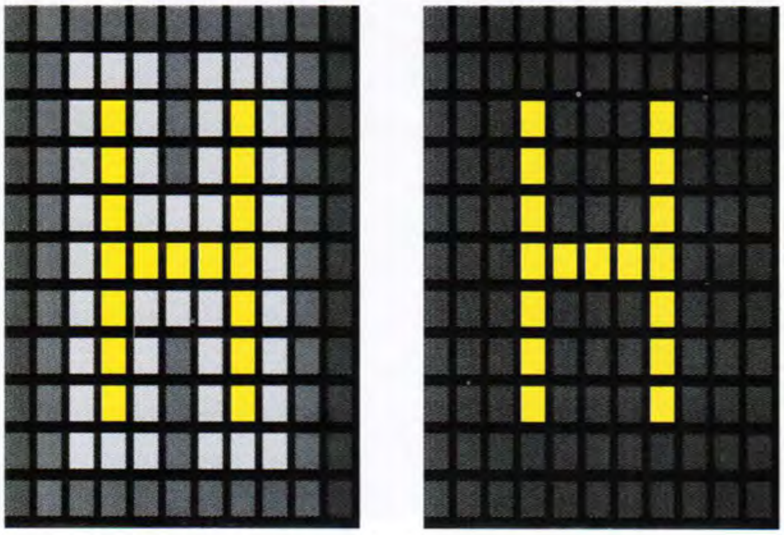


Fig. 2: Blooming in EL displays occurs when light emitted by a lit pixel is reflected internally and exits at an adjacent unlit pixel (left). An appropriately designed internal layer can absorb the stray light, suppress the blooming, and improve the crispness of the display (right).

Conclusion

Advances in EL display architecture have permitted the fabrication of displays with double the brightness, five times the contrast under normal lighting conditions, and low-power operating modes for extended battery life. Production quantities of the most advanced of these displays are now available. ■

conference report

Color Science Goes Commercial

Applications provided the excitement in Scottsdale – and scientists and engineers both seemed happy about it.

by Ken Werner

AT THE SECOND ANNUAL Color Imaging Conference, jointly sponsored by the Society for Information Display (SID) and the Society for Imaging Science and Technology (IS&T), held in Scottsdale, Arizona, November 15–18, 1994, color science gave birth to its own engineering discipline.

The attending obstetrician in the delivery room was James C. King, Director of Advanced Technology at Adobe Systems, who assembled, named, and chaired the session entitled, "Color Engineering." In introducing the session King said, "Scientists look for truth and beauty. Engineers use that truth and beauty to make useful things. Many of us do color engineering. I'd like to make that an official discipline." With typical promotional elan, King distributed badges saying, "Color engineers run the gamut" (Fig. 1). The badges were worn widely throughout the meeting.

Both color technologists and color scientists said the baptism of the new discipline was significant. Gerald M. Murch, Vice President, Xerox Desktop Document Systems Divisions, said, "Color engineering as a new discipline is very exciting. At next year's Color Imaging Conference, I would expect to see this new discipline being brought to bear on an increasing number of electronic imaging applications."

Roy S. Berns, R. S. Hunter Professor of Color Science, Appearance, and Technology at Rochester Institute of Technology (RIT): "A significant trend at this meeting is that our understanding of color science is now being applied, so 'color engineering' really is more than just a newly coined word. However, this trend is not universal. As an educator, it is disappointing, but that's the way things happen."

The new stature of color engineering and color applications at the conference coincides with the imminent introduction of second-generation color-management systems that will, for the first time, reach a large body of users. Apple's ColorSync 2.0 will ship early in 1995, and the similar color-matching module in Microsoft's Windows '95 will ship whenever Win '95 does. Agfa-Gevaert's impressive FotoTune 2.0 is geared to publishing applications and is available now.

The Tutorials

The Second Annual Color Imaging Conference kicked off on Tuesday, November 15th, with five half-day tutorials. Joann Taylor's "Color Fundamentals" was a clear introduction to color science, color vision, the interaction of materials with light, colorimetry, color-measuring instruments, and color spaces and systems.

Kodak's Majid Rabbani gave one tutorial on image processing and another on image compression. Larry Tannas's "Color in Electronic Displays" focused on the color-generating principles of the major display technologies, and surveyed problems in color spectrum, consistency, gamma corrections, gray shades, and color variations with changes in ambient illumination.

Finally, Apple's Gary Starkweather surveyed color-printing technologies, explaining why the CMYK subtractive color system is so much harder to manage than the RGB additive system used in displays. He observed that the sophisticated color-matching systems that are now coming on line will match the colorimetric aspects – such as hue, value, and lightness – of the original image on the reproduction. This is a significant achievement, but it does not guarantee a match in the subjective appearance if, for example, the original image is on an emissive display and the reproduction is on reflective hard copy, if the surrounds of the two images are different, or if the ambient illumination has a different intensity or color temperature. One of the most widely discussed topics throughout the conference was how to implement the step after color matching, which is appearance matching.

Vision and Appearance

The technical sessions began on Wednesday morning in a single-track format that most registrants seemed to appreciate and that the organizing committee vowed to preserve next year.

Brian Wandell and E. J. Chichilnisky of the Psychology and Neuroscience Department at Stanford University started the color-science session by presenting a framework for predicting the color appearance of image data by using standardizing transformations to convert image data into simpler stimuli with the same color appearance. Along the way, the authors commented that human beings don't perceive patterns well under short-wavelength illumination, an understanding that is built into both the JPEG compression system and the NTSC TV encoding system.

Ken Werner is editor of Information Display Magazine.

John J. McCann of Polaroid presented the results of experiments comparing human image processing with photographic, hybrid, and electronic imaging systems. He concluded that human vision normalizes to the maxima in an image, but in a way that depends on the spatial properties of the image. During his talk, McCann stated that in color appearance, the "radiance of the maxima counts, contrast with the maxima counts, and distance from the maxima counts." McCann also commented that "imaging systems would have improved color and tone-scale performance if they mimicked human vision."

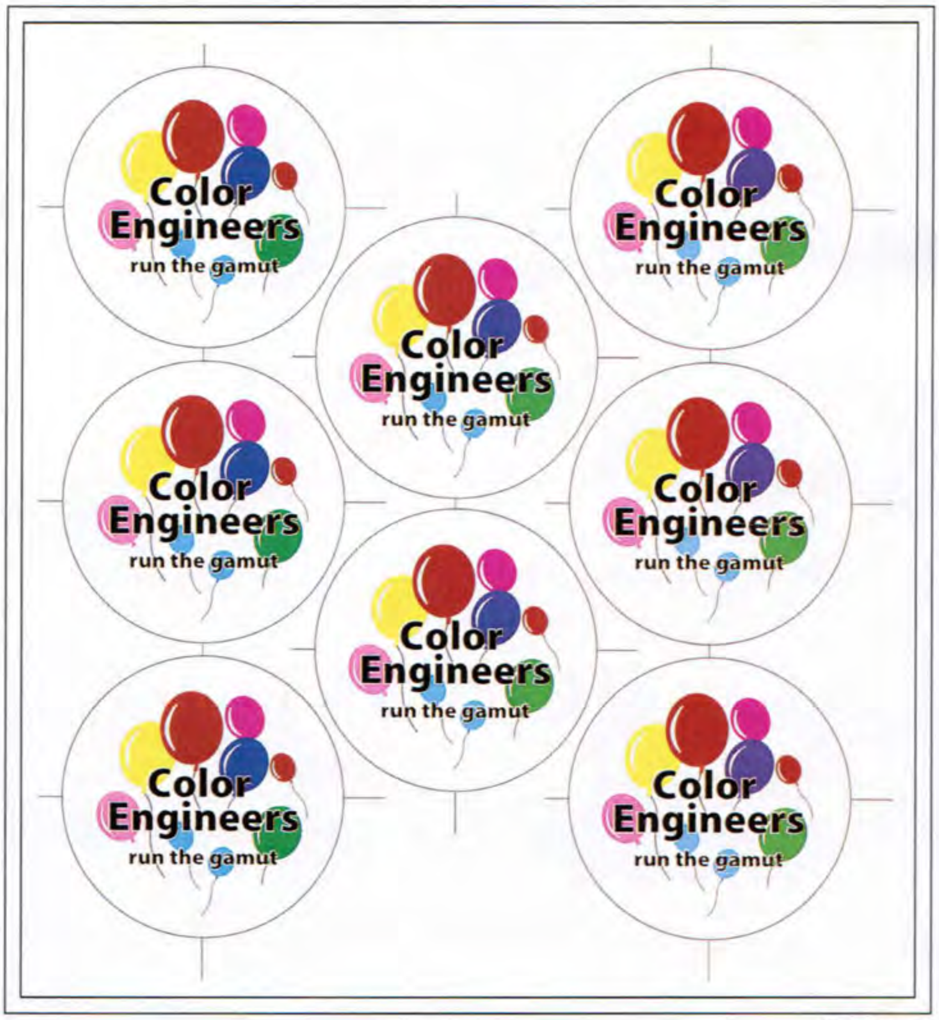
In his paper, McCann mentioned a new consumer application of eye tracking. Some camera viewfinders now contain an infrared light-emitting diode (LED) whose radiation is bounced off the pupil of the photographer's eye and sensed by a segmented photocell. The camera can thus determine what part of the scene the photographer is looking at and automatically focus on that part of the scene.

