CRT ISSUE

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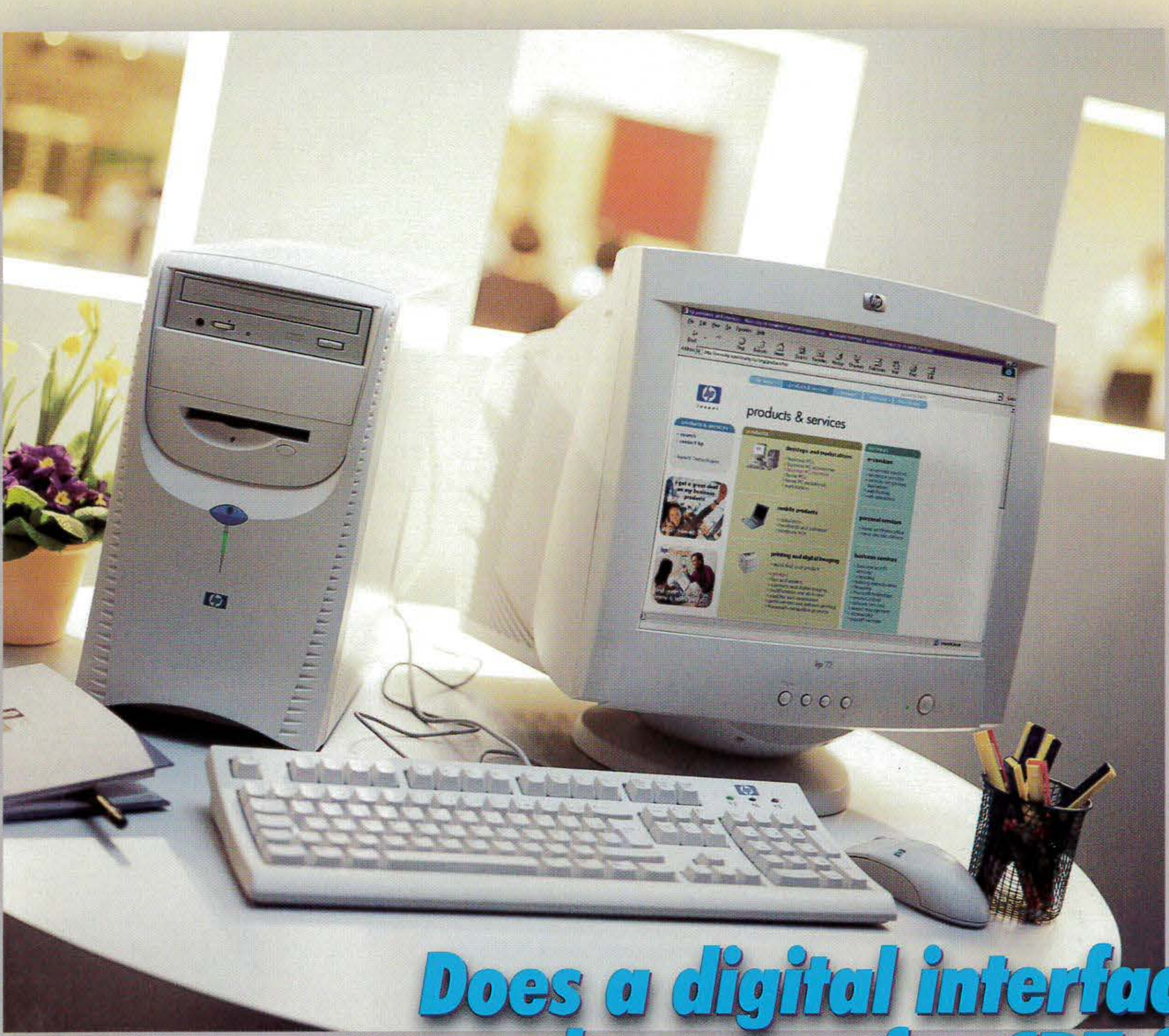

Does a digital interface make sense for CRTs?

- **Digital Interfaces for CRTs**
- **Larger and Lighter TV Tubes**
- **Is There a Future for Flat CRTs?**
- **How Do FEDs Really Fail?**
- **Creating a Mass Market for PDPs**

COVER: There is insufficient reason to go through the costly and painful transition to an all-digital model for CRTs as long as the digital interface remains little more than a duplication of analog systems. But new developments will force the transition to an "all-digital" world. To find out when and how, see Bob Myers' article beginning on page 14.

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

Next Month in *Information Display*

Industry Directory Issue
- Directory of the Display Industry
- Manufacturing Avionics AMLCDs
- AMLCD Fundamentals
- Digital Television
- CeBIT Report

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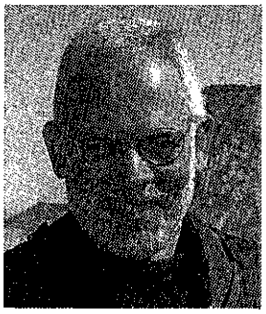
editorial



Kahn International

Putting an LCD and CRT Side by Side

Some time ago, the folks at Compaq sent us an evaluation unit of the company's TFT8020 LCD monitor. Introduced in February 2000, this 18-in. SXGA (1280 × 1024) monitor is still part of the company's LCD-monitor line-up, and currently has an MSRP of $1995. Compaq targeted the 8020 at the desks of financial traders, executives, and receptionists in offices where image counts. We plugged it into the analog-video output jack of one of our editorial-office computers and used it as a workhorse for an extended period. The only fault we noted during this period was a single stuck pixel, which now seems to have repaired itself.

The 8020 accepts both analog and digital inputs, and one of the things we wanted to evaluate was whether there was a significant practical difference between the two interfaces. This was not to be, though. When we installed the Matrix Millennium G400 Dual Head card and DVI daughter card supplied by Compaq, the 8020 did not detect any digital signal. We tried the obvious things, gave up, and ran the 8020 from one of the G400's two analog outputs. We placed it next to our prime display – a standard of comparison – a Sony GDM-F500 21-in. FD Trinitron™ flat-screen CRT monitor. We ran the two monitors "cloned" – that is, with each displaying the same full Windows™ desktop. To do that, we had to reduce the Sony's screen resolution to 1280 × 1024.

For our evaluation, we used a pre-release copy of DisplayMate® for Windows Multimedia with Motion Edition Version 2.0 (courtesy of DisplayMate Technologies of Amherst, New Hampshire; telephone 800/932-6323, e-mail: www.displaymate.com) and the 2000 edition of the SID Display Technology Showcase CD-ROM (Society for Information Display, San Jose, California; telephone 408/977-1013, e-mail: www.sid.org). All conclusions are comparative. We did not take any photometric or colorimetric measurements (with one exception).

First, some details. The 21-in. CRT has an active display area that measured 19¾ in. on the diagonal. The 18-in. LCD's active area measured 18⅛ in. on the diagonal. (Both numbers are consistent with the manufacturers' claims.) The LCD has a specified pixel pitch of 0.28 mm; the CRT has a specified aperture-grille pitch of 0.22 mm. When the Sony monitor was introduced in June 1998 as a professional monitor, it carried an MSRP of $1899.99. The GDM-F500 does not appear in Sony's current line-up, but Sony does sell the consumer-grade 21-in. flat-screen CPD-G500 with a 0.24-mm aperture-grille pitch at an MSRP of $799.99.

Sony did not list luminance or contrast in the GDM-F500's specifications. Compaq claims an average luminance of 200 cd/m^2 and a typical contrast ratio of 300:1 for the TFT8020. And the TFT is much brighter than the CRT. To make the two monitors look similarly bright (and produce the same reading on an old photographic light meter), we adjusted the CRT to 100% luminance and the LCD to 21% of its luminance as indicated by the on-screen-display (OSD) brightness control. And to roughly match the appearance of gray Windows™ slider bars, we set the CRT's contrast setting to 100% and the LCD's to 83%.

In looking at various dot and dither patterns, including DisplayMate pixel-clock patterns, it became necessary to adjust the LCD's pixel clock and clock

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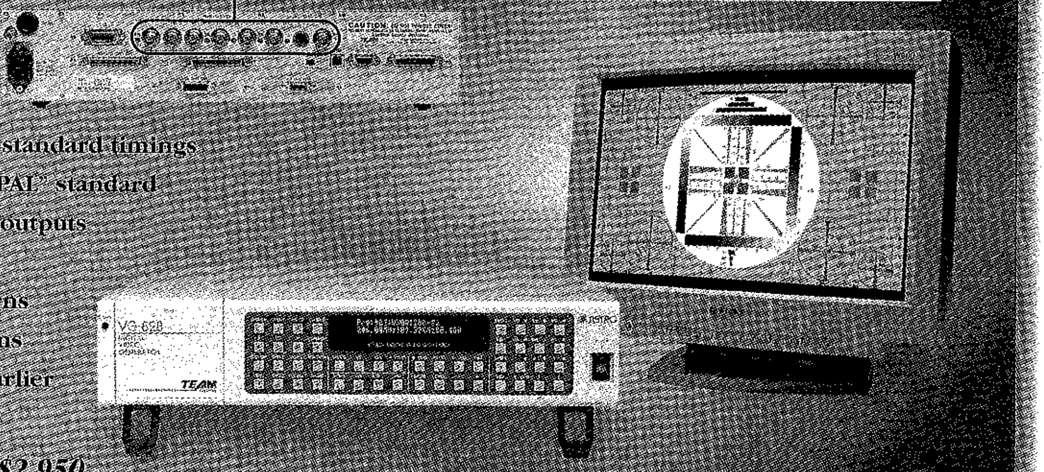

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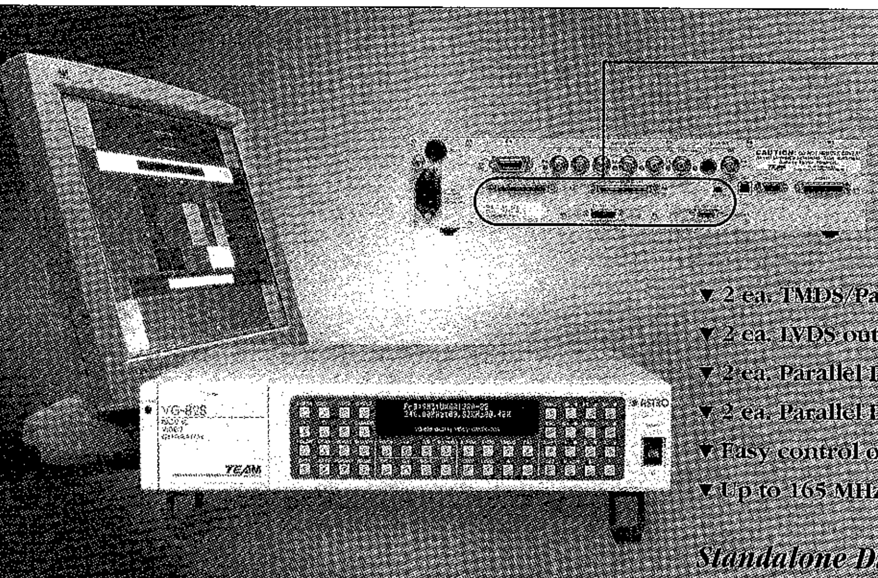

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a view from the hilltop

The Four-Minute Mile . . .

by Aris Silzars

Some years ago, after completing graduate school and settling into my professional career, I decided that I should add some physical activity to my otherwise sedentary lifestyle. The specific motivation was a week-long camping trip to the Yosemite Valley and the realization that my hiking and climbing abilities were not nearly what I wanted them to be. Thus, I selected an exercise program that was intended to build my aerobic capabilities by gradually increasing the distance walked/jogged while reducing the time required to cover that distance – more commonly known as "getting in shape." The stated goal was to be able to run a distance of one-and-a-half miles in under twelve minutes after three months of training.

During the first week, I walked a mile each day in about twenty minutes. The second week, the times dropped to about sixteen minutes. The third week, I tried adding some jogging and the times dropped to about twelve minutes. The following week, I increased the distance to one-and-a-half miles and kept the pace about the same. Without too much pushing, I was able to achieve my interim eighteen-minute target. This was beginning to look like a really easy project. In no time at all, I should be meeting the twelve-minute objective.

Getting from eighteen to fifteen minutes took a few more weeks and a little more effort, but I still felt that I was pretty much on track. *But, after that, it got a lot harder.* Over the next several months, my enthusiasm wavered, and, with a few business trips to break the intended routine, my diligence evaporated. Suddenly, there were all kinds of good excuses for why I couldn't find time to do the daily runs.

It was not until more than a year later that I once again decided to try this activity on a sustained basis. However, this time I knew that whatever goals I set, the results would not come easily. Fortunately, for this second effort, I also had the additional motivation of participating in a youth soccer league as a coach and referee. Over the next few years, not only did I gain the ability to run the mile-and-a-half in twelve minutes, but I was able to increase my conditioning to consistently run five miles at a pace of less than seven minutes per mile.

Is there a four-minute mile in my future? I think you and I both know the answer to that. However, what has been an unexpected result is that even now, after many years, I continue to be able to run eight to ten miles at a decent pace on a near-regular basis.

If we were to graph my rate of improvement, from the first efforts of walking a mile in twenty minutes to my eventual capabilities, there would be a clear asymptote to this graph. In addition, there would be gaps of no progress and even steps backward.

It seems to me that new technology developments and getting new products to market follow quite the same behavior. The early stages of concept demonstration are much easier than the subsequent challenges of creating cost-effective and profitable products that meet the unforgiving competitive demands of an international marketplace.