Mark D. Fairchild of the Munsell Color Science Laboratory at RIT presented a description and evaluation of a color space called RLAB, which was developed for practical appearance matching. The Munsell Laboratory developed RLAB so that it would have color-appearance predictors similar to those of the CIELAB color space: lightness, redness-greenness, yellowness-blueness, chroma, and hue angle. Fairchild described simplified RLAB equations that produced even better results than the previous versions. RLAB performed as well as – or better than – more complicated spaces in matching color appearance from photographic print to photographic print, from CRT to print, and from print to slide. During his talk, Fairchild presented one of the week's tidiest descriptions of the distinction between color matching and appearance matching:

Device-independent color spaces allow you to match what is physically appearing on the display. That solves part of the problem. But the appearance of Stimulus 1 may not match the appearance of Stimulus 2 even if the two stimuli are the same. In other words, we know the stimulus, but what color does it appear to be? This is the arena of color-appearance modeling and measurements.

A. P. Petrov of the Kurchatov Institute took a unique approach to color appearance in "Epiphenomenon of Color in Visual Perception." Petrov defined color constancy as "keeping unchanged the perceived color when bending a surface," a formulation well-suited to the problems faced by automobile manufacturers. Petrov noted that the light that reaches the eye depends on the layout of reflecting surfaces, and that the human visual system ignores contradictions in illumination. Since "the inverse optics problem does not have a unique solution in terms of light sources," Petrov eliminates the light source from his analysis. He does this by moving a small white ball throughout the region of interest to probe the incoming illumination and map it to a perceived color at each location by a "white" matrix. If the sphere is colored, the mapping changes. The surface color is defined by a new matrix. One distinguished U.S. color scientist in the audience expressed cautious admiration for the approach, which, he said, addresses some nagging analytical problems in an elegant way. However, he was not yet sure whether Petrov's approach was also leaving out something significant by defining light sources and observers as being external to the basic problem.

In "Using Color in Computer Applications: A Psychophysical Perspective," Bernice Rogowitz of IBM's T. J. Watson Research Center discussed the challenges of using color effectively. The challenges certainly include



Adobe Systems

Fig. 1: *Color Engineering became a formally defined discipline at the Second Annual Color Imaging Conference. "Color engineer" badges, supplied by Jim King of Adobe Systems, were widely distributed and worn throughout the conference.*

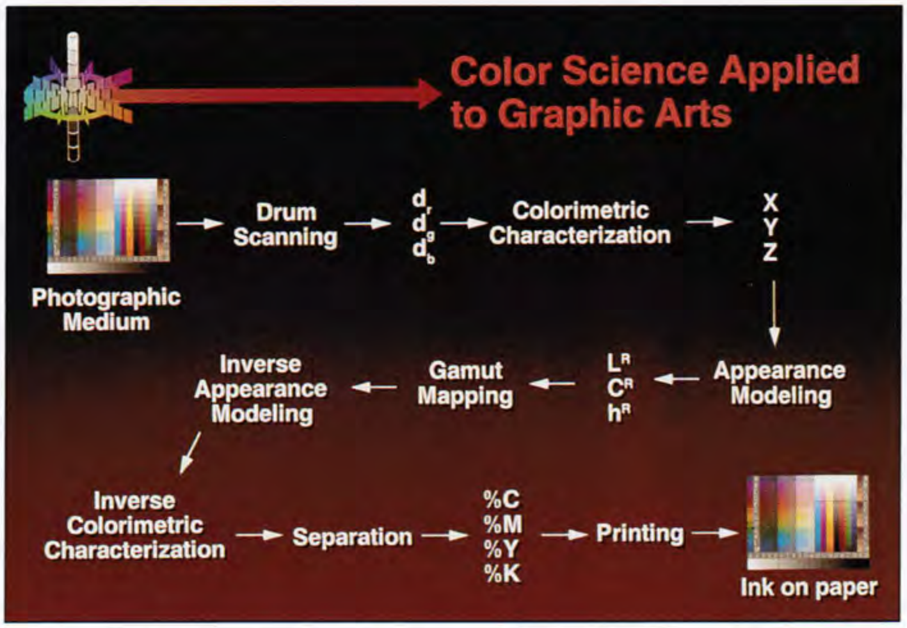
considerations of color appearance and color matching, but go beyond them to a consideration of how color can be used to optimally code data for different purposes. "Please think about the task and application, not just color spaces and receptors. Higher-level mechanisms of color perception, such as image and color semantics, color memory, aesthetics, attention and emotion . . . will fuel the development of future systems." Anyone who is using color or gray-scale coding for data visualization and does not have a background in the subject – and that's most of us – would find the few minutes it takes to read about the specific approaches in the written version of Rogowitz's paper to be a good investment.

In many applications, such as textiles and publications printing, determining whether or not there is a difference between two colors is critical. Can such determinations be made reliably on a display, or will we be eternally exchanging fabric swatches and color press proofs by Federal Express? In "A Comparison of Color-Difference Perception on Soft-Display versus Hardcopy," King Choi described ongoing experiments at Kodak that are designed to answer this question. His conclusion is that, generally, you *can* use CRTs for making color-difference determinations. Choi's test subjects included experienced and inexperienced color observers. Not surprisingly, the experts were able to detect smaller color differences than the novices.

Color Measurement and Calibration

In the measurement and calibration session, the eminent J. Rennilson reviewed the history of colorimetric and photometric measurement. Among the interesting tidbits: James Clerk Maxwell developed a portable colorimeter (for testing people with anomalous color vision) that used prisms and variable slits in a layout that is similar to that found in today's instruments (1860). Rennilson concluded by saying that after you make all your measurements, "The visual perception is the important thing."

In "Colorimetric Characterization of a Desktop Drum Scanner via Image Modeling," Roy Berns and M. J. Shyu of the Munsell Color Science Laboratory at RIT proposed that color accuracy could be improved and prepress time could be reduced if a scanner could produce spectral data – rather than color-space data – as an input for desktop-publishing systems. Since it is currently impractical to do this directly, the authors developed an indirect approach to produce the spectral data. Although the approach was specifically developed for the needs of the printing industry, the general strategy throws light on the color-management problem in many different systems (Fig. 2). And it should be quite a bit easier to spectrally characterize a CRT than it is to characterize a transparency on a drum scanner.



Roy Berns, Munsell Color Science Laboratory, RIT

Fig. 2: *Although this strategy from Munsell Color Science Laboratory for matching colors between two different devices was specifically developed for the printing industry, the approach throws light on the color-management problem in many different systems.*

Color Engineering

In Jim King's color-engineering session, Andrew Mutz and Daniel T. Lee of Hewlett-Packard Laboratories described the color-facsimile standard for transmission of continuous-tone color and gray-scale documents that was approved at the June 1994 meeting of the ITU in Geneva. The standard will have received formal approval by the time you read this; publication is scheduled for February.

The standard uses CIELAB as its color space because it is a flexible, relatively uniform, and device-independent color specification. The color default is 8 bits/channel (full color) with a 12-bit option. This is massive overkill for most business applications, but the system was designed to be usable for color proofing. Machines based on the new standard will be backward-compatible with current binary Group 3 machines. The modulation scheme is half-duplex and conforms to V.32bis and V.32 (14.4 and 9.6 kbits/s).

A one-page 24-bit 200 × 200-dpi image contains 11 megabytes (MB) of data, which would take about an hour to transmit at 9.6 kbits/s. This is obviously unacceptable, so the standard incorporates JPEG to compress the image to 150 kilobytes (kB). Transmission takes about 2 min at 9.6 kB/s, with excellent color rendition.

ITU Study Group 8 intends to continue developing the color-fax standard. Extensions will include soft-copy gamut definition and a recommendation for hard-copy/soft-copy interchange.

Martin Maltz and Raja Balasubramanian addressed a subject close to Xerox's corporate heart: multigeneration color copying. A "major enabler of the black-and-white copier business is the ability to make a copy of a copy," said Maltz. But in black-and-white copying, gray levels get distorted fast, and in color "grays" are what you're doing. The authors explored ways of maintaining color fidelity through practical ways of processing the signal. The techniques are promising, and the authors now wish to extend them to the multigenerational copying of halftones.

Rob Cook described the strategy behind Light Sources' development of a low-cost spectrophotometer:

> *"As people increasingly send files and not proofs to printers, unambiguous color info on the original becomes increasingly important. So, low-cost spectrophotometers for the desktop are important things to have. Color-management systems will be incomplete until spectral data is available. Our prediction is that color science will be lurking behind every desktop."*

Building Color Systems

Gerald Murch of Xerox led off this session with an invited paper, "Cross-Platform Image Fidelity." He said, "Color management offers the means of transmitting color images and documents containing color across local and wide-area networks and between diverse operating systems and applications while maintaining the fidelity of the colors of the original image or document." Point and application "color-management solutions came about due to a lack of color-management support at the level of the desktop operating system. This lack is changing rapidly as all of the major manufacturers of operating systems, with the exception of IBM, have announced color management as an integral part of the OS." Apple's ColorSync 2.0 and Microsoft's Kodak ColorSense-based module in Windows '95 will both ship in 1995. But the problem of cross-platform color portability still remains. Apple, Microsoft, SUN, SGI, Taligent, Adobe, Kodak, and Agfa formed a consortium (to which new members are now being added) to develop a color-profile format based on ColorSync 2.0 that would solve this problem. This format has now been named InterColor™. An important element of the format is the notion of embedded device profiles. The format outlines the requirements for the file headers and formats to carry profile information with images or for multiple images within compound documents. PICT, EPS, and TIFF formats are supported now, and additional formats will be added in future releases.

James R. Sullivan, Program Manager for Kodak's Image Processing Business Unit, spoke on "Color and Image Management for Telecommunication Applications." The information-highway infrastructure will evolve to support "a wide range of imaging applications from low-resolution entertainment such as video-on-demand to the high-resolution image exchange of the medical and graphics arts industries." The huge diversity and volume of applications for color management in telecommunications will probably exceed even that for desktop management.

Color Imaging on the Highway

About 75 people attended the evening panel session, which was unusually lively. The good spirits may have been stimulated by the premium beverages supplied by the organizers and the complimentary copies of "Acrobat Reader" distributed by Adobe Systems.

The session, chaired by Jim King, started with an on-line demonstration of surfing on the Internet's "World Wide Web" by Adobe's Michael Bourgoin. While Michael was surfing, Jo Kirkenaer of Kodak Color Management Systems said to me that at the first Color Imaging Conference last year, people were still talking about color issues. This year they want to manage color with the tools that have become available in the last few months. This is a major change.

Kodak's Jim Sullivan kicked off the panelist comments by saying that the user interface has to get very much better before regular people will use an information highway in large numbers. "If it looks like a computer interface, it won't fly. It has to be easy and fun." Brian Reid, Director of Digital Equipment Corporation's Network Systems Lab, said, "We spend a lot of time studying the low end. How bad can it get and still be useful?"

James M. Kasson, an IBM Fellow at the IBM Almaden Research Center, had a different point of view. "When I think of the information highway, I think of the Internet grown up, not a fancier TV set. Think of accessing information seamlessly from the Web into your document (Insert/Object/WWW/Clipart). It will be a more democratic, less-top-down way of interacting with information."

Brian Reid: "99.9% of the information on the Internet is garbage. The editorial function is badly needed, but editors will need powerful tools. There are already one-third million suppliers of information on the Web. This is the ultimate Jeffersonian medium. Freedom of the press extends only to those who own a press. On the Net, everyone can own a press.

"Copyright law is interesting. Electrons don't know about international boundaries. If you get an image from a country with weak copyright laws and import the image into the U.S., which law applies? You may not know where the image comes from yourself."

Jim Sullivan: "It's retail business and advertising that will drive the mass-market information highway – and that's *not* the Internet. The Internet is uncontrollable, insecure, and it's difficult to implement transactions on it."

Brian Reid: "Wrong. There are lots of transactions now."

Jim Kasson: "The biggest issues are privacy, security, and developing mechanisms for how suppliers get paid for their information. These will have solutions."

Jim Sullivan: "The model is not the computer. Examples of interactive TV are now in trial over wide-area cable in which notable personalities model clothes. The viewer can pull down still images of different items of clothing and can push a button to talk to a real person. If people are going to buy products in this way, reliable color-appearance matching over the network is essential."

The Last Day

Friday was devoted to two color imaging applications sessions and a nicely presented poster session. M. Wolski and his colleagues from Purdue began the regular session with an invited paper on gamut mapping – mapping the color gamut of one device to the gamut of another – which is an important component of device-independent color. The authors conclude that a gamut mapper that can vary its mapping technique depending on the color's location in color space can offer substantially improved image quality, but a lot of work remains to be done.

Those of us old enough to remember color TV before the advent of automatic flesh-tone and blue-sky correction circuits may have wondered at the scarcity of discussion concerning automatic color correction for computer monitors. Pekka Laihanen and a team from the Laboratory of Graphic Arts Technology at Helsinki University of Technology, along with Pekka Kekolahti of Grafimedia/

ICL, were apparently wondering the same thing. They have developed a fully automatic algorithm that corrects color balance, tone rendering, and skin colors of a 24-bit RGB monitor image. The algorithm improved most test images. The authors expect to be able to improve the software further using neural-network techniques. Demo versions of the software are available.

In the poster session, Jan De Clippeleer of Agfa-Gevaert discussed second-generation color-management systems, particularly Agfa's FotoTune 2.0.

Atsushi Takagi and a team from Toyota Motor Corp. presented the results of a project to do computer printing with a dye-sublimation printer and an increased number of inks to attain a wider color gamut. Printed images of Toyota automobiles had such depth of color that they appeared photographic until the viewer got close enough to see the usual printer artifacts.

David L. Spooner of rhoMetric Associates presented an anthology of color-measurement errors in "Why Do Measured Values Taken with Different Color Instruments Usually Differ?" Among these is lateral diffusion error, the failure of an instrument to measure all the light reflected from a sample because some of the light penetrates the surface and is scattered laterally before re-emerging from the surface. The error can often be eliminated by making the area viewed by the measurement system much larger than the illuminated area, but many instruments can not practically implement this technique and the errors persist.

N. M. Moroney and Steve Viggiano of the RIT Research Corporation showed the output of a developmental variable-dot thermal wax-transfer printer, which brings gray levels to wax-transfer printing. The image quality approaches that of dye-diffusion printers, and the technique offers substantial advantages in cost, speed, and energy consumption.

The second color image applications session began with an invited paper by the legendary Robert Hunt of City University, London, and Michael Pointer of Kodak, Ltd. The authors attempted to do what might seem to be impossible: develop a single metric – a color-reproduction index – that would embody differences in hue, lightness, and chroma to come up with a measure of fidelity in color reproduction. Remarkably, their index correlates well with the subjective evaluations of groups of observers. All members of the audience I spoke with thought the work had substantial practical significance.

Binh Pham of Griffith University, Brisbane, presented a method based on regression analysis for making seamless composites of many color images. The method provides a gradual transition with minimum changes to the original data. Sample images were impressive. Future work will be devoted to allowing users to specify the seam along which images will be combined, along with other parameters. A member of the audience commented that the work seems applicable to remote sensing and satellite imaging. It would be interesting to see if the work might also be applicable to the tiling of displays.

In "Putting Color Displays to Work," David Travis of BT Labs developed a simple user-centered method for color calibration that should be accurate enough for mass-market applications. Along the way, he mentioned that the draft of ISO 9241, Part 8, contains psychophysical tests for monitors that are badly flawed. Specifically, the tests fail monitors that are entirely acceptable to users. Travis proposed a revised test method that gave more appropriate results.