Perhaps, the recently much-maligned dot.com businesses are an illustrative example of this. Following their model (and exaggerating only slightly), we

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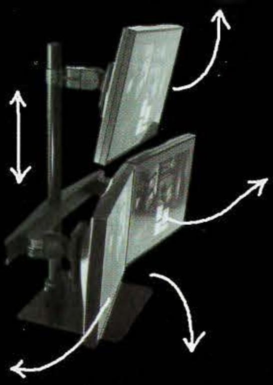

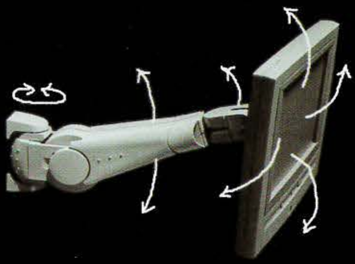

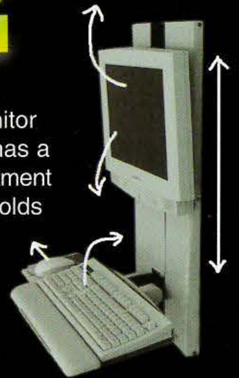

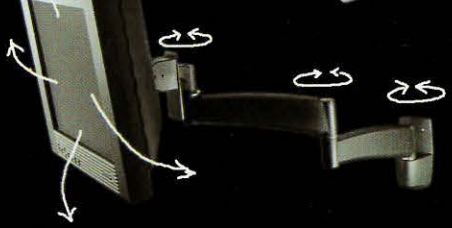

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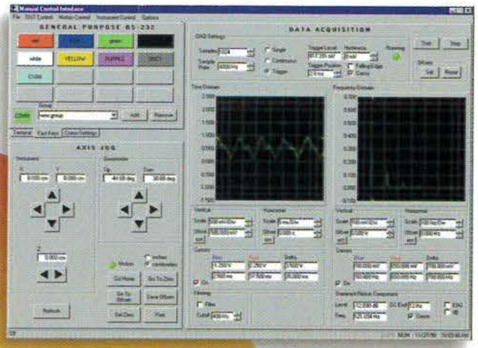

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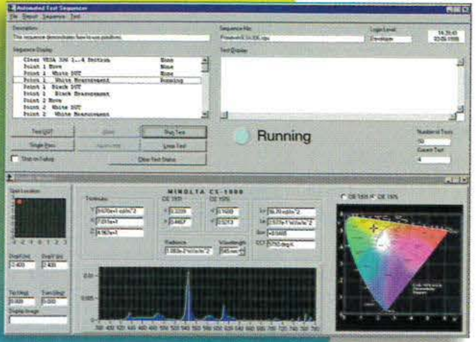

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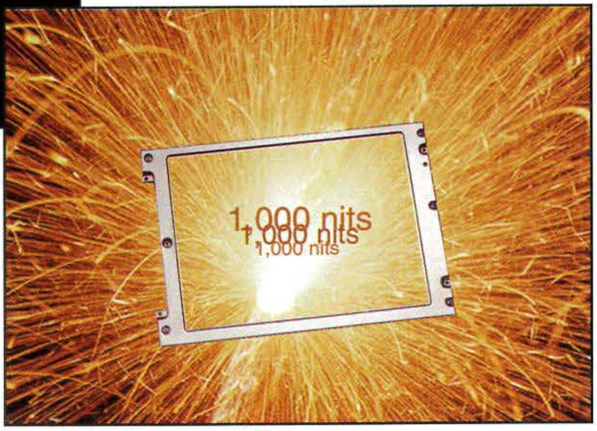

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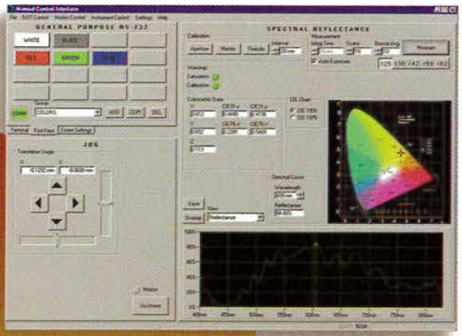
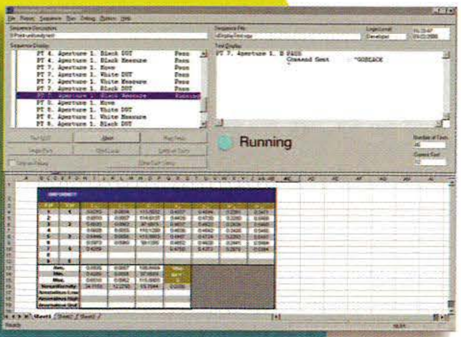


Manual Control Interface (MCI) mode



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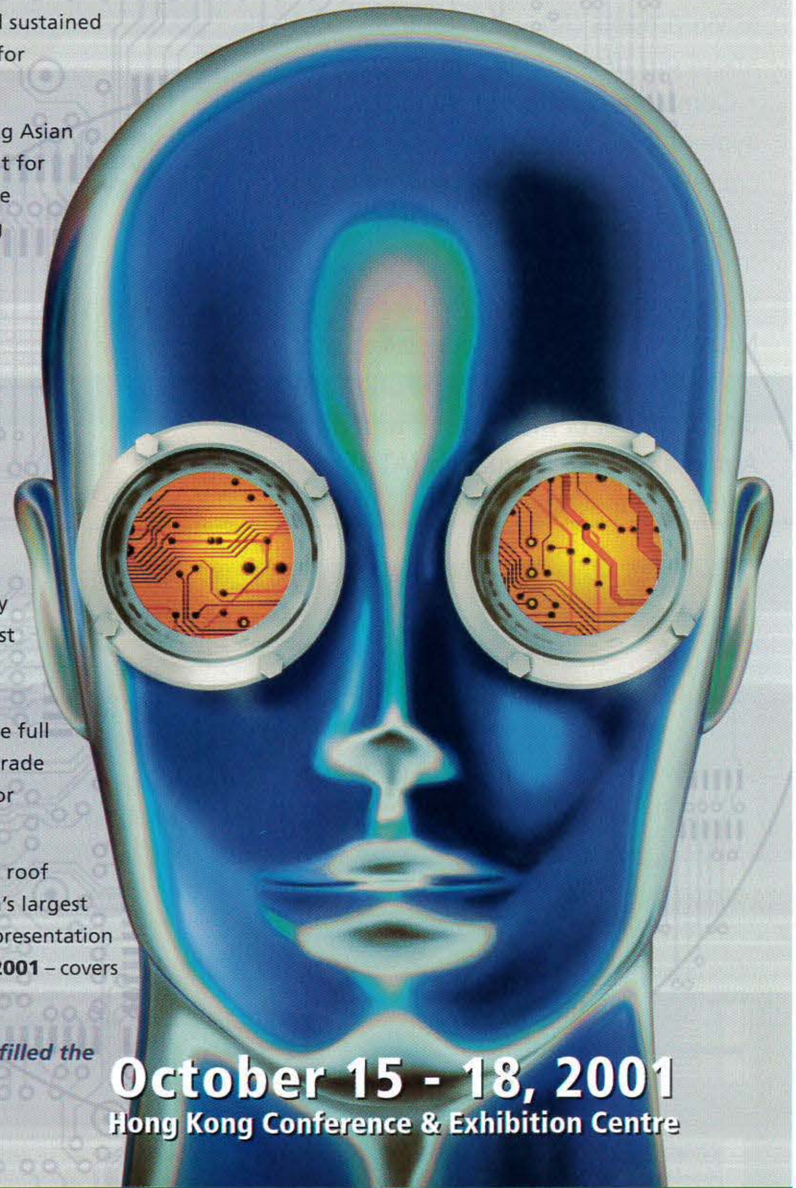

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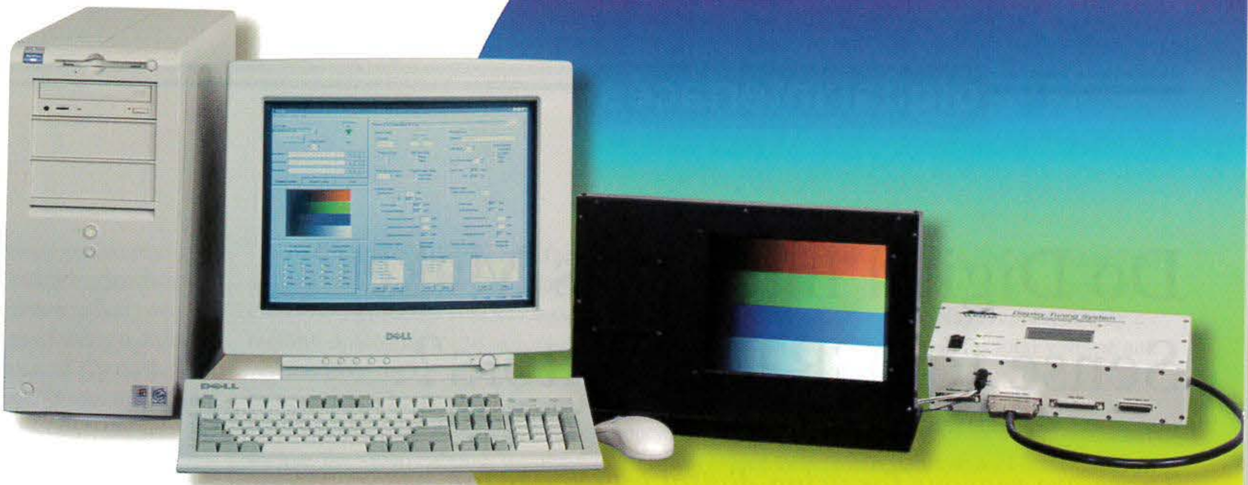

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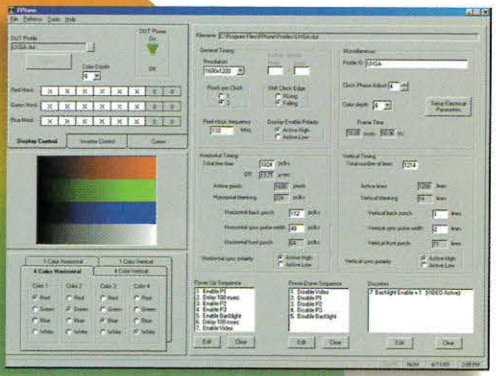

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Do Digital Interfaces Make Sense for CRT Monitors?

There are reasons for using digital interfaces for some displays, but the cost/benefits do not make sense for most CRT monitors – at least not yet.

by Bob Myers

THE adoption of digital display-interface standards by the computer industry has stimulated a great deal of discussion regarding the use of digital interfaces in CRT monitors. The idea of a "digital CRT" is being aggressively promoted by several manufacturers, and a number of examples have appeared on the market, although generally in the form of a monitor that accepts digital input *in addition* to analog signals. But it is still appropriate to ask if this change provides significant advantages and how likely it is that the use of digital interfaces in CRTs will increase in the future. (Interestingly, the answer to the second of these questions is almost independent of the answer to the first.) We can be even more blunt: Why should we expect "digital CRTs" to become the norm?

Many supposed advantages have been cited for digital interfaces, but these must be weighed against the expected costs of the transition from analog to digital. These costs come not only from providing the interfaces in new hardware, but from modifying or scrapping the huge installed base of analog-input displays (Fig. 1). This presents a much larger problem than we would have if discussing merely a change in the PC itself;

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This article was adapted from the author's invited paper, "Digital Interfaces and the CRT Display," presented on November 29, 2000, at IDW 2000 in Kobe, Japan.

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***Fig. 1:** Most PC systems with CRT displays still use analog video connections. Are the benefits of digital interfaces worth the cost in the case of CRT monitors?*

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display devices tend to have significantly longer useful lives than computing hardware.

So the questions come down to just two: (1) what are the advantages of using a digital interface for a CRT display and (2) do these advantages warrant the cost? From the standpoint of the systems manufacturer, the second question is especially important. In these days of ever-increasing cost pressures, we cannot add any cost – or replace an established standard with a new one – without a very clear benefit to the majority of customers. Added-cost features that do not benefit the majority always wind up relegated to the status of extra-cost options.

Digital *Must* Be Good, Right?

There's no denying the marketing advantages of using the word "digital" in a product description. The buying public has been told for many years to equate "digital" with "modern" and "high performance." But if we look at digital display interfaces, we find that the supposed advantages of "going digital" either do not exist, relative to what can be achieved in the analog domain, or have little to do with the fact that the interface in question is "digital."

There is also little argument that the current VGA connector is a poor choice for high-frequency video, but this does not inevitably lead one to the conclusion that its replacement *must* be digital. And there is little argument that digital interfaces provide certain advantages for many non-CRT displays, not because these displays are inherently digital, but because they are fixed-format devices requiring very precise pixel-level timing (Fig. 2). (FPDs are *not* somehow "digital" simply by virtue of being fixed-format displays. The LCD, for example, is fundamentally an *analog* device at the pixel level!) But what, specifically, are the advantages being claimed for digital interfaces in the case of CRT-based displays?

The Cost of Digital

Proponents – and there are many of them – claim that adopting a digital CRT interface, as a replacement for an analog connection, will result in a net cost savings. This claim requires consideration on two levels: (1) simple replacement of the existing analog interface with a digital version and (2) replacement coupled with modifications in the display system's behavior.

The first case, a digital interface functionally identical to the current analog standard, offers no significant cost advantage. A CRT requires analog drive, so at some point conversion from digital data to analog will always be necessary. In the second case, when considering the cost impact on other components, such as the video cabling, we again do not see much of a clear cost advantage for digital. (The opposite is more often the case, as in trying to connect "digitally" over more than a few meters.)

It has also been claimed that digital interfaces become more cost effective as video frequencies increase, owing to the increased costs of items such as analog cabling and connectors. Although this is true, it ignores the fact that high-end displays represent only a small part of the industry's total volume and that lower-frequency displays must still be accommodated in a cost-effective manner. It may be interesting to speak of a digital-interface system in relation to a 21-in. 135-kHz CRT monitor, but the host system must still be designed to support that monitor *in addition* to the much-higher-volume 15- and 17-in. monitors, for which the analog interface is more than adequate – as well as less costly. Unless this hypothetical high-end monitor supports *both* interface types, the host system


Hewlett-Packard Co.

Fig. 2: *LCD monitors benefit from digital connections because they provide the pixel-clock information required for a fixed-format display. This 18-in. LCD monitor from Hewlett-Packard provides both analog and digital inputs.*

must do so. In either event, the total cost of the system is increased.

A different scenario, however, is most often used to argue for cost benefits: to run the CRT at fixed rates results in reduced complexity thereby reducing the cost of part of the monitor design. But this would also require the addition of digital image scaling, and probably of frame-rate conversion, as is now the case with LCD-based monitors. This is unlikely to produce a net cost reduction for the system, and it is not supportable at all in terms of the cost impact on lower-end display products.

An alternative, in which the entire system always operates in one mode – the "preferred" or native format of the display – is really not relevant to the interface question at all. Fixed-frequency operation might provide certain benefits with *either* interface, and has already been used in many "pure-analog" applications. But this is not a model that can be quickly adopted by the industry.

PC applications have developed under the assumption that the display device would be capable of quickly adapting to a wide range of display formats and timings. Abandoning this model would require a major change in system behavior, so it will not come easily. In fact, it will not come at all unless significant benefits accrue from such a change and those benefits are made clear.

But What about Performance?

If there is no clear cost advantage to digital-interface CRTs, can we at least justify such a move on the basis of improving overall performance and quality? Proponents of the digital CRT claim that such benefits *do* justify this change, pointing to successes in non-CRT displays as an example.

We should note again, however, that the benefit of the digital-interface model for LCDs and PDPs has little to do with the information being in digital form. The fact that these displays are fixed-format devices makes it difficult for them to use analog video without a precise sampling clock. Because this was not needed by the CRT, it was never provided in analog-interface standards. The image stability seen in LCD monitors when using a digital interface comes from the provision of a stable pixel clock, *not* from the information's being in digital form!

Again, the current *de facto* analog standard – the VGA connector – has clear limitations in terms of signal quality. But this does not mean that the only alternative is a digital solution. In fact, the current digital-interface standard connectors – the DVI interface, as well as its predecessor, the VESA Plug & Display connector standard – have their roots in a connector design originally intended to provide greatly improved analog performance! Both the DVI and P&D standards wisely retain the analog signal support of the earlier VESA Enhanced Video Connector (EVC), and the cost of adding improved analog support to the new digital interface is trivial.

In any discussion of the relative performance of these interfaces, we should be comparing the digital interface to what is possible with improved analog connections, not to the poor performance of the past. If this is done, any remaining performance advantages of the digital interface – as far as CRT displays are concerned – essentially disappear. (And a dual-output interface, using either the DVI-I or P&D–A/D connectors, is far more likely to be adopted in the near future by systems manufacturers than is a digital-only scheme.)

One last argument that is made to support the "performance/quality" position is that the use of a digital interface for CRTs would place the responsibility for CRT image quality solely in the hands of the CRT-monitor manufacturers. That might be a desirable goal, but the majority of CRT image-quality factors – such as image geometry, CRT focus, convergence, and beam landing – are *already* under the sole control of the monitor maker. None of these will be affected by changing the video signal to digital form; and those factors to which the interface *does* contribute, such as image "ghosting" and similar problems, will be addressed more than adequately simply by taking advantage of the new analog standards.

What about New Features?

One final argument for using digital interfaces is that they are essential for incorporating new or enhanced features in the display. In contrast to the cost and performance factors considered so far, this line of argument will, I think, ultimately provide the impetus to move CRT displays to a digital interface – but for different reasons from those considered so far.

One "new feature" that the digital interface enables is "copy protection," the prevention of copyrighted material from being duplicated by devices "downstream" of the host. An example of this is the High-Bandwidth Digital Content Protection (HDCP) scheme developed by Intel Corp., which is allowed under the DVI standard. Although the protection of copyrighted material is certainly a serious concern, it is a significantly greater concern when signal transmission is digital than when traditional analog interfaces of computer displays are being used. It was, in fact, the introduction of digital interfaces that raised such concerns to their current level in the first place.

Images in the digital domain are subject to "perfect" duplication, which is basically impossible in a completely analog system. But, more importantly, there is no widely available means of recording high-resolution analog RGB signals, at least not without down-conversion into some other format, such as TV video, at which point current copy-protection methods could be applied anyway! Content protection, although a valid concern in general, is simply not a significant reason for moving away from the PC's analog interface.

However, there *is* now a possible future development that could result in the adoption of digital interfaces for all display types. This has been best embodied in a proposal made at the 2000 SID International Symposium (J. Mamiya *et al.*, "Digital PV-Link for a Next-Generation Video Interface and Its System Architecture," *SID Intl. Symp. Digest Tech. Papers*, 38–42, 2000). "Digital PV-Link" – as presented by IBM Japan, Sharp, Hitachi, and Toshiba – is based on the notion that images should not be transmitted as has been done in the past, *i.e.*, they should not be transmitted as repeated updates of the entire screen, directed only to one display. Instead, a system such as PV-Link treats displays more as networked devices, permitting the conditional update of particular areas within the display space and permitting multiple physical displays to be driven by a single output.

The advantages to such a system are readily apparent. Eliminating the need for regular, full-screen-refresh drive will permit much more efficient use of the interface data capacity, while making multiple display systems (independent displays sharing a single driver, or tiled displays) very easy to set up. But a very large standardization effort will be required prior to widespread adoption of this model.

Adopting the PV-Link system, or something like it, requires some very fundamental changes to the overall display-system architecture and raises a number of additional issues – such as ensuring consistent color appearance – that can only be addressed through new industry standards. Fortunately, the Video Electronics Standards Association (VESA) has recently begun such an effort, working closely with the original DPVL developers.

Will Digital Interfaces Make Sense for CRTs?

Although digital interfaces certainly have a place in today's PC systems, we should not yet expect them to displace traditional analog video – or an upgraded version of that interface – in CRT-based displays. As long as the digital interface remains little more than a duplication of the earlier analog systems, there is simply insufficient reason to go through the costly and painful transition to an all-digital model for all displays. But new developments, which provide significant advantages through a much more complete overhaul of the display system architecture, will finally result in the transition to an all-digital world – a transition for which we need to start planning today.

Notes

[1] Specifications for Video Electronics Standards Association (VESA) standards are available at www.vesa.org. The Digital Visual Interface (DVI) specification is available from the Digital Display Working Group (DDWG) at www.ddwg.org.

[2] For an extended overview of digital interfaces, see the author's "Digital Interfaces for Displays," *SID 2000 Seminar Lecture Notes*, Vol. II (Society for Information Display, 2000). ■

Making Larger, Lighter, Safer TV Tubes

Mastering the secrets of strong glass is the key to making TV tubes that are both lighter and safe – but implementation requires a CRT company with a high degree of vertical integration.

by Mohammed Khalil

INVENTED over 100 years ago, the CRT has been remarkably successful in keeping pace with consumer demand for larger, flatter TV displays. Even for high-end mass-produced TV sets, the CRT still remains the most cost-effective display solution. However, during its metamorphosis from a relatively deep structure made up of spherical and conical surfaces to the much flatter and slimmer structures of today, much of the tube's inherent strength has been lost.

To pass the requisite static and dynamic safety tests, today's tubes typically rely on thicker glass structures that significantly increase the tube's weight and cost. One company – Philips Display Components – is leveraging its vertically integrated structure to master a well-known but difficult-to-implement technology referred to as high-surface-compression glass. The company's goal is to pioneer the production of high-safety completely flat TV tubes that do not suffer the penalty of excessive glass weight.

Static and Dynamic Safety

There are several different aspects of CRT design that relate to safety. First, the tube must be inherently strong enough to withstand the static vacuum pressure that is applied to it during manufacture. Second, tubes must be made safe enough for handling when they are assembled into TV sets and for normal use, and, most importantly, they must be designed to break safely if the tube ever shatters. This can be tested by means of the "missile test," which is a standard requirement in the U.S.A.

TV tubes can pass the missile test if they have been modified by the application of a polyethylene terephthalate (PET) plastic foil to the surface of the screen. This holds the glass fragments together when the screen fractures in much the same way that a modern automobile windscreen remains in place when it shatters. At the same time, this plastic film can provide the screen with anti-static and anti-reflective properties, enhance picture contrast, or give the screen a tinted appearance.

These foils, however, which are normally applied only to the face of the screen, do not

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Making High-Surface-Compression Glass

The surface layers of high-surface-compression glass are held in compression by a central core of glass that is under tension. The tensile stress in the glass core maintains the surface of the glass under compression when the glass bends in the same way that the tensioned steel rods within a prestressed concrete beam maintain the surface of the concrete beam under compression despite the imposition of a bending moment.

Thermally inducing the necessary compressive and tensile stresses in the glass depends on creating the right temperature gradients between the bulk and the surface of the glass during the cooling phase of the panel-manufacturing process. One of the factors that produces these stresses is the different coefficient of expansion of glass in the liquid and solid states, the coefficient of liquid glass being three times that of solid glass.

If a sheet of glass is heated to the point at which it becomes viscous – as happens at the beginning of the glass-pressing process – all stresses within the glass are relieved. As the surface layer of the glass subsequently cools, it solidifies, at which point it begins to contract at a much slower rate than the still-molten core. Because the core is now contracting three times faster than the solidified surface layer, it induces compressive stress in the surface layers and itself goes into tension. The gradual decrease in the temperature difference between the bulk and the surface of the glass builds up the stress gradient between the bulk and the surface. As the entire section slowly solidifies, these compressive and tensile stresses become frozen into the glass.

The distribution and extent of the high surface compression therefore depends on the thermal gradients within the glass and the cooling rate, both of which can be controlled by correct design of the pressing tools that form the screen and the cone of the TV tube.

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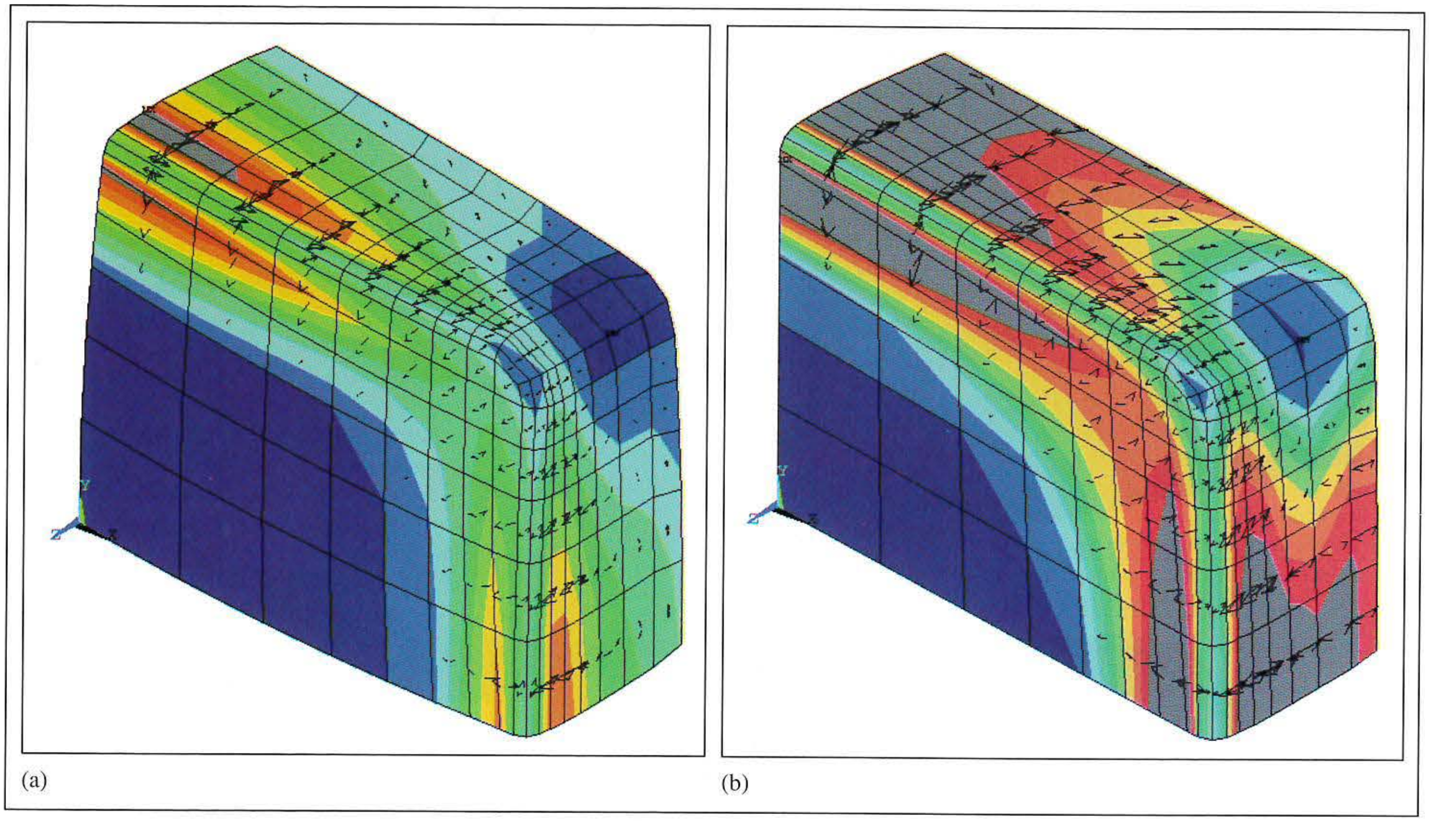

Fig. 1: As tubes get flatter and slimmer, the mechanical stresses at various points in the glass structure increase. The stresses induced by the internal vacuum on a flat slim tube (b) can be more than three times higher at the seal edge and 1.5 higher on the face than those on a conventional tube (a).

provide the static (vacuum pressure) or dynamic (ball-drop test) protection required to prevent the tube from imploding in the first place. As tubes get flatter and slimmer, the mechanical stresses at various points in the glass structure increase [Figs. 1(a) and 1(b)]. The temptation is to compensate for these higher stresses by simply making the glass thicker, but adopting such an approach has a number of severe disadvantages.