Finally, Joann M. Taylor of Color Technology Solutions and Lawrence D. Picciano of ECRI discussed color imaging in endoscopy – the medical technique in which imaging and surgical procedures are performed via a tube inserted into a body orifice or, in the closely related technique called laparoscopy, a surgical incision. Early endoscopes presented an image directly via optical-fiber bundles. Images are now generally provided via video, but there are virtually no color-management facilities. Therefore, the color the physician observes is not well-correlated with the color seen viewing the site directly, nor is it well-correlated with what would be seen on another manufacturer's system (or even another unit made by the same manufacturer). There are clearly opportunities here for color science and engineering to contribute to better medical diagnosis and image communication.

Analysis

What did the experts have to say about the Second Annual Color Imaging Conference and the plans for the third conference scheduled for November 7–10, 1995, in Scottsdale?

Mark Fairchild (Munsell Color Lab, RIT): "The most important trend to be seen at this conference is that the color-matching problem is being handled, but it turns out to be just one layer. The next layer is appearance matching. The gamut-matching – or gamut mis-match – problem still has not really been addressed."

Gerald Murch (Xerox): "The formal creation of 'color engineering' as a discipline legitimizes the application of conventional color-science values to new media. The right thing to do now is to bring to future editions of this meeting the color problems people are having with displays – such as color changes with gray level. This group can be very helpful with such problems."

Jim King (Adobe Systems): "I'm pleasantly surprised at the degree of interest in the activities of the International Color Committee (ICC). I'm disappointed that smart devices have not come along more quickly. For example, scanners can deliver L*a*b* data and printers and displays can accept L*a*b* data, but the characterization still needs to be supplied externally." Things must get *simpler.* We have to get the characterization to be in the device.

Andras Lakatos (SID President and Advisory Board Co-Chair for the conference): "The Color Imaging Conference has quickly established a unique and valuable personality that is very much appreciated by the attendees. There is very significant participation from Europe and Asia, as well as from North America. In the planning meeting for next year's conference, it was noted that registrants like the single-track format and appreciate the interactivity. Registration is up to about 170 from about 150 last year, and the conference is more than supporting itself.

"Next year we will cover the same central topics, which were clearly appreciated this year. In addition, we will attempt to bring in more coverage of color engineering and bring together the color problems encountered in display design and applications with the expertise on color problems possessed by many of the attendees at this meeting. There will be more coverage of second-generation color-matching systems, which are rapidly maturing, and we intend to combine many demonstrations of these systems and products containing them with the poster session.

"Scottsdale is proving to be a good 'home' for the Color Imaging Conference. Next year, we are making the conference a week earlier so it will not conflict with COMDEX." ■

Edited by JOAN GORMAN

10.4-in. SVGA color LCD module

Sharp Electronics Corp., Camas, Washington, has introduced the LM80C03P, a high-resolution 10.4-in.-diagonal liquid-crystal display (LCD). With an array of 800 × 600 pixels, the LM80C03P conforms to the SVGA standard, bringing exceptional resolution, clarity, and contrast to notebook PCs, information kiosks, and other electronic devices. SVGA displays can clearly show an entire page of text and a larger segment of a detailed spread sheet. The dual-scan passive color display features a large display area in a package with the same mechanical dimensions as Sharp's existing 8.4-, 9.4-, and 10.4-in. displays. This breakthrough in viewing area is made possible by innovations in connection technology, backlighting, and packaging. The LM80C03P is equivalent to a 12-in. CRT monitor in screen size and definition, and delivers a 25:1 contrast ratio. The LM80C03P's mechanical compatibility with other active and passive color displays will save computer manufacturers significant tooling and manufacturing costs. The single-tube backlight design also yields a lighter and thinner overall package. Power consumption is 3.5 W.

Information: Sharp Electronics Corp., 5700 N.W. Pacific Rim Blvd., M/S 20, Camas, WA 98607. 1-800-642-0261.

Circle no. 1

CAD/CAM monitors

Panasonic Communications & Systems Co., a division of Matsushita Electric Corp. of America, Secaucus, New Jersey, is entering the high-end color-monitor market with the introduction of the PanaSync™/Pro Series of ultra-high-resolution monitors. The 21-in. C-2192P and 17-in. C-1792P qualify for the CAD/CAM category of monitors, with their 1600 × 1280 resolution, Panasonic's patented DQ-DAF™ (double-quadrupole dynamic astigmatism and focus) electronic gun technology, and a full-featured on-screen display. Designed for CAD/CAM, computer graphics, and desktop-publishing applications, both models feature Panasonic's state-of-the-art digital technology to achieve a high 160-Hz scanning rate for enhanced viewing of 3-D images with stereoscopic glasses. The C-2192P has a 0.25-mm dot pitch, a factory preset display area of 380 × 285 mm, and a full scan setting of 402 × 301 mm. The C-1792P has a 0.27-mm dot pitch, a factory preset active display area of 300 × 225 mm, and a full scan setting of 325 × 240 mm. Both include eight preset timing modes and frequency ranges of 30–82 kHz horizontal and 50–160 Hz vertical. They are compatible with VGA, SVGA, VESA, and high-resolution video boards of 1280 × 1024 lines at 76 Hz. Suggested retail prices are $1999 for the C-2192P and $1099 for the C-1792P. Both models carry a 3-year CRT warranty.

Information: Panasonic Communications & Systems Co., Two Panasonic Way, Secaucus, NJ 07094. 1-800-742-8086.

Circle no. 2

Hi-res monochrome monitors

Data Ray Corp., Westminster, Colorado, has introduced its new line of ultra-high-resolution monochrome monitors, designed specifically to meet the demanding requirements of high-performance medical-imaging applications. The DR80 and DR110 models can display resolutions up to 2048 × 2560. The DR80 utilizes a high-contrast 25-in. CRT with a magnetic focusing system that allows superior focus over the entire display area. The monitor is capable of displaying more than a full 14 × 17-in. image at a light output of 150 fL for primary diagnostic and viewing applications. The DR110 utilizes a high-contrast 21-in. (12.5 × 16.5 in.) 90° CRT with a unique electron-gun design that enables excellent focus at 150-fL light output. The monitor also incorporates electronic geometry- and focus-correction circuitry which allows the image quality to be fully optimized. The DR110 is designed to meet ultra-high-performance imaging requirements with excellent price/performance in mind. The DR90 monitor utilizes a 21-in. 110° flat CRT with 34% glass transmission, which provides very high contrast for easy viewing of gray-scale images. With a maximum light output of 65 fL, it is suitable for consultative or referral applications.

Information: Data Ray Corp., 12300 Pecos, Westminster, CO 80234. 303/451-1300, fax -1143.

Circle no. 3

Passive-matrix LCD panel

Telex Communications, Inc., Minneapolis, Minnesota, has expanded its MagnaByte® LCD line to include a dual-scan passive-matrix model offering 640 × 480 resolution. The MagnaByte® M1p is the LCD solution for small-business and education presenters, where value is as important as quality color output. With 1.4-million colors on its palette, no other passive panel in the industry offers more color flexibility. The M1p can also support Apple's QuickTime™ and Microsoft's Video for Windows™. The M1p weighs 5 lbs. (2.3 kg) and is compact, lightweight, and very portable. The panel incorporates a full-function control feature on the panel or via an optional IR remote control. Controls include focus, inverse video, image alignment, contrast, picture, tint, palette, contract, expand, brightness, text display select (nine settings) mode (text adjustment for IBM VGA users only), and reset. Other features include simultaneous monitor and panel support and a light-activated cooling system for quiet operation when the overhead is turned off. The M1p is designed for IBM compatibles and Macintosh computer platforms. Power supply (110–240 V, 50/60 Hz) and all necessary cables are included.

Information: Telex Communications, Inc., 9600 Aldrich Avenue South, Minneapolis, MN 55420. 612/884-4051, fax -0043.

Circle no. 4

Mini high-voltage power supply for HUDs

WinTron, Bellefonte, Pennsylvania, has introduced a mini regulated high-voltage power supply for miniature head-up and helmet-mounted displays. The small 3.0 × 0.7 × 1.5-in. unit weighs less than 100 g. The anode voltage can be as high as 8.5 kV, the cathode output as high as 750 μA with an adjustable G2 (150–550), and focus outputs to 1500 V. The power supply operates with +12 Vdc (±2 V) input with a low ripple on all outputs. The anode is 0.025%, providing power for the best resolution and overall performance in miniature CRT displays. Custom variations with a wide range of electrical parameters can be manufactured for similar or other applications.

Information: Melissa Hein, WinTron, 250 Runville Road, Bellefonte, PA 16823. 814/355-1521, fax -1524.