In addition to increasing the final weight of the tube, it significantly increases the cost of production, both in terms of the raw materials used and the electrical, mechanical, and thermal energy consumed in the manufacturing process. Thicker glass not only means heavier tubes, it also means more expensive tubes.

Stronger Glass

The right, convenient answer is not to increase the glass thickness, but to increase the strength of the glass itself. This is normally achieved by tempering the glass panels during the manufacturing process. Of the two commonly used methods for strengthening glass – chemical and thermal tempering – only thermal tempering is practical for TV-tube manufacturing. Chemical tempering, which involves immersion of the glass components in an acid bath for several hours, is difficult to integrate into the panel-manufacturing process, and also tempers the glass to a depth of only a few microns. As a result, the tempered layer may easily be removed by subsequent tube polishing.

On the other hand, thermal tempering, which involves carefully controlled heating and cooling of the glass, fits neatly into the panel-manufacturing process. Such heating and cooling operations are already an integral part of the existing manufacturing process for panels, and no additional process steps or components are required. Thermally tempered glass, usually referred to as high-surface-compression glass, also has the advantage that the tempering can be made to penetrate as much as 20% of the glass thickness from both sides of the panel, thus making the strengthened layers highly durable.

But mastering the thermal-tempering process is by no means easy. For a given tube design, one must first determine where the stresses in the glass will occur and then where and to what extent the glass must be tempered to provide the necessary amount of strengthening. Too little tempering will not be enough to pass the necessary static and dynamic safety tests. Too much tempering will result in a tube that has so much energy stored in internal stresses that it exceeds the allowable energy release when it cracks during dynamic safety tests.

Introducing the correct level of high surface compression in the right places depends on creating the proper temperature profiles in the glass at the right times during the panel pressing and forming process. In physical terms, this primarily affects the way the pressing tool allows the glass to cool. Equally important, it must be possible for the measurement data

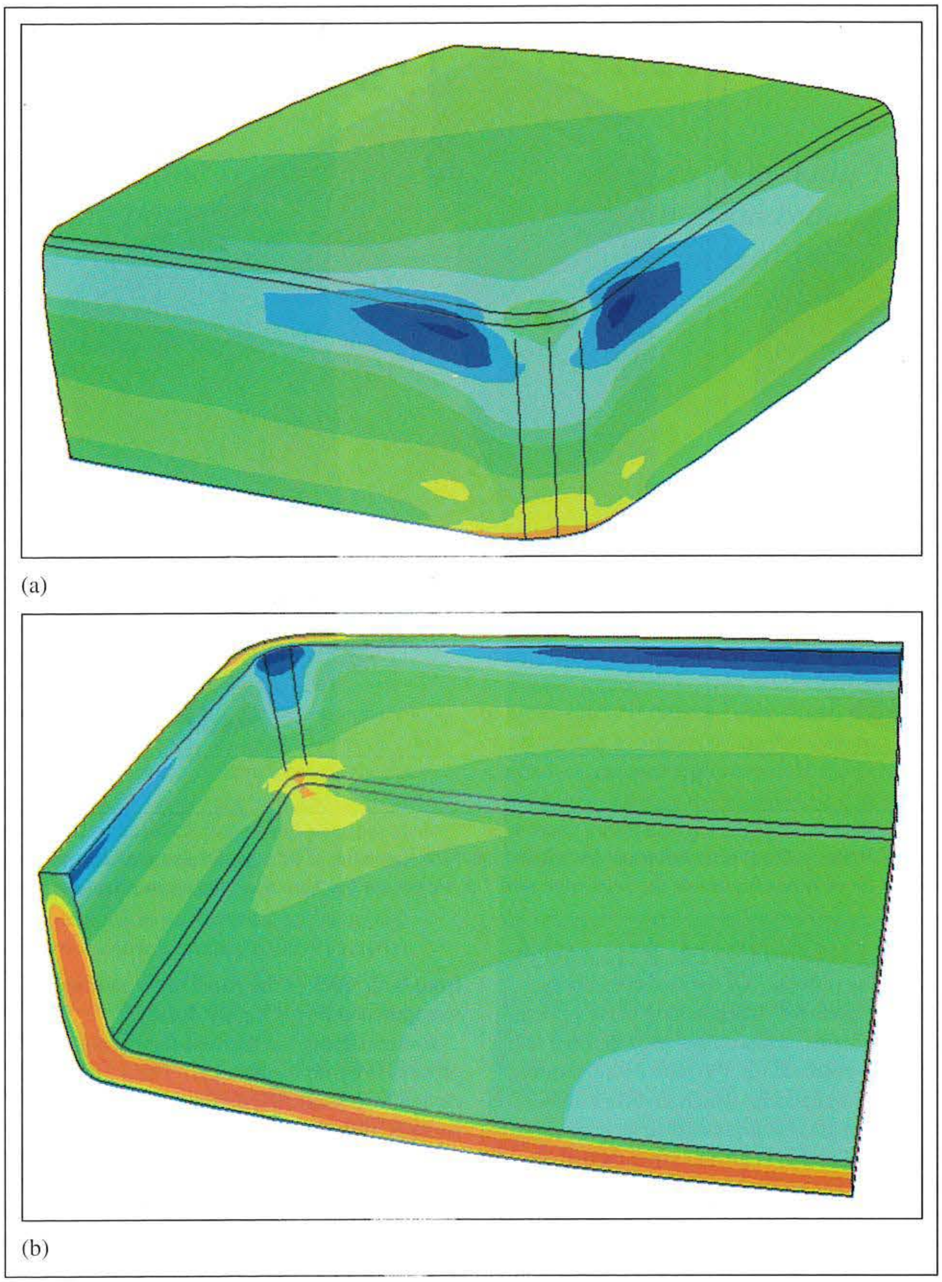

Fig. 2: Computer modeling of the visco-elastic behavior of glass is necessary to effectively design envelopes of high-surface-compression glass. Visco-elastic calculations can, for example, reveal the strength distribution on the (a) outside and (b) inside surfaces of a screen panel.

acquired during later stages of the tube-manufacturing process – such as stress measurements, safety-test results, and failure rates – to be fed back into the glass-pressing process.

Process Control

In the conventional TV-tube manufacturing model, it is very difficult to provide the feedback loops necessary for the required tight control of the tempering process because the glass components are made by one company, assembled by another, and built into TV sets by yet another. As a result, successful implementation of high surface compression to optimize TV-tube strength-to-weight ratios has been rare.

However, the unique level of vertical integration within Philips Display Components – which gives the company access to in-house glass-processing factories at one end of the manufacturing chain and a TV-set manufacturer at the other – has enabled the company to put in place the feedback mechanisms needed to accurately control the tempering process.

Fusing the screen and the cone together during the frit-sealing process, for example, involves reheating the rim of the screen and cone to a high temperature. This reheating relieves some of the surface compression induced into these components during the initial glass pressing, which means that the level of surface compression induced during the panel-manufacturing process must be modified to compensate for these losses incurred during frit-sealing.

By mastering the whole process in-house, Philips Display Components can provide the right feedback to its external glass suppliers as well.

Modeling and Measurement

Also necessary for mastering the high-surface-compression technique is expertise in computer modeling of the visco-elastic behavior of glass as it is heated and cooled. Without this advanced computer-modeling capability, which matches the glass thickness with the correct distribution and degree of surface compression, it would be impossible to produce a tube with the optimum strength-to-weight ratio and safety margin. Visco-elastic calculations can, for example, reveal the strength distribution on the outside and inside surfaces of a screen panel at the corner, the weakest part of the panel [Figs. 2(a) and 2(b)].

The ability to accurately measure surface-compression levels is also important in providing the correct feedback to the production process. Although this testing is currently done by sectioning production samples and measuring the stress levels in the glass using a polarimeter (Fig. 3), we are currently working on a non-destructive method of measuring stress.

High surface compression is used in all of Philips Display Components' "real-flat" Cybertube models as well as in several other TV tubes the company produces. The technology makes Cybertubes lighter than equivalent competing tubes.

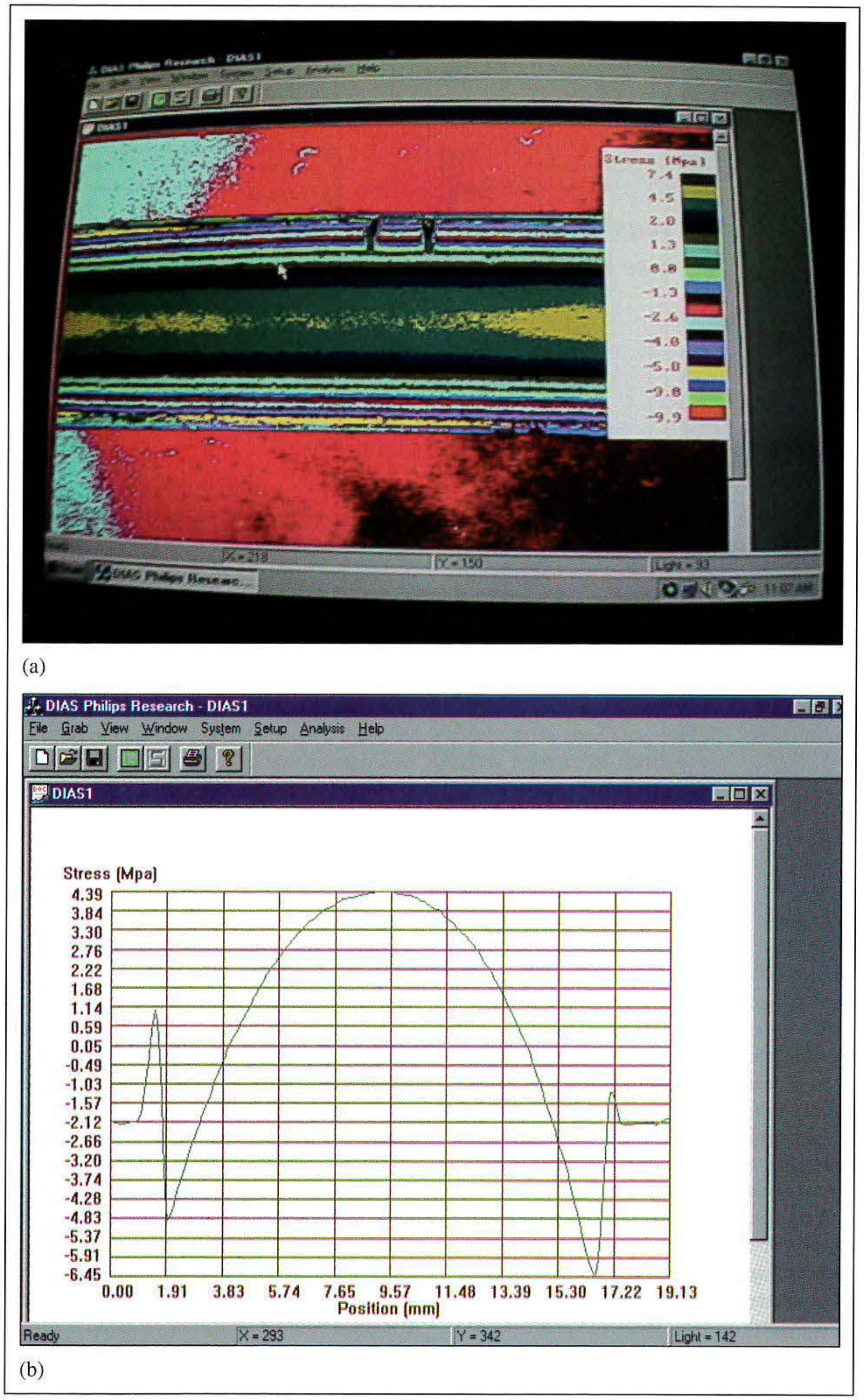

Fig. 3: *(a) Surface-compression levels are currently measured by sectioning production samples and measuring the stress in the glass using a polarimeter. (b) The results have been plotted to provide a high-surface-compression profile through a typical glass section.*

Even with high surface compression, Cybertubes still require the glass wedge (the difference between the thickness of the glass at the center of the screen and the thickness at the edge) in the screen to allow standard shadow-mask technology to be employed while maintaining required tube performance. The wedge naturally produces brightness variations across the screen, so large-format Cybertubes currently use screens made out of high-transmission glass coupled with a transmission foil to improve contrast ratios and daylight viewing.

We are now refining the design rules and high-surface-compression techniques to make a large-format screen that is thin enough to increase our flexibility in choosing glass transmission. These modifications will enable the production of tubes that are even lower in weight than the current models while being highly manufacturable at low cost. ■

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Is There a Future for Flat-Panel Cathode-Ray Tubes?