Circle no. 5

3-D graphics chips

Yamaha Systems Technology Division, San Jose, California, has introduced their first two "virtuality" high-performance 3-D graphics chips. The rendering polygon accelerator (RPA) Yamaha YGV611, and a lower-cost system version, provide high-quality 2-D or 3-D performance on PCs and low-end workstations at unmatched low cost. Graphics boards designed with these graphics controllers will bring sophisticated drawing, shading, texture mapping, and video capture to animation, presentations, modeling, CAD/CAM, and virtual reality. The YGV611 performs Gouraud shading and texture mapping at 210K polygons/s (50-pixel polygons), and also performs hidden surface removal, video capture, and bit block transfer (BitBLT). The frame-buffer interface is 128 bits wide (64 bits interleaved), providing high-performance graphics. The 16- or 32-bit-wide host bus interface operates up to 33 MHz. The chip supports resolutions up to 1280 × 1024 16-bit color. CMOS processing is used for lower power consumption. The YGV611 evaluation boards are available now. Engineering samples will be available in Q1, 1995. Production quantities are scheduled for Q2, 1995. Price is expected to be $80/1000 pieces.

Information: Henry Choy, Yamaha Systems Technology Division, 100 Century Center Court, Suite 800, San Jose, CA 95112. 408/437-3133, fax -8791.

Circle no. 6

Industrial touch monitor

Nortech Engineering, Inc., Medfield, Massachusetts, has announced the CM1510, a 15-in. industrial video monitor available with resistive or capacitive touch screens. Housed in a sheet-metal enclosure, with the front panel sealed to NEMA-4 ratings, the CM1510 is available in either a rack or panel mounting configuration. Controls are normally mounted in the front of the monitor for convenience, but may be optionally mounted in the rear for full NEMA-4 compliance. Featuring on-screen display (OSD), which displays all of the adjustment functions directly on the screen, and digital controls, the monitor's video modes can be easily preset or changed and the quality of the video image readily optimized. The CRT display has a resolution of 1280 × 1024 non-interlaced and uses a 15-in. flat square CRT, allowing image adjustment to the edge of the screen. It is compatible with all of the IBM and VESA standards, the Apple Macintosh II family, and Sun workstation standards. A model without a touch screen is also available for $895; prices are $1785 for touch-screen models. Delivery is 2–4 weeks ARO.

Information: Mel Silverstein, Nortech Engineering, Inc., 19 Wichita Road, Medfield, MA 02052. 508/359-6063, fax -7746.

Circle no. 7

Fine-grain titanium target

Tosoh SMD, Inc., Grove City, Ohio, has introduced a new fine-grain titanium target that provides greater consistency, reliability, and repeatability in sputtering processes. Designed for use in large planar systems, it is also available in low oxygen for titanium nitride applications. In response to customer requirements for a finer grain size, Tosoh SMD, with its controlled metallurgy and target fabrication processes, has cut the average grain size in half. The result is an ultrafine microstructure throughout the Ti target, ensuring consistent film performance through target life and from target to target. Tosoh's new proprietary nondestructive ultrasonic testing procedures help to achieve a more homogeneous grain size for more consistent performance in the customer's sputtering process, thereby reducing manufacturing costs.

Information: Steve Bardus, Product Manager, Semiconductor Planar Systems, Tosoh SMD, Inc., 3600 Gantz Rd., Grove City, OH 43123-1895. 614/875-7912.

Circle no. 8

64-bit card for PC simulators

RPI Advanced Technology Group, San Francisco, California, has announced the Pixel-Pump VGAPCI™, a dual-channel accelerated VGA board for 3-D stereoscopic personal simulator, games, and visualization applications. The advantages of the RPI unit over competitive units include lower cost ($950), higher resolution (1600 × 1200), two independently programmable VGA channels in one PCI slot, feature connectors, video-display memory, and GUI accelerator functions contained in the hardware. The boards are in stock and ready to ship immediately. They come with support for OS/2, MS-DOS, Unix, NT, and Windows applications.

Information: Howard Prestidge, RPI Advanced Technology Group, P.O. Box 14607, San Francisco, CA 94114. 415/495-5671, fax -5124.

Circle no. 9

Projectors with automatic convergence

Electrohome Limited, Kitchener, Ontario, Canada, has introduced the Marquee 8001 and 9001 data graphics projectors with patented automatic convergence (ACON) capabilities. ACON is a hardware/software system that automatically accurately aligns CRTs in 3 minutes after four keystrokes on the keypad. The patented photodiode sensor system is more accurate, reliable, and consistent than camera-based convergence systems. The Marquee 8001 and 9001 projectors with ACON deliver optimal display quality while eliminating time-consuming manual adjustments. Intended for applications such as presentation graphics, status display for control rooms, and multimedia, both the 8001 and 9001 offer scanning rates of up to 130 kHz. The Marquee 8001 uses three 8-in. electromagnetically focused CRTs; its horizontal scanning range is unmatched by any projector in its price range. The Marquee 9001 features three 9-in. electromagnetically focused CRTs combined with liquid-coupled lenses with true Scheimpflug adjustment for optimum top-to-bottom and side-to-side focus along with exceptional contrast. In addition, the Marquee 9001 is the first projection system to include electronic astigmatism correction. The suggested U.S. list price of the Marquee 8001 is $24,995 and $36,995 for the Marquee 9001. Both projectors are available immediately through Electrohome's North American and international dealer network. The ACON upgrade kit for installed projectors is priced at $2495.

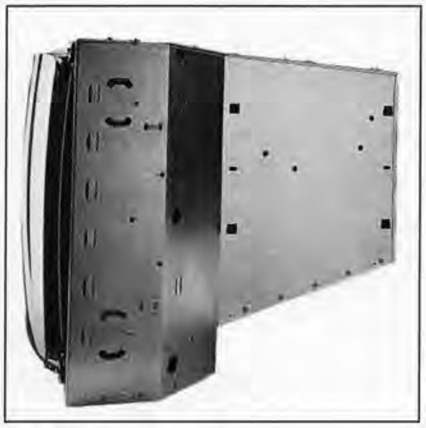
Information: Jeffrey Brum, Electrohome Limited, 809 Wellington Street North, Kitchener, Ontario, Canada N2G 4JG. 519/744-7111.

Circle no. 10

Finally, color monitors

Nokia Display Products, Inc., Sausalito, California, has announced that its recently introduced Valuegraph™ 447L line of low-cost speaker-equipped 17-in. monitors is now available in stylishly colored Europalette™ enclosures, including red, blue, teal, gray, and beige. The flat square monitors feature 0.28-mm dot pitch, a maximum ergonomic resolution of 1024 × 768, and a refresh rate of 75 Hz. Front-panel digital screen and volume adjustments and stereo speakers mounted invisibly under the bezel make Valuegraph™ 447L monitors ideally suited for the graphics-rich multimedia entertainment software that is driving growth of the home market. Brightly colored Europalette™ enclosures bring added excitement to the home environment. The European ergonomics of these monitors reduces eyestrain and fatigue, making them more comfortable to view for extended periods. The monitors are manufactured in Finland and feature the Nokia-pioneered emissions standards that have been broadly adopted in the industry, earning them Sweden's MPR-II certification. Valuegraph™ 447L monitors offer as standard many other Nokia-pioneered features and picture-quality enhancements not found on most monitors: antiglare and antistatic coatings, dynamic auto focus, and VESA DPMS power-saving technology. The Europalette™ 447 monitors carry a 3-year parts-and-labor warranty. Valuegraph™ 447L monitors also include Nokia's FullScreen™, which eliminates the black border found on most monitors, expanding the viewable application area by up to 10% without distortion. European research has shown that this solution reduces eyestrain. The suggested retail price of the Valuegraph™ 447L is $699.

Information: Mike Tomko, Nokia Display Products, Inc., 1505 Bridgeway Blvd., Suite 128, Sausalito, CA 94965. 415/331-0322, fax -0424.



Circle no. 11

Projection exposure systems

Tamarack Scientific Co., Inc., Anaheim, California, has introduced a new series of fully automated high-speed projection exposure systems for processing flat panels up to 20 × 24 in. for displays, color filters, MCMs, and ultra-high-density PCBs. The automated Series 300A's exclusive scanning projection technology is ideally suited for many standard lithographic-process steps requiring 4-µm resolution. Special optical design provides a large depth of field to accommodate thickness variations in films and MCM substrates. The Series 300 eliminates stitching errors, provides faster processing, and is substantially lower in cost than stepper systems. With a typical total process time of 59 s from pick-up to return of a 360 × 465 × 1.1-mm panel, the Series 300 offers a totally new and economical production option for large-area lithographic processing. In the automated processing sequence, a pick-and-place arm lifts a flat panel from the start position and loads it on the scanning chuck, where it is automatically aligned and exposed by high-speed scanning projection. The panel is then unloaded by a secondary arm and placed in the finished position while the first arm is loading the next panel.