The history of flat thin CRTs reveals common reasons for their commercial failures – failures that FED technologies promise to transcend.

by Peter Seats and Bruce Gnade

EVER SINCE the rise of television after World War II, display engineers have been trying to reduce the length of cathode-ray tubes (CRTs). After reducing neck lengths and increasing deflection angles to a practical maximum of about 110°, research focused on a wide variety of flat-sandwich configurations. The flat-sandwich approaches generally fall into three categories: (1) a single beam requiring full deflection in both x and y axes, (2) hybrid designs incorporating multiple beams in one axis combined with a method for deflection in the second axis, and (3) a fixed x-y matrix not requiring beam deflection.

Early approaches in the 1950s by D. Gabor[1] and W. R. Aiken[2] employed a single e-gun sealed in the side or corner of a flat glass sandwich that incorporated electrostatic deflection plates and/or charge patterns on the glass walls to deflect the beam into the screen after two or more 90° bends. This approach involved high electrostatic switching voltages and caused serious beam-distortion and display-linearity problems. Nevertheless, development continued for more than 15 years, with demonstration models – particularly the Aiken tube – being publicly exhibited.

A simple version of the Aiken–Gabor approach, in which the beam was deflected at a low glancing angle onto a tilted screen, proved to be an effective design for small CRTs. Sanyo, Sinclair, and Sony all produced such tubes, including beam-index color versions, in the 5-in. range. Sony's monochrome version remains in production, with more than 10 million produced to date (Fig. 1).

Designers have investigated many hybrid designs for flat CRTs, with the goals of reducing deflection requirements and providing scalability to large sizes. These designs have incorporated a fixed array of line cathodes or beams parallel to the screen, coupled with deflection electrodes that direct the beams into the phosphor screen over short path lengths. Most of these hybrid designs use a secondary deflection technique to spread each beam over a number of screen elements and generate a sub-raster, thus reducing the number of primary beams or line cathodes required.

A number of substantial development programs were conducted over many years by corporations such as RCA ("Guided Beam"),[3] Matsushita ("Flat Vision"),[4] and Philips to bring hybrid designs into commercial use. The Philips programs incorporated ingenious gain techniques using secondary emission to increase beam current, which is important in designs operating at low anode voltages (J. R. Mansell *et al.*[5] and G. G. P. van Gorkom *et al.*[6]). Other examples of hybrid designs include the back-modulation design of A. Takahashi *et al.*[7] and the flat CRT of E. Miyazaki *et al.*[8]

Of the many hybrid flat-panel-CRT programs conducted, only one reached the commercial stage. Matsushita announced in 1993 that their 14-in. "Flat Vision" display device would go on sale in Japan, selling for about $2800 (Fig. 2). But Matsushita subsequently withdrew the panel, stating that high cost was a major factor.

In 1973, W. F. Goede described a classic approach to flat-panel-CRT design, the "Digisplay."[9] This was a true xy-matrix design not requiring beam deflection (Fig. 3). It used an area cathode and a series of aperture grids to modulate and direct current flow to the screen. Although simple in concept, the design was pursued for 30 years without commercial success, originally by Northrop Electronics, and then by Texas Instruments, Sylvania, and others. A major difficulty was achieving sufficient current transmission through the small apertures in the first grid structure, and then providing accurate and stable registration in the stack of grid components.

No summary of flat-panel CRTs would be complete without mentioning a small matrix-type CRT known as the vacuum fluorescent display (VFD), which was an early outcome of CRT flat-panel research. Operating mainly at 12 V, with zinc oxide monochrome screens, VFD technology is ubiquitous in domestic and automotive instrumentation applications.

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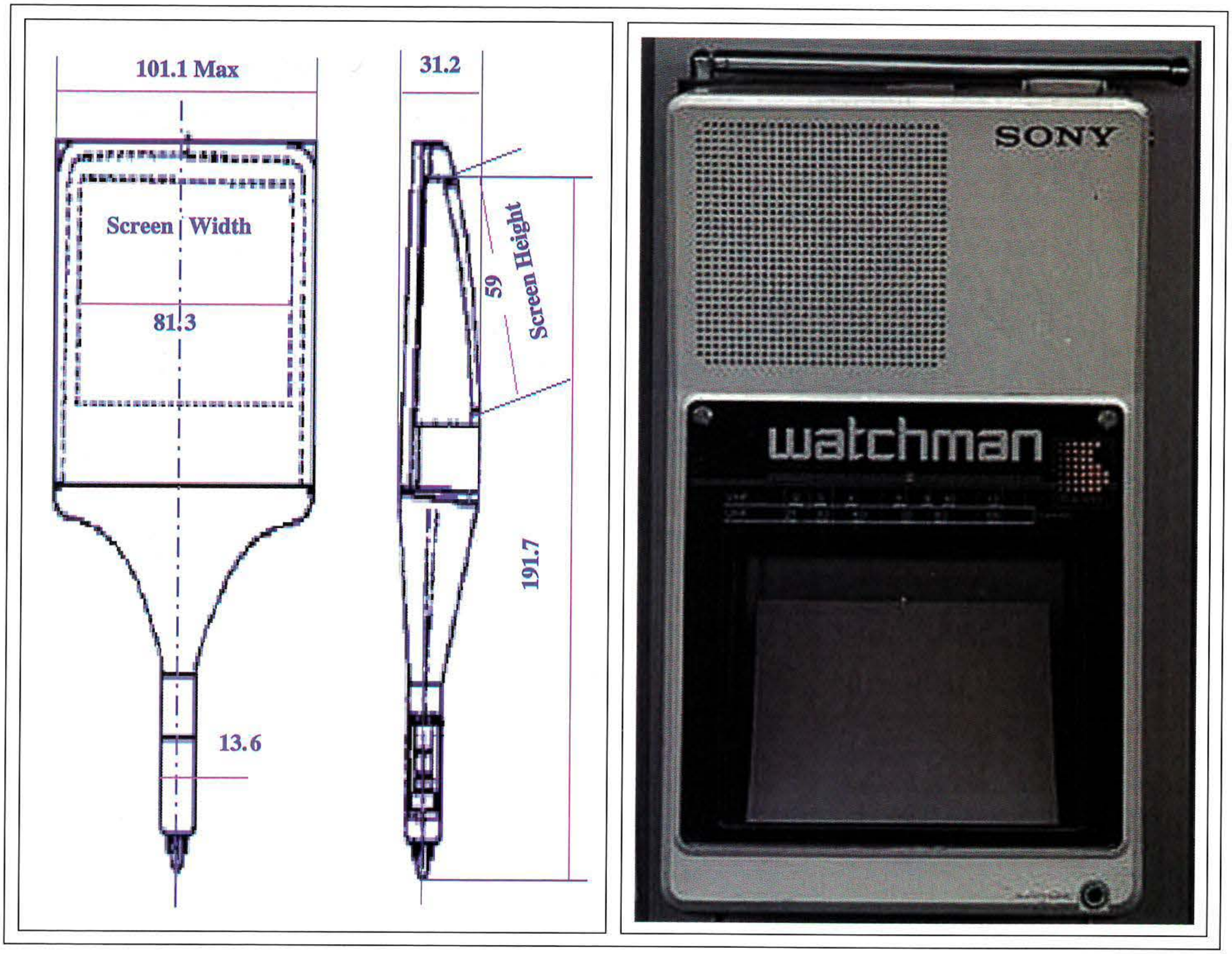


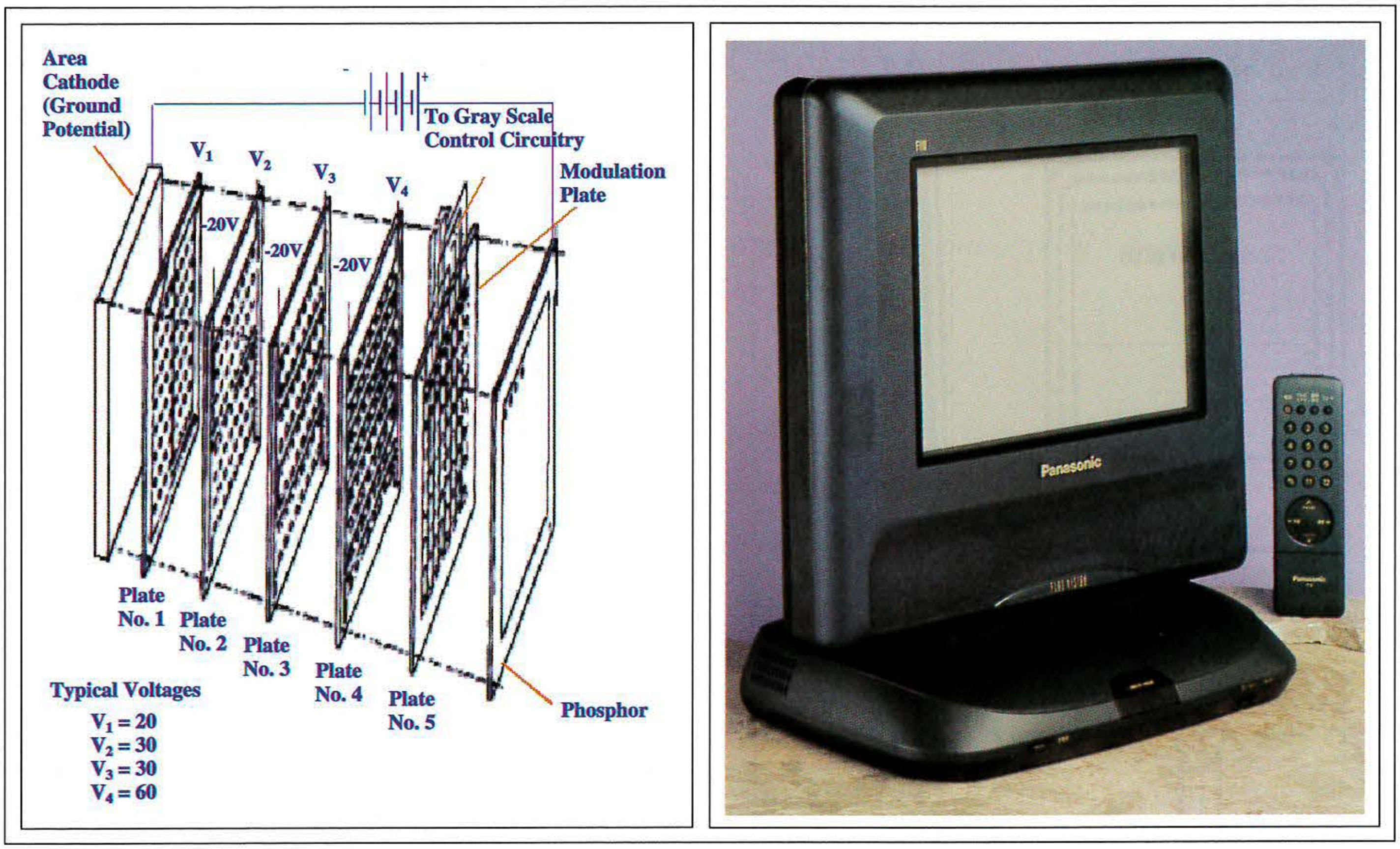
Sony

Fig. 1: *Sony has made 10 million units of its Model 04JM 4-in. monochrome flat display tube (left), which has been used in a variety of portable TV sets, such as Sony's FD-40E (right). The tube remains in production to this day.*

In reviewing the many approaches to building flat-panel CRTs, we found that, clearly, a number of recurring problems are common to all of these designs. The first and most significant problem is scalability. The conventional CRT envelope is constructed from components that are curved and have thick sections in critical areas such as corners and edges. But flat-panel designs beyond a few square inches can not be self-supporting against atmospheric pressure without employing excessively thick glass. The 1-ton/ft.^{2} external pressure makes the use of mechanical spacers necessary. Such spacers, which must not produce visible artifacts in the phosphor screen, present difficult problems for medium-sized and/or high-resolution displays in which phosphor subpixel sizes are less than or approximately equal to 100 μm.

The second problem is producing cathodes that meet the beam-current requirements. When thermionic cathodes are arrayed as multiple sources, problems of uniformity and mechanical stability arise. When small grid apertures are used to form discrete beams – as in the Northrop xy design – mean current density over the area of a typical filament matrix is generally much too low, which requires the use of field-shaping structures or other complexities. Such area arrays also dissipate considerable power – more than 50 W for a medium-sized display.

The third problem is to meet the beam-landing and registration requirements of color CRTs. In conventional CRTs, linearity, convergence, and landing errors are corrected externally in conjunction with the deflection coil. External corrections are generally not feasible in flat-panel-CRT designs. Where local beam spreading or sub-rasters are employed, edge-matching can be a serious problem, and we can expect fila-



Matsushita

Fig. 2: *Only one hybrid flat-panel CRT reached the commercial stage (left). Matsushita announced in 1993 that its 14-in. "Flat Vision" TV (right) would go on sale in Japan, but the panel and the receiver were subsequently withdrawn (see Ref. 4).*

mentary cathodes to produce non-uniform emissions.

Designers can achieve the required registration – to a fraction of a color subpixel's dimensions – only by building very close tolerances into the component parts of the internal assemblies, and this is the case whether the beams emerge normal from a final electrode assembly or pass through a sub-deflection field. Furthermore, the electrode structures, spacers, and connectors must withstand the high temperatures, greater than 400°C, of vacuum-tube processing. The consequent high cost of these internal structures is a major contributor to the failure, thus far, of flat-panel CRTs to achieve commercial success.

Recently, field-emission-display (FED) technology has emerged as a leading contender for a flat-panel CRT. FEDs are based on the cold-cathode emission of electrons. The renewed interest in FEDs was stimulated by several technological advances in field emitters that have taken place over the past several years. These advances include (1) large-area 1-µm lithography, (2) large-area thin-film processing capabilities, (3) high emitter-tip densities, (4) the lateral resistive layer, (5) anode switching, (6) new emitter structures and materials, and (7) low-voltage phosphors.

FEDs offer potential solutions to two of the three chronic problems experienced by flat-panel-CRT designs. Field-emission arrays (FEAs) can provide large-area high-current uniform electron sources addressable as an x-y matrix. Because FEAs can provide high current, the required acceleration voltage can be less than 5 kV. The low acceleration voltage allows for a minimal distance between the cathode and anode, reducing the cathode-to-anode registration requirements. The FED package (Fig. 4) can be much simpler than the traditional flat-panel-CRT package (Figs. 2 and 3).

Research Milestones

Work on vacuum microelectronics as we know it today was started by Kenneth R. Shoulders[10] of Stanford Research Institute (SRI). The most important technical advance leading to the current state of vacuum microelectronics was produced at SRI in 1968 by Charles A. Spindt.[11] The thin-film deposition process developed by Spindt led to self-aligned tip and gate structures using established semiconductor process technology.

The first work on silicon-based field emitters was performed by Henry Gray[12] at the Naval Research Laboratory, Washington, D.C. D. K. Schroeder *et al.*[13] at Westinghouse Research Laboratories were able to create large silicon FEAs using preferential etching and polishing.

One problem with simple Spindt-type cathode structures is device failure resulting from the uncontrolled emission current that occurs when a few active emission sites produce

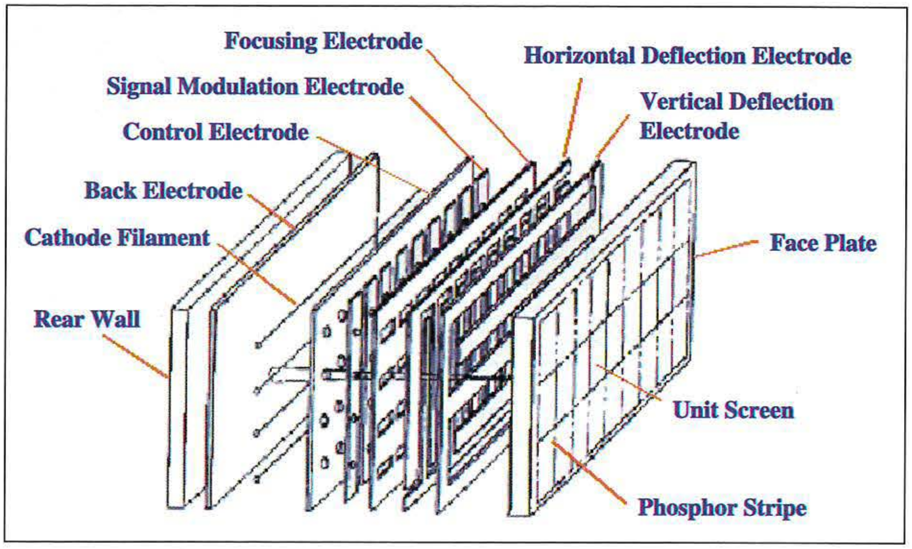


Fig. 3: In 1973, W. F. Goede described the "Digisplay" – a true xy-matrix design which did not require beam deflection. It used an area cathode and a series of aperture grids to modulate and direct current flow to the screen. (Figure similar to that in Ref. 10.)

most of the current. The extremely high current density causes localized heating, which leads to catastrophic failures and gate-to-cathode electrical shorting. A major advance was made by Robert Meyer and his colleagues when they introduced a resistive layer under the emitter cones.[14] The layer acts like a load resistor or a current limiter.

The most recent type of field emitter is the surface-emitting cathode (SEC) introduced by Canon, which employs inelastic scattering of electrons at an electrode edge. The device is based on the creation of nanometer-wide cracks in thin-film materials containing nanocrystalline particles. Canon has demonstrated a 10-in. full-color prototype display based on this technology. The SEC structure can be created with simple printing techniques such as ink-jet deposition and with minimal use of expensive semiconductor process equipment. Engineers are also investigating other FED device configurations, including edge emitters, diode emitter configurations using diamond-like carbon-type materials, and metal-insulator-semiconductor (MIS) and metal-insulator-metal (MIM) tunneling devices.

Although a significant amount of research has been invested in cathode development for FEDs, much less time has been spent on anode and vacuum-packaging development. An important design criterion in FEDs is the choice of anode voltage, which is based on the type of phosphors and the desired display characteristics. Besides affecting the choice of phosphors, the anode voltage also sets the cathode-to-anode spacing – which is typically no less than 0.2 μm/V.

When the distance between the anode and cathode glass plates is small (approximately 200 μm), adequate beam control is achieved without any need for electrostatic focusing. At high voltages (greater than 2000 V), a spacing of 0.5–1.0 mm is required between the cathode and anode plates. In order to achieve fine subpixel pitches of less than 100 μm, electrostatic focusing may be required for cathode–anode spacings greater than 500 μm.

Another important design concern is vacuum packaging. Vacuum quality is crucial for any electron-emission source, especially for field-emission devices. Emission degradation was a very serious problem in CRTs until the introduction of flashable barium getters, which efficiently adsorb residual gases in the vacuum envelope. Field-emission sources are even more sensitive than thermionic emitters to residual gases because the emission probability is sensitive to small work-function changes. FEDs have an added complexity: the small dimensions of the panel provide poor pumping conductance for both initial pump-down and vacuum. For these reasons, most current FEDs use non-evaporable getters or flashable getters – or a combination of the two – to maintain as low a vacuum as possible during operation.

An important difference in the ways CRTs and FEDs generate light is related to effective electron current density. In a CRT, each pixel is addressed sequentially by sweeping the

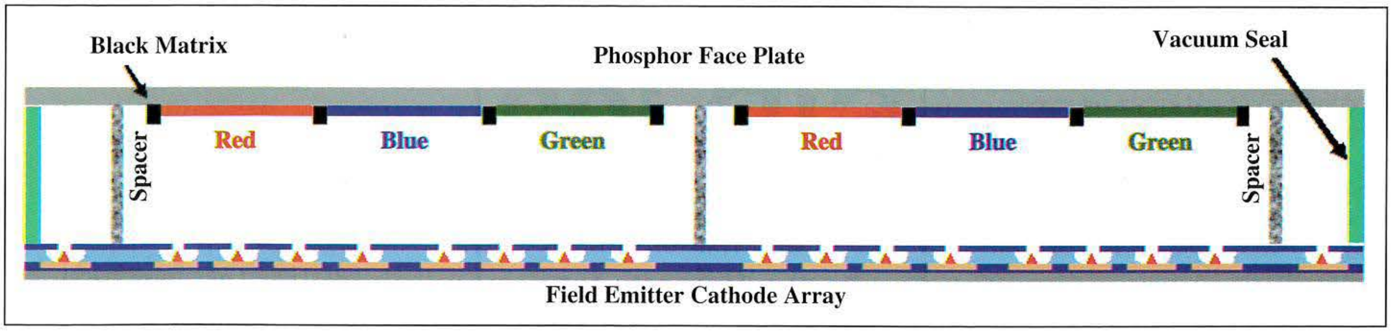


Fig. 4: The internal structure of a typical FED solves the problems of previous flat-panel-CRT designs. Only the ramp-up to high-volume manufacturing remains, but that has not been a trivial step.

electron beam. The excitation dwell time for each addressed pixel location is measured in nanoseconds. In an FED, the display is addressed one row at a time. The dwell time is measured in microseconds. This difference has an impact on the choice of phosphors: short-decay-time phosphors are less sensitive to saturation from high current densities.

Because a lower excitation voltage requires an increase in current density, low-voltage FEDs can experience greater differential aging due to the accelerated phosphor degradation which is normally associated with the cumulative electron dose – measured in C/cm^2. At lower anode voltage, the required electron dose increases both because the phosphor efficiency is lower and because more of the anode power is supplied by the electron current rather than the anode voltage, when compared to a high-voltage display. The key is the development of low-voltage phosphors with increased efficiency.

Many of the problems associated with FED manufacturing have been solved, and several companies around the world are producing prototypes of both monochrome and color FEDs. The main challenges remaining are in the conversion of laboratory processes into full-scale manufacturing.

There is general industry agreement that these hurdles are largest in the vacuum sealing and processing area. Maintenance of good vacuum is essential for achieving long display life, so this is a critical area of research for FED developers. Materials improvements, particularly in phosphors, are also needed to increase brightness and reduce power. This is especially true for FEDs with low-voltage anodes. High-voltage FEDs will benefit from advances in spacer technology as well as in phosphors. Although there are still problems to be solved, the near-term future for FEDs looks very promising. Display lifetimes of 10,000 hours and greater have been demonstrated by PixTech and Futaba for monochrome displays that are commercially available. Candescent has demonstrated a high-brightness high-resolution full-color FED. Increased worldwide activity in FED research and development should provide continued improvement.

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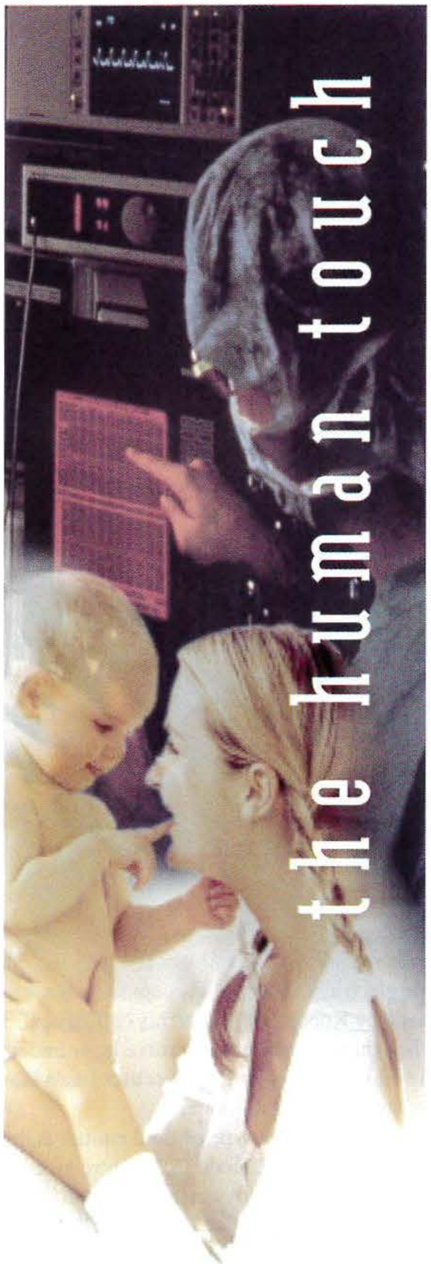

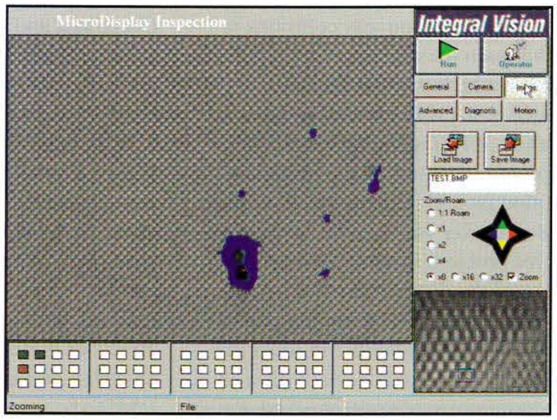
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device physics

How Do FEDs Really Fail?

There have been several explanations for the rapid current degradation in molybdenum field-emitter arrays, but none are consistent with observed device behavior.

by Robert H. Reuss and Babu R. Chalamala

FIELD-ENHANCED electron emission is the physical principle that distinguishes field-emission displays (FEDs) from other display types. In field-emitter arrays (FEAs), electron emission occurs through the quantum-mechanical tunneling of electrons from a microfabricated tip. The tunneling is very strongly enhanced by the application of a positive potential on an adjacent gate electrode [see, D. Temple, *Mater. Sci. Engrg. Rep.* **R24**, 185 (1999) and I. Brodie and C. A. Spindt, *Adv. Electron. Phys.* **47**, 1 (1992)]. To reduce the probability of electron–gas collisions in the space between the electrodes, FEDs must be operated in a high internal vacuum.

One major obstacle to the successful commercialization of FEDs has been the rapid degradation of emission current during display operation [see, G. Hopple and C. Curtin, *Information Display* **16**, No. 4/5, 34 (Apr/May 2000)]. This problem is related to how difficult it is to seal the display and then operate it while maintaining high vacuum inside the thin vacuum envelope. Gas – either residual gas not removed by the bake-and-seal cycles or gas liberated by electron bombardment of display components – interacts with the FEAs, producing decay in the emission current.

Recent research on FEAs has focused on understanding the degradation mechanisms caused by these residual gases, notably oxygen and other oxygenic gases [see, S. Itoh *et al., J. Vac. Sci. Technol.* **B11**, 647 (1993) and B. R. Chalamala *et al., J. Vac. Sci. Technol.* **B16**, 2859 (1998)]. The degradation mechanism was thought to be oxidation of the molybdenum (Mo) tip surface [see, B. R. Chalamala and R. H. Reuss, *J. Vac. Sci. Technol.* **B18**, 1825 (2000)]. But oxidation alone can not explain the degradation in the emission current.

Interactions between gases and FEAs are known to result in current degradation, but there have been few reports of systematic work that examines the effects of different gases and different pressures for extended periods. If we look at the characteristics of residual gases inside sealed FEDs and the effects of these gases on field emission over extended periods, and if we also look at the relation between the inter-electrode spacing and device life, we will see that the experimental data is inconsistent with a degradation model based on oxidation alone. In fact, we will see that a model based on shallow ion implantation explains the device behavior effectively. Let's begin our experimental analysis.