Information: Tamarack Scientific Co., Inc., 1040 North Armando St., Anaheim, CA 92806. 714/632-5030, fax -1455.

Circle no. 12 ■

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.

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continued from page 4

how strong the influence of current events can be when one tries to imagine what the future may hold. Apparently, paradigm shifts are no easier for movie creators than for us.

With this grounding in practical technology forecasting, I returned to the review of what the folks at *Playboy* thought would happen – not 200 years from now, not even 30 years from now, but in the very immediate future of 1 to 9 years ahead – the decade of the 80s. Looking back from 1994, the predictions are amazing – by how far they missed what really happened. Many of the predictions made then are *still* being made today of technologies that are "just around the corner." And, perhaps, some of them actually are.

So, let's look at the future as seen from 1980. If nothing else, I think you will find some of these predictions quite entertaining. If I were to ask you to make your predictions for 1995, 1996, or 1997, how many of them would you mention? Or do you have some of your own not found here? If you like, please send me your thoughts for a possible follow-up column.

1981 – Video-text broadcasting begins as a commercial service, bringing still pictures and printed data to the nation's TV screens. Two systems appear: Teletext, sending limited amounts of information by broadcast TV signal, and Viewdata, using phone lines to carry a greater variety of information.

- The French begin substituting computer terminals for printed phone directories.
- AM stereo broadcasting, proposed to the FCC in 1980, is finally approved.

1982 – Growth of home-computer use and inter-computer networks leads to strong competition for the U.S. Postal Service, as millions gain ability to transmit written messages electronically. Postal rates are raised to compensate for reduced volume.

- First flat TV picture tube reaches market – small, black-and-white, and expensive. TV can be hung on the wall.
- Appliances now include built-in decoders that react to remote-control signals sent over house wiring.

1983 – Reference books fade from market, gradually supplanted by data banks accessible from home computers for small fees.

- Two-way cable-TV systems become widespread. Viewers can participate in opinion polls, vote from an on-screen "menu" for specific programs and films, order goods seen in commercials, and call for emergency assistance, all via cable.

1984 – Picture-phone service arrives. After some embarrassments, service is revised so that neither camera nor view screen becomes active until turned on by user.

- First flat-tube color-TV screen arrives, small and expensive.
- Bookstores stock only the biggest sellers; books in low demand are available on microfiche sheets "printed" by a computer in the store.
- Game playing by computer network becomes a national mania; players all over the country match wits in fast-paced games that end in minutes, and extended games that continue for days or weeks.

1985 – Facsimile printers tied into home video systems give instant printouts of newspapers and other information. Users can scan headlines and request printouts of the stories that interest them. System puts available stories in order of viewer's priority.

- Appliances, while still sporting control panels, now almost universally respond to vocal commands.
- High commuting costs lead to "distributed offices," which means workers stay home and communicate via home-computer terminals.
- Flat color-TV screens grow in size, shrink in price, gain in popularity.

1986 – Bookstores begin printing "instant books" on recycled paper, as well as instant microfiches. New books can be printed in the user's choice of type size – bigger sizes for easier reading, smaller ones for easier carrying.

- Total ambience control for home audio systems lets a listener dial in precisely the room acoustics he wants, either according to personal taste or by calling up the name of the concert hall whose sound he wants to duplicate.
- TV screens grow to wall size, making movies into MOVIES!

1987 – Hi-Fi systems linked to computer-data networks conquer "music lover's itch." Whistle a tune, and the system will identify it and play a recording of it.

- Pattern generators project fixed or moving patterns on wall-size TVs, turning them into "wallpaper."

1988 – High-resolution video arrives, following years of viewer complaints about coarse 525-line pictures on wall-size screens. Using multiple blocks of cable-TV channels, special tuners and projectors, new systems receive 2100-line pictures.

- Flat-screen wrist television arrives.

1989 – Flat speakers share wall space with flat video screens.

- The kitchen computer arrives; not just the long-predicted recipe bank, but a system that checks groceries as they enter and leave kitchen shelves, keeps an inventory, and suggests menus on the basis of food on hand, diet preferences, food prices.
- Holographic (3-D) TV appears.

After reading these predictions, don't you feel like the world hit a bump in the time-continuum and went off in a completely different direction? Over a period of just a few years, virtually nothing happened as predicted. Can we learn anything from these missed experiences to help guide our next attempts at the future?

One immediate observation is that bringing technology to market almost always happens at a significantly slower rate than those involved with the technology are likely to predict. It seems that technologists are great at conveniently forgetting about such "minor details" as manufacturing process development, manufacturing scale-up, development of a supplier infrastructure, and time to achieve market acceptance.

However, of equal importance to the implementation of technologies are the *political, social, ecological,* and *economic* environments. For example, sending a man to the moon was first a political decision and only then was the technology called on to make it happen. That the permanent moon base is not going to happen in 2001 is similarly a political decision. But, it is also an economic and social one. As a society, we have decided that we do not wish to spend our resources on such a project. Look at another example. The limitations placed on the growth of nuclear power plants are social and ecological, not technological or economic. And closer to our own interests, the fact that we don't have an HDTV standard today is not a problem of technology but one of the political, social, and economic decisions that slow the process to a near-standstill.

Whatever our current environment, it narrows our vision so that it is difficult to see a future significantly different from the present until it is nearly upon us. It's a sneaky combination of an evolutionary and revolutionary process in which the many concepts of what the world *should* look like mix in a virtually unpredictable way – and out of the many, a few of the most useful and desirable combinations become accepted. This surviving set then determines the next direction and so on. It's like a drive down a very foggy road. We can see what is immediately in front of us, but the distant vision fades quickly and what looks like a lamppost may instead turn out to be a tree.

Consequently, I've been working on a new invention: Technology-Fog-Penetrating Goggles (TFPGs). I expect to have my first prototype ready for testing in just a few weeks. Unfortunately, some of the critical parts for my new invention are still on back-order. In the interim, I will suggest the following general guidelines for predicting how technology reaches commercial markets and succeeds in them.

> *From the first demonstration of a new technology concept, it typically takes 10–20 years before major commercial exploitation is successfully accomplished.* LC, EL, and plasma displays are examples.
>
> *Once product-level capability has been demonstrated, sufficient time must be allowed for the development of manufacturing processes and manufacturing scale-up, including a materials-supplier and equipment-producer infrastructure.* The bigger the market, and/or the more novel the technology, the more investment and the more time must be allowed for this: 3–5 years is a reasonable starting point.
>
> *If an industry standard is required for the technology to be adopted, add 5–10 years to the above. If one or more governments must be involved, add 10–20 years.* HDTV is an excellent example.
>
> *Most human beings dislike change and distrust technology. A new product must provide a useful and significantly better capability before it will be accepted.* For this reason, the computer-controlled house is still some years away.
>
> *In assessing whether and how quickly a new technology can make it to market, assume at least as much (and probably greater) impact from political, social, economic, and ecological forces than from technology forces.*

We technologists must be an unusual lot. We work on projects that seldom succeed as originally planned. Then when we do succeed, it takes us on the order of 2–5 times longer than estimated to get a product ready to sell at an acceptable price. And finally, after we do all that, we find suspicious and unappreciative customers. Once in a great while, after years of trying, one of us achieves an unexpected major success. I would say we are more like the wildcat oil-well drillers of the 1920s than the shy technology-nerds depicted by the popular press.

In this month's industry news segment, we find a continuing expansion of a strong display-industry infrastructure.

Jeff Hartson has been appointed as the Vice President of Sales for **RGB Spectrum** of Alameda, California. This is a new position for the company. Prior to this appointment, Jeff was Director of Strategic Partners at Pyramid Technologies. RGB Spectrum is a designer and manufacturer of videographic and multimedia products for workstations and personal computers. Products include the **ComputerWall**™ multi-screen display processors, the **RGB/View**® line of video windowing systems, the **RGB/Videolink**® line of scan converters, and the **Watchdog**® video multiplexor. Key applications include command-and-control, training and simulation, and remote video monitoring.

After a 38-year career with the **Schott Corporation, Hans F. W. Moeller** will retire as Vice Chairman of the Board of Directors. Mr. Moeller began his career with Schott Glaswerke in Mainz, Germany, in 1956. In 1961, he came to the United States to represent the firm in America, and in 1963 he established Schott's first North American subsidiary, of which he later became President. Mr. Moeller also played a key role in founding Schott Glass Technologies in Duryea, Pennsylvania.

The **American Electronics Association** has provided an update on the 1995 U.S. Congressional Defense Appropriation Bill that, as of this writing in late October, has made it through conference with money allocations that are important to the U.S. display community. The $68-million Administration request for high-definition systems was increased by $15 million, with $15 million of the total earmarked for TFEL. The Administration's $10-million request for advanced lithography was increased by $50 million to a total of $60 million. The $100-million Administration request for Multi-Chip Modules was increased by $10 million, with $5 million earmarked for diamond and $5 million for superconducting materials. The buy-America provision for advanced ceramics and FPDs was removed in the final legislation.

Integrated Circuits Testing GmbH of Munich, Germany, and **MRS Technology, Inc.**, of Chelmsford, Massachusetts, have signed an agreement for a strategic partnership to develop and introduce an electrical test system for active-matrix liquid-crystal displays (AMLCDs). ICT has developed focused electron-beam-probing technology for IC testing and is now developing an electrical tester for flat-panel displays (FPDs) based on this e-beam technology. Under the agreements, MRS will develop materials-handling systems and high-level user interfaces for the tester, and will distribute test systems in all markets except Europe. ICT will handle the European market. ICT will deliver two testers to MRS in 1995. In addition, MRS will acquire a 10% equity position in ICT.

Brooks Automation of Lowell, Massachusetts, has delivered its second HERCULES 6500 platform for the production of flat-panel substrates up to 600 × 700 mm to **Leybold AG** of Alzenau, Germany. Leybold has already taken delivery of one HERCULES 6500 for the purpose of process development. This unit will ship to a third-generation AMLCD fab in Japan in early 1995. The HERCULES 6500 is a high-throughput ultra-clean cluster tool that will allow the world's leading FPD producers to accommodate third-generation substrates. The transition to third-generation substrates should allow FPD producers to increase fab capacity by 50% and reduce display costs. **Ross Young**, FPD Product Manager at Brooks Automation, recently hosted a visit by **Dr. Kenneth Flamm**, Principal Deputy Assistant Secretary of Defense for Dual Use Technology, who was interested in seeing first hand the capability of this new fabrication equipment.

Edward D. Surjan, Jr., has been elected President and Chief Operating Officer of **Crystaloid** of Hudson, Ohio. He will continue his responsibilities as Vice President, Sales/Marketing, and report directly to the company's Chairman and CEO, **Robert R. Dahl.** In addition, **R. Edward Koskie**, previously President, was elected Vice Chairman, also reporting to Dahl. Surjan, who joined Crystaloid in 1982 as Vice President, Sales/Marketing, was previously with Bull HN Information Systems. Crystaloid is a manufacturer and supplier of liquid-crystal displays for commercial and avionics applications. The company is known for specialized custom-designed twisted-nematic, super-twisted-nematic, and dichroic displays.

Carolyn Russell has been named Director of Marketing Communications for **Brite Voice Systems, Inc.**, of Wichita, Kansas, which provides voice processing systems and services worldwide. She was previously public relations manager for Boeing Defense and Space Group, Product Support Division. Her work at Boeing included all national and international media-relations activity for the new "Air Force One."

Gus Ligthart has been named Northwestern Regional Sales Manager for **Karl Suss America** and will be located in San Jose, California. Prior to joining Suss, he was employed by Canon USA as District Sales Manager, handling wafer steppers. Karl Suss America, Inc., of Waterbury Center, Vermont, is a supplier of mask aligners, flip-chip and anodic bonders, spin coaters, and probe stations. The company develops and produces machines in Vermont, Munich, Germany, and Saint Jeoire, France.

NuVision Technologies, Inc., the newly created spin-out of the Tektronix liquid-crystal color-shutter technology, has leased space in the Twin Oaks Center in Beaverton, Oregon. NuVision will hire many of the employees who worked in the Tektronix Display Products Division. **Rich Hockenbrock**, who will head up the new operation, reports that they will begin with 12 employees and expand as business warrants.

As always, I enjoy hearing your thoughts about this column. However, this month I am particularly interested in having some of you respond with your own thoughts and predictions of where display technology is heading between now and 2001. You may reach me by e-mail at aris_silzars@maca.sarnoff.com or by fax at 609/734-2127 or by phone at 609/734-2949. As a last resort, you may wish to use the pony express and send your information to Jay Morreale at Palisades Institute for Research Services, 201 Varick Street, Suite 1006, New York, NY 10014. ■

Edited by Joan Gorman

Restructuring at Plasmaco

Plasmaco, Inc., Highland, New York, has announced a major restructuring of its operations as a first step towards enabling the company to pursue the commercialization of its recently demonstrated full-color flat-panel display. The total financing, which included debt restructuring and new equity, exceeded $6 million. The working capital infusion was provided by a new group of U.S.-based private investors, which now own a majority of the outstanding stock of Plasmaco and will become active participants in the financing and operation of the company. The new equity financing and restructuring were spearheaded by Atlantic Venture Group, Inc., a New York City-based merchant banking firm, together with a group of new shareholders led by Samuel Schwartz, the Chairman of Sono-Tek Corp. (SOTK), a Milton-based manufacturer of ultrasonic spray products. Stephen E. Globus, Chairman of Globus Growth Group, Inc., a New York City-based investment firm, will become the Chairman of Plasmaco, with John J. Antretter (President of Atlantic Venture Group) assuming the positions of Acting Chief Executive Officer and Director. Dr. Larry F. Weber, a founder of Plasmaco in 1987, was named President and a Director of the company; Donald F. Neville (Vice President of Atlantic Ventures) was named Chief Financial Officer and a Director; and Michael J. Sprague was elected a Vice President of the company. Additional Directors include Wolfgang Drescher, Samuel Schwartz, and James L. Kehoe. According to Dr. Larry F. Weber, "The combination of a significantly cleaned-up balance sheet, the infusion of new working capital, and the resources of the new board of directors should position Plasmaco to pursue all of the business and engineering activities required to get our state-of-the-art full-color display to market." Plasmaco was founded in 1987, when it acquired production equipment and technology from IBM. The company is located in Highland, New York, and currently employs approximately 30 people.

The price of plasma

Fujitsu's 21-in. color plasma display panel (PDP) is currently priced at approximately $8000, and the sample price in Japan for Mitsubishi's new 20-in. full-color PDP is $10,800. According to an unnamed source quoted by Yoshiko Hara in an article in the *EE Times* of October 24, 1994, it should be possible to reduce the price to $100 per diagonal inch within 3 years. That, says Hara, indirectly quoting his source, is "a price point that will cause demand for plasma displays to explode."

Thin-CRT alliance

Silicon Video Corp., Cupertino, California, has been selected to receive the U.S. Flat Panel Display Initiative's Technology Reinvestment Program (TRP) funding for its first two phases of a three-phase program. Total costs, distributed over 18 months, are $67.2 million; TRP will contribute about a third. This TRP award enables the company to receive its second $250,000 matching-fund award from the State of California's Goldstrike Program. These awards will help Silicon Video complete the development of custom-manufacturing equipment, tooling, and factory-automation testing for the company's pre-production facility. Founded in 1991, Silicon Video's goal is to engineer and produce a new class of flat-panel display called a thin cathode-ray tube ("Thin CRT"). Hewlett-Packard Co., Compaq Computer Corp., Advanced Technology Materials, Wyse Technology, Planar Advance, Accu-Fab Systems, Spectrum Science, and Lawrence Livermore National Laboratory all confirmed their co-development support and involvement with Silicon Video's technology program.

Restructuring at Motif

Motif, Inc., Wilsonville, Oregon, has announced that it is restructuring its operation in order to focus greater attention on its core Active Addressing™ technology. Its LCD-manufacturing operation will be shut down as a result of the restructuring. As previously announced, Motif has been working toward delivery of its first Active Addressing Integrated Circuits (AAICs). Motif, a joint venture between Motorola and In Focus Systems, will continue to establish Active Addressing™ technology in the marketplace through its panel partner alliances.