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Experimental Background

The issue of residual gas and its effects on FED performance can be seen from the following. High vacuum – package pressure less than 10^{-6} torr – is suggested for long-lived FED operation. Figure 1 shows typical emission-current behavior of an FED with a package pressure of approximately 10^{-5} torr. A variety of packages fabricated in the same manner yielded similar results.

Residual-gas analysis of a number of FEDs showed that typical package pressures were much higher than 10^{-6} torr. The total pressure data for more than 50 displays is summarized in Fig. 2, which shows that pressure in most of the packages was in the 10^{-6}–10^{-2} range. This high pressure resulted from the display components because dummy glass packages without the FEAs inside showed package pressures in the 10^{-6} torr range.

Analyzing the residual gases showed that the dominant gas inside the FEDs – over 90% by volume – was argon (Ar). The source was found to be the sputtered Mo films in FEAs. Despite the various bake cycles, sufficient Ar had remained trapped in the metal films to outgas within the display envelope. Seeing the deleterious effect of Ar, in conjunction with the known problems caused by oxygenic gases, motivated us to perform a systematic study of the effects of gases on the field-emission properties of Mo arrays. To set a performance baseline, FEAs were operated under ultra-high-vacuum conditions. Naturally, we expected to see significant performance improvements, but they did not materialize (Fig. 3).

Experimental Results

These results moved our investigations in two directions. First, we wanted to find the necessary conditions to achieve stable field-emitter

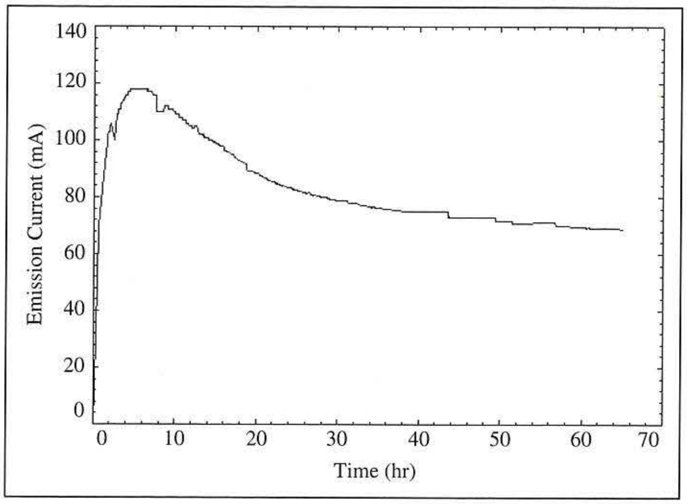

Fig. 1: This emission characteristic is typical of FEDs in high-vacuum packages. In this case, the FED had an internal pressure of 10^{-5} torr, 300 V on the anode, and a gate voltage of 80 V. A variety of packages fabricated in the same manner produced similar results.

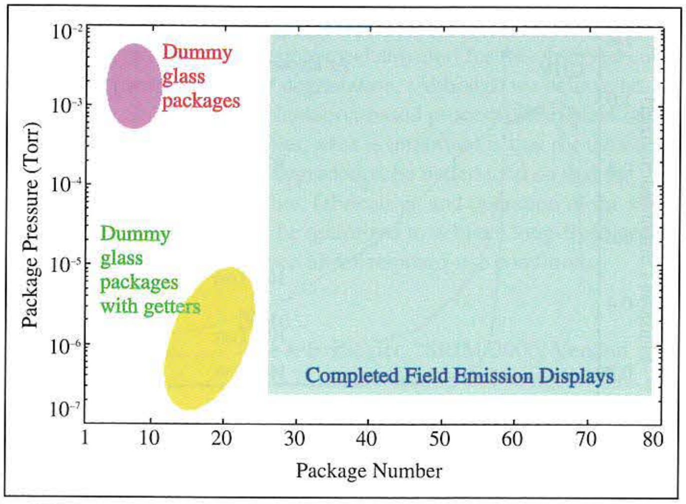

Fig. 2: As indicated by the package pressures for a number of FEDs and dummy glass packages as well, high internal pressure is due to the presence of display components because dummy glass packages with getters but without the FEAs inside showed much lower package pressures than did complete devices.

operation, and, second, we wanted to determine the key characteristics of potential contaminant gases that interact with FEAs. We used a variety of baking and/or cleaning techniques in an attempt to produce a stable emission current. However, with a 1-mm spacing between the stainless-steel anode and the FEA, only marginal improvements were noted.

Current-degradation rates were relatively high, similar to those shown in Fig. 1. This suggested that, despite the excellent vacuum conditions, liberated gas was still being trapped locally by the FEA before it could be pumped away. When the anode–cathode spacing was increased, the current degradation

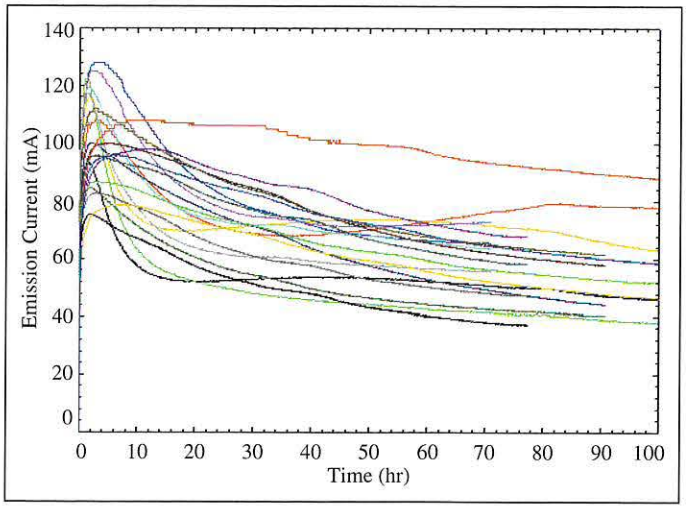

Fig. 3: When molybdenum FEAs were operated under ultra-high-vacuum conditions, the expected significant performance improvements did not materialize. The devices were tested with 80 V on the gate and 300 V on the stainless-steel anode.

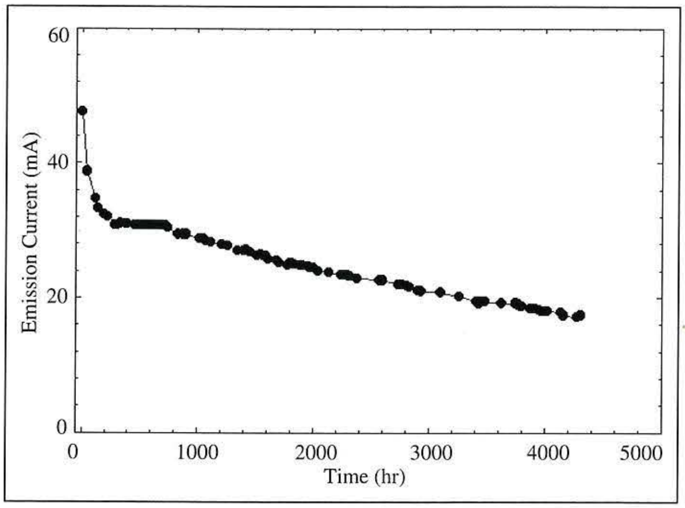

Fig. 4: The degradation of the FEA emission current became much less when the anode-to-cathode spacing was increased to 40 mm, indicating that local gas conditions are a factor in the degradation of FEDs with more typical anode-to-cathode spacings of about 1 mm (compare with Fig. 3). The stainless-steel anode was at 2 kV; the FEA gate voltage was 85 V.

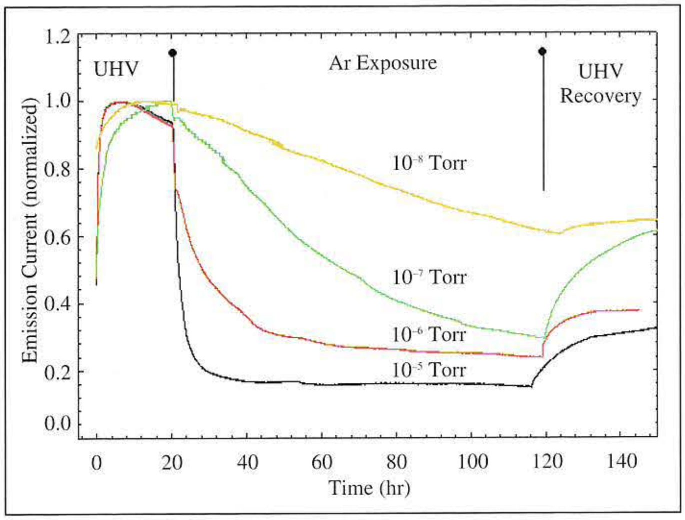

Fig. 5: *The emission current of an experimental FEA decreased more rapidly over a total exposure time of approximately 100 hours when the partial pressure of argon was higher. The inter-electrode spacing was 1 mm and the anode voltage was 300 V.*

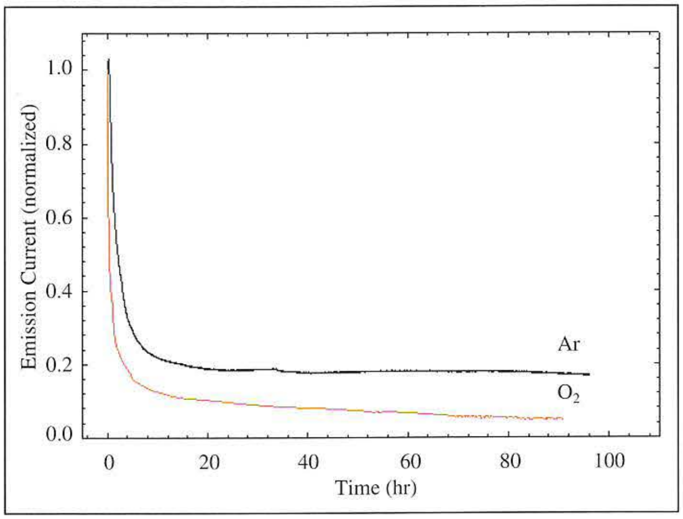

Fig. 6: *The emission current of an experimental FEA degraded similarly in the presence of Ar and O_2 at 10^{-5} torr, with 1-mm inter-electrode spacing and 300 V on the stainless-steel anode. We therefore conclude that oxidation is not the primary degradation mechanism.*

rate was diminished (Fig. 4). This demonstrates that devices have improved emission-current stability when the anode-to-cathode spacing is increased, and it highlights the importance of eliminating sources of gases from the active area of the device.

To emphasize the importance of keeping a low local pressure, we continuously operated an FEA with a 40-mm anode-to-cathode spacing for a period of more than 4000 hours, and the emission current decayed by less than 50%. This compares with less than 100 hours when the spacing is 1 mm, as shown in Fig. 3.

In addition to the current degradation caused by the inter-electrode spacing, substrate material was also found to affect the emission characteristics significantly. Experiments performed on a number of FEAs fabricated on borosilicate-glass substrates showed device performance that was superior to that of FEAs fabricated on soda-lime-glass substrates.

Because of the suspected adverse impact of Ar on sealed FEDs, and to clarify what effects other gases might have, we performed experiments on a number of Mo FEAs. The emission-current stability of these devices was studied under ultra-high vacuum and with gases intentionally introduced into the device envelope for extended periods of time under controlled gas pressures. Gas-exposure experiments were performed with Ar, He, Xe, H_2, and O_2 at partial pressures of 10^{-5}–10^{-8} torr. The emission-current degradation was similar and very rapid for all the gases tested except H_2. The data for Ar at various partial pressures are shown in Fig. 5.

To further highlight the similarities between noble gases and oxygen, we operated two devices under similar test conditions in Ar or O_2 at 10^{-5} torr (Fig. 6). The emission drop in both cases was found to be greater than 80% within the first 10 hours of operation. After this initial drop, the degradation rate was slightly slower for Ar. In both cases, when gas exposure was ended and the device operation continued, the current gradually increased. Similar experiments with He and Xe produced the same results. In all cases, increasing the partial pressure of the gas led to faster degradation.

How Do FEDs Really Fail?

The experimental results illuminate several important points. First, we can understand the relatively short lifetime of packaged FEDs with high gas pressure – even when the gas is inert – by observing the behavior of FEAs under similar, but controlled, ambient conditions. Second, even when FEAs are operated in ultra-high vacuum, we can observe current degradation if local gas pressure is high – a point that is made clear by our observations of the stability of FEAs operated with large anode–cathode spacing. Taken together, these results indicate that neither oxidation, gas adsorption, or sputter-induced damage can adequately account for the effect of gases on the emission behavior of FEAs.

This conclusion is supported by the following experimental observations. First, degradation of emission current occurred only when the device was operating, indicating that electron–gas interactions are necessary to create emission changes. Second, if the interactions were due to surface coverage alone, emission should have recovered essentially instantaneously after gas removal. This was not the case. Current recovery was slow and followed a diffusion-like pattern. Recovery appears to be faster for lower-pressure exposure and for gases of higher atomic weight. Third, effects associated with sputtering – such as current increases resulting from growth of nanoprotrusions or permanent current degradation from tip damage – were not detected. Fourth, except for H_2, all gases including O_2 degraded the emission. This argues against oxidation as a degradation mechanism. Initial exposure produced a rapid decrease in current, which was followed by fairly stable current emission for a prolonged period. The rate of current degradation was higher at higher gas pressure and for gases of lower atomic weight.