ARPA award to Photon Dynamics

Photon Dynamics, Inc. (PDI), Milpitas, California, has been awarded an ARPA contract to continue work on its test equipment for flat-panel display (FPD) manufacturing. The $4.2 million co-development contract is to develop PDI's next-generation In Process Test System (IPT-MPS™), designed to test and characterize flat panels during the more critical array stages of FPD mass production. Testing during the array stage of manufacturing is essential to reduce manufacturing costs and improve production yields. The contract will enable the development of features including enhanced test-system throughput and maximum reliability, coupled with a smaller equipment footprint and a complete robotics system. The IPT-MPS will also give process and characterization information to the FPD manufacturer, allowing them to manage line failures during production. "This cost-sharing method allows Photon Dynamics to expand its competitive edge while sharing its expertise with ARPA," said Francois Henley, PDI's chief technical officer. "The improvements funded by ARPA will speed the availability of IPT-MPS technology, allowing its more rapid introduction into the on-line manufacturing of flat-panel displays. This effort builds on the basic in-process test technology recently developed with ARPA support and will advance FPD-testing capability to meet the demanding testing and throughput needs of high-volume manufacturing," stated ARPA program manager, Dr. David Slobodin. According to Slobodin, "This contract is a key element of the ARPA program to strengthen the U.S. equipment and materials infrastructure and to further advance the domestic FPD industry."

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Partnership to develop FPD tester

Integrated Circuit Testing GmbH (ICT), Munich, Germany, and MRS Technology, Inc., Chelmsford, Massachusetts, have signed agreements for a strategic partnership to develop and introduce an electrical test system for active-matrix liquid-crystal displays (AMLCDs). ICT has developed focused electron-beam probing technology for IC testing and is now developing an electrical tester for flat-panel displays (FPDs) based on this e-beam technology. Under the agreements, MRS will develop materials-handling systems and high-level user interfaces for the tester, and will distribute test systems in all markets except Europe. ICT will distribute test systems in Europe and will deliver two testers to MRS in 1995. In addition, MRS will acquire a 10% equity position in ICT.

Boxless TV sets

Living up to its name for one-of-a-kind service, the new Concierge Series color-TV product line from Zenith Electronics Corp., Glenview, Illinois, includes unique "boxless" sets that offer compatibility with any of the three major in-room pay-per-view (PPV) services. The line was introduced at the 1994 Hotel/Motel & Restaurant Show in New York. The Concierge Series' most significant new breakthrough is a software upgrade in the multiple protocol interface (MPI) or "smart plug," in two of its models (H2015Y and H2522A/Y). This enhancement gives the Concierge Series a unique position in the marketplace – compatibility with any of the industry's three largest PPV services: Spectradyne, LodgeNet Entertainment, and On Command Video. Zenith will enter the international lodging industry with its introduction of the Passport Series color-TV product line. It offers MPI compatibility, operates with PAL-M/N and NTSC broadcast systems, and includes a "universal plug" to support international line cords. Both the Concierge and Passport Series are part of Zenith's new color-TV product lines designed to serve the lodging, health-care, education, and international markets.

Grant to LCI

Technology developed at Kent State University's Glenn H. Brown Liquid Crystal Institute (LCI) is another step closer to revolutionizing the multibillion-dollar display industry. "The display industry is looking for a flat-panel display screen that is purely reflective, so that it looks just like a piece of paper, but has the potential for full-color," said LCI Director, Dr. J. William Doane. LCI researchers have developed a technology capable of playing a pivotal role in the development of just such a display. Supported by a $1.93 million 3-year grant from the Advanced Research Projects Agency (ARPA), LCI will pursue the development of this functional display. With the production of a reflective flat-panel display, the advent of interactive electronic newspapers, magazines, and books whose pages appear on a lightweight tablet-size viewer could be about 3 years away, said Dr. Roger Fidler, Director of Knight-Ridder's Information Design Laboratory, during a recent lecture at the University.

New EL-lamp plant

Durel Corp., Tempe, Arizona, has announced the construction of a new plant in Chandler, Arizona, to be completed in April 1995, which will accommodate its growing business in electroluminescent (EL) lamps. The company is currently based nearby in Tempe, Arizona, and operates a second manufacturing facility in Chandler. Durel has experienced tremendous growth, with sales volume tripling during 1993 as production volume in units increased nearly sevenfold; 1994 volume is up 60%. "The new facility will allow Durel Corp. to increase volume production to support our rapidly growing domestic and international sales," said Durel President, Robert Krafcik.

Alternative to steppers and contact printing

Utilizing new and innovative technology, Tamarack Scientific Co., Inc., of Anaheim, California, has introduced a series of fully automated high-speed scanning projection exposure systems for processing flat panels up to 500 × 600 mm. With very large depths of field and resolutions down to 4 μm, this new technology offers a completely new production alternative to many process steps in the manufacture of flat-panel displays, color filters, MCMs, and ultra-high-density PCBs. Compared with steppers, the new systems process large areas faster, eliminate stitching errors, are substantially lower in cost, and are fully compatible in mix-and-match configurations.

Information: Tamarack Scientific Co., Inc., 1040 N. Armando St., Anaheim, CA 92806. 714/632-5030, fax -1455. ■

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.

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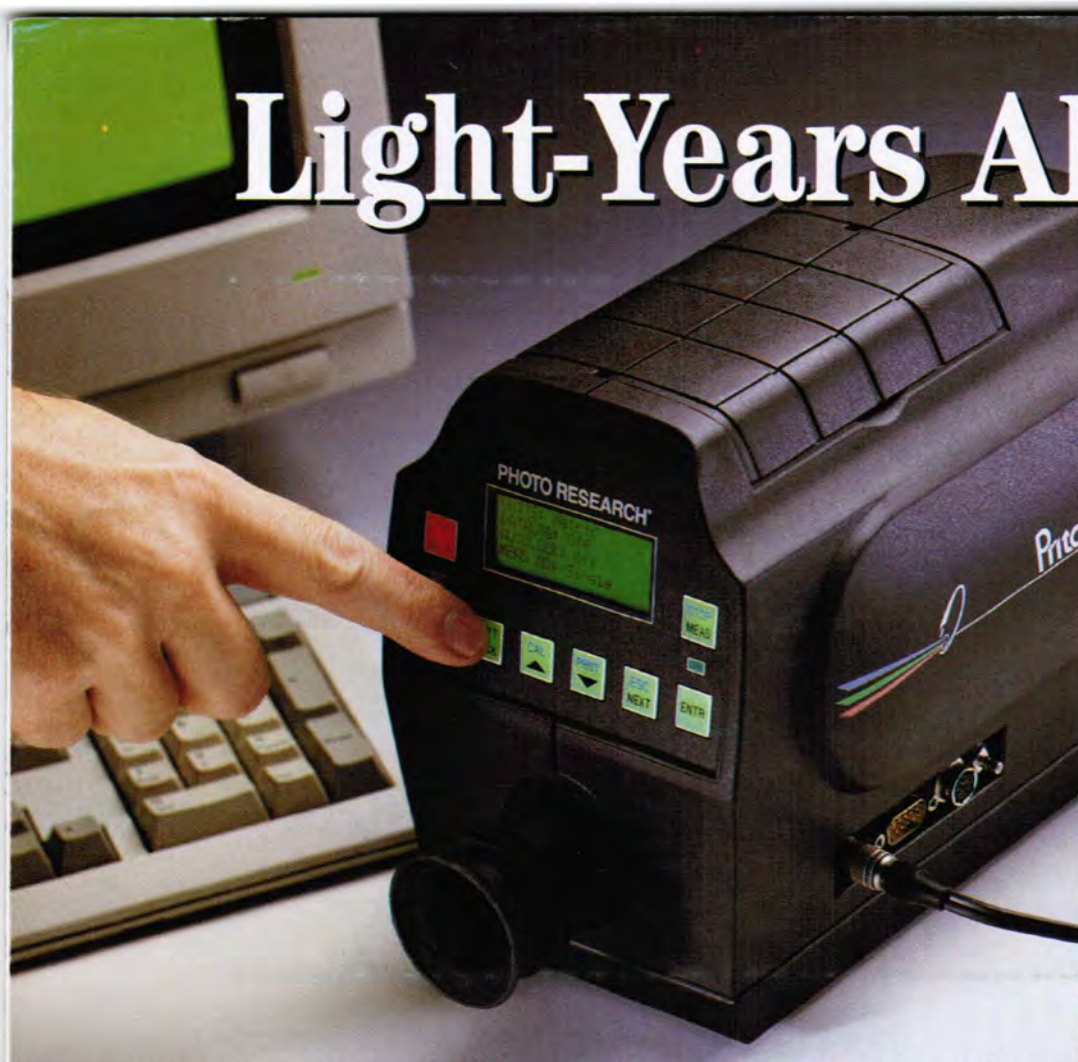

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