We suggest that ion implantation might be the key factor in current degradation of Mo FEAs in gas environments. We propose the following mechanism to explain our experimental results. Ambient gas is ionized by collision with the field-emitted electrons, and these ions are implanted into emitter cones and the surrounding gate areas. From calculations of the implant depths using TRIM – a software program developed by J. F. Ziegler for calculating the penetration depth of ions into solids – we estimate that the penetration depth of 300-eV Ar^+ ions into Mo is about 10 Å, reaching almost 50 Å at 5 keV (see note). For He and H_2, the penetration depth is more than 100 Å at 5 keV (Fig. 7).

This kind of ion-implantation mechanism is well known. It forms the basis of ion pumps and has been exploited in FEDs to reduce package pressure [see, C.-C. Peng and C.-H. Tsai, U.S. Patent 5578900 (1996)].

Gas ions implanted into tips create a region that increases the tunneling barrier width by forming a highly resistive surface layer. This leads to a rapid current decrease, followed by saturation or slow roll-off. As more ions are implanted into the near-surface region, diffusion and outgassing can compete. This establishes equilibrium between the implant and diffusion rates, leading to current saturation.

Lighter atoms, higher pressure, or increased ion energy produces a deeper implant and/or thicker resistive layer. This results in a lower emission current, and slower diffusion out of the material prolongs subsequent current recovery. Although various cleaning mechanisms have been attributed to H_2, we suggest that implantation may be the dominant effect for H_2 as well. But, because hydrogen implanted into metals and metallic hydrides are conductive, current may increase depending on the hydrogen's partial pressure.

So, all of the tested gases have a common effect: ionization and subsequent implantation into the near surface of the emitter tip modifies the tunneling barrier and, therefore, the emission characteristics. The time frame for these interactions is relatively short (10–100 hours) as shown in these experiments. However, other longer-term damage mechanisms such as oxidation and sputter damage are not precluded.

The results of these experiments reinforce the imperative of maintaining extreme vacuum conditions – and especially the local pressure conditions of all gases – if FEDs are to be successfully commercialized. Additional work is needed to better understand the physical mechanism(s) for the observed current degradation. Although we believe an implantation-based process can explain our results, what is important is that the details of the degradation be understood so that the design, fabrication, and operation of the FED can be optimized to achieve long-lived performance under standard-use conditions.

Note

[1] See J. F. Ziegler, "SRIM-2000, Version 2000.38, The Stopping and Range of Ions in Matter" (SRIM-2000). SRIM-2000 is the most recent version of TRIM. Public versions of the program can be found at www.research.ibm.com/ionbeams. ■

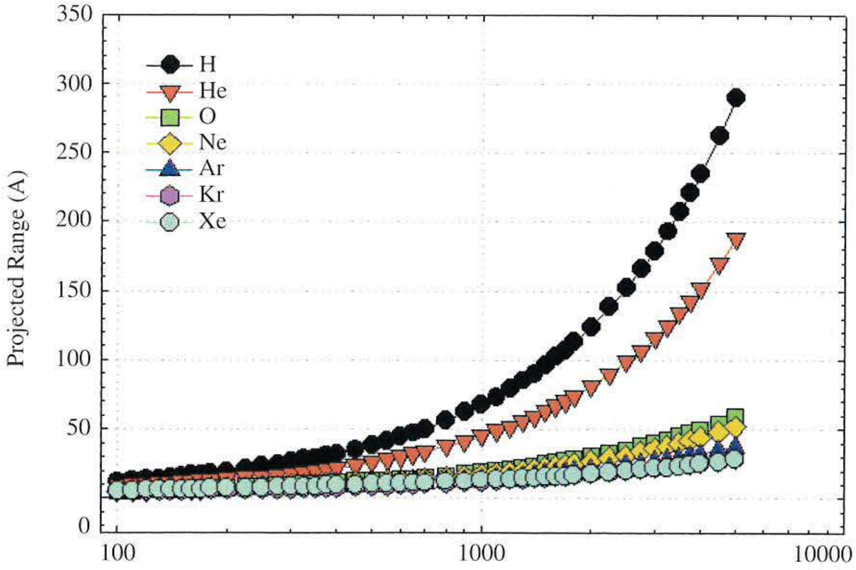

Fig. 7: TRIM calculations of the penetration depth of various ions in molybdenum confirm the proposition that ion implantation is the primary degradation mechanism in FEAs.

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Getting Plasma Displays into the Home

To expand consumer sales of still-expensive PDPs a new strategy may be required. FHP has one.

by Shunsuke Matsuyana and Koichi Takahashi

OVER the next 5 years, makers of plasma-display panels (PDPs) will struggle to have their displays widely used in the home-television market. The launch of this epic marketing and technology battle is scheduled for the second half of 2001.

PDP sales have been growing largely on the strength of commercial and industrial applications, but the industry has long coveted the mass consumer-television market. The first step in the new strategy is to launch 32–42-in. PDPs in the Japanese and European markets, which have a high concentration of television manufacturers and in which high demand can be expected. The second step is to use falling prices and high image quality to stimulate strong demand for 50–60-in. large-screen models in North America.

The Assumption of Growth

In the future, the display industry will maintain its high average annual growth rate of 20%, and in 2005 it is expected to be a ¥10 trillion industry – US$83 billion at 120¥ to the dollar. In 2001, sales of flat-panel displays (FPDs) are expected to surpass sales of cathode-ray-tube (CRT) displays for the first time in history. PDP sales will start to take off in 2001, and we believe that in 2002 television applications will surpass business applications (Fig. 1). The PDP-television market will then be established.

The size of the PDP market was about 100,000 units in 1999. In 2000, it increased to about 250,000 units. In 2001, it will grow rapidly to about 900,000 units, and in 2002 it is forecasted to be about 1.45 million units.

***Shunsuke Matsuyana** is Executive Director at Fujitsu Hitachi Plasma (FHP) Display Ltd., Kanagawa, Japan. **Koichi Takahashi** is also with the company. This article was adapted, with permission, from the article "Redrafting of the Scenario for the Spread of PDP TVs: 32-in. Will Be the First Target" appearing in the English edition of Nikkei Microdevices'* Flat Panel Display 2001, *translated and published by Interlingua.com, Inc. For more information, contact Jack Bernstein, President, Interlingua, 423 South Pacific Coast Highway, Suite 208, Redondo Beach, CA 90277; telephone 310/792-3639, fax 310/792-3642, e-mail: publishing@fpdonline.com, Web site: www.interlinguacom.com.*

Growth Factors

Satellite digital broadcasting, which began in Japan at the end of 2000, is critical in increasing consumer demand for PDP television, and it is expected that the 2002 World Cup Soccer Tournament will accelerate the use of PDP television. The combination of a maturing infrastructure in 2002–2003 with a concentration of major televisable events is encouraging PDP manufacturers to build more manufacturing plants.

Manufacturers are positioning the PDP as a "multipurpose digital television" for home networks in the era of digital broadcasting. In this new era, displays will not only receive digital broadcasts, but they will also be

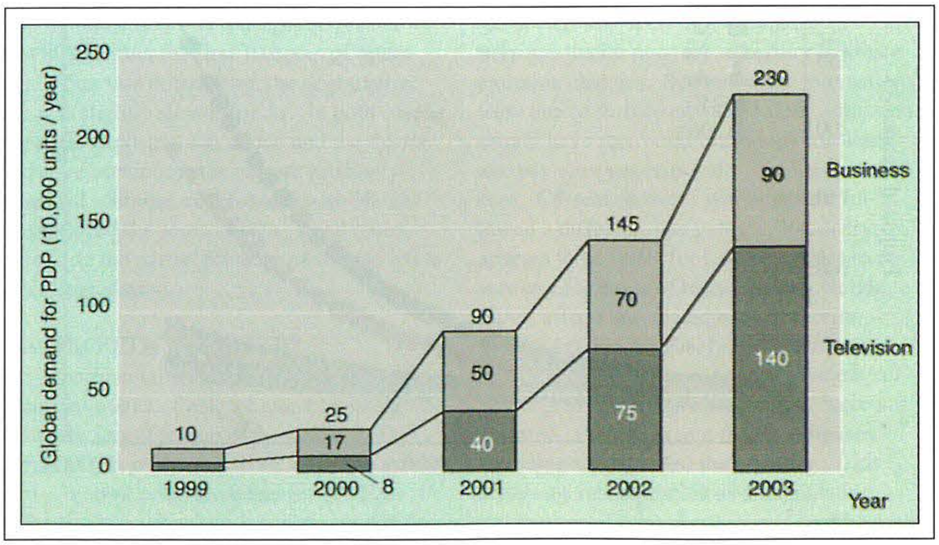

Fig. 1: In 2002, the TV applications of plasma-display panels (PDPs) are expected to surpass business applications for the first time.

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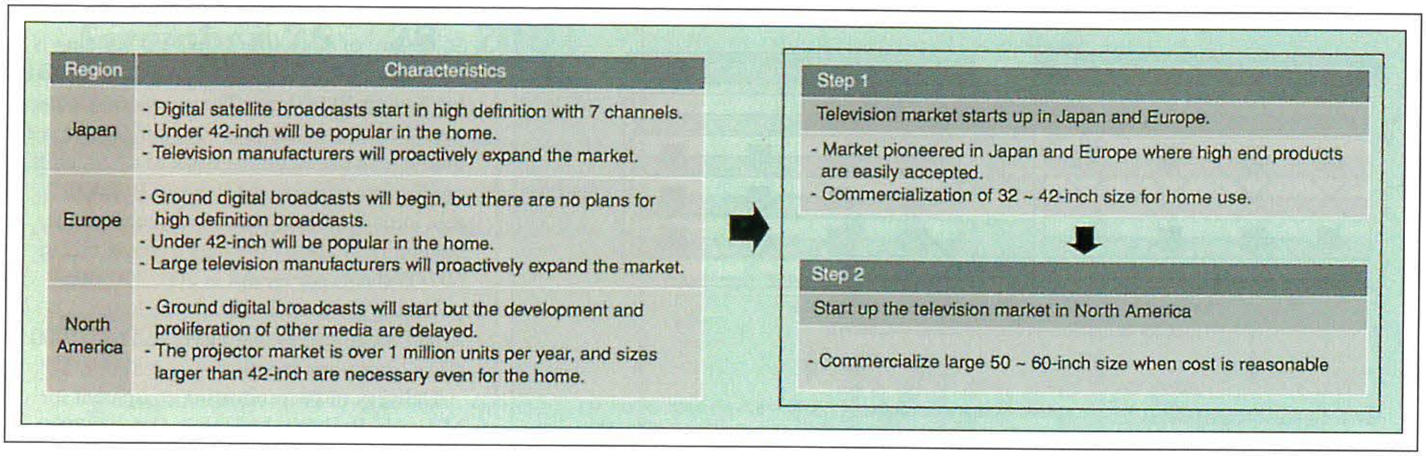

Region	Characteristics
Japan	- Digital satellite broadcasts start in high definition with 7 channels. - Under 42-inch will be popular in the home. - Television manufacturers will proactively expand the market.
Europe	- Ground digital broadcasts will begin, but there are no plans for high definition broadcasts. - Under 42-inch will be popular in the home. - Large television manufacturers will proactively expand the market.
North America	- Ground digital broadcasts will start but the development and proliferation of other media are delayed. - The projector market is over 1 million units per year, and sizes larger than 42-inch are necessary even for the home.

Step 1

Television market starts up in Japan and Europe.

- Market pioneered in Japan and Europe where high end products are easily accepted.
- Commercialization of 32 ~ 42-inch size for home use.

Step 2

Start up the television market in North America

- Commercialize large 50 ~ 60-inch size when cost is reasonable

Fig. 2: The new strategy for increasing consumer use of PDP television in the home consists of two steps. The first step is to initiate sales of 32- and 42-in. PDP-television sales in the Japanese and European markets that readily accept high-end products. The second step will be to develop large 50–60-in. TV products when prices drop sufficiently to make them appropriate for the North American market.

required to support high-definition television, multiple channels, and data broadcasts. The PDP is a large-screen display device that can handle all of this. It can display exciting images and high-quality information.

Displayed images are exciting when they can express beauty and reality, such as an actress's face in life size or a charge of Mongol horsemen across the broad vista of the Gobi Desert on a 16:9 wide screen. A high-quality information display in the digital-broadcast era, on the other hand, will be able to handle both the images and written information that are sent. It will be able to display vivid characters without distortion.

Critical for TV: Size and Price

If PDP television is to become widely used, the price must come down. Television manufacturers are still working toward the long-held 1 in. = ¥10,000 target. This would be a major step forward, but we all know that a mass-market 50-in. television can not sell for ¥500,000 (US$4200), nor can a mass-market 10-in. set sell for ¥100,000 (US$830).

Consumers evaluate the acceptability of television prices in the context of size and performance. One milestone is thought to be the ¥300,000 (US$2500) mark, which was broken by PCs not that long ago (although prices have continued to hurtle downward).

To use an old example, sales of color televisions increased rapidly during the 1964 Tokyo Olympics. At the time, a college graduate's starting salary was ¥20,000 per month, yet even ¥200,000 color televisions were selling well because the pleasure of owning and watching television represented a genuine experience. Similarly, the value-added features of PDP television – such as the aesthetics of a large screen, high resolution, and versatile installation – that conventional television does not offer may make a high price acceptable by enhancing the overall viewing and ownership experience.

A key question is "What size of large-screen high-resolution television will be in demand?" CRT rear-projection 50–60-in. television sets are currently sold in North America. The price is close to $2000, and the market is about a million units per year. This television is used as a secondary set for groups of people to enjoy movies and sporting events, and sales will not be high. On the other hand, high-end products in the 30-in. class are selling in the Japanese and European markets as a primary unit for the living room.

Promoting Consumer Demand

As the aforementioned market trends have

Ken Werner

Fig. 3: This pre-production version of FHP's 32-in. PDP was photographed at IDW 2000 in Kobe, Japan, in late November.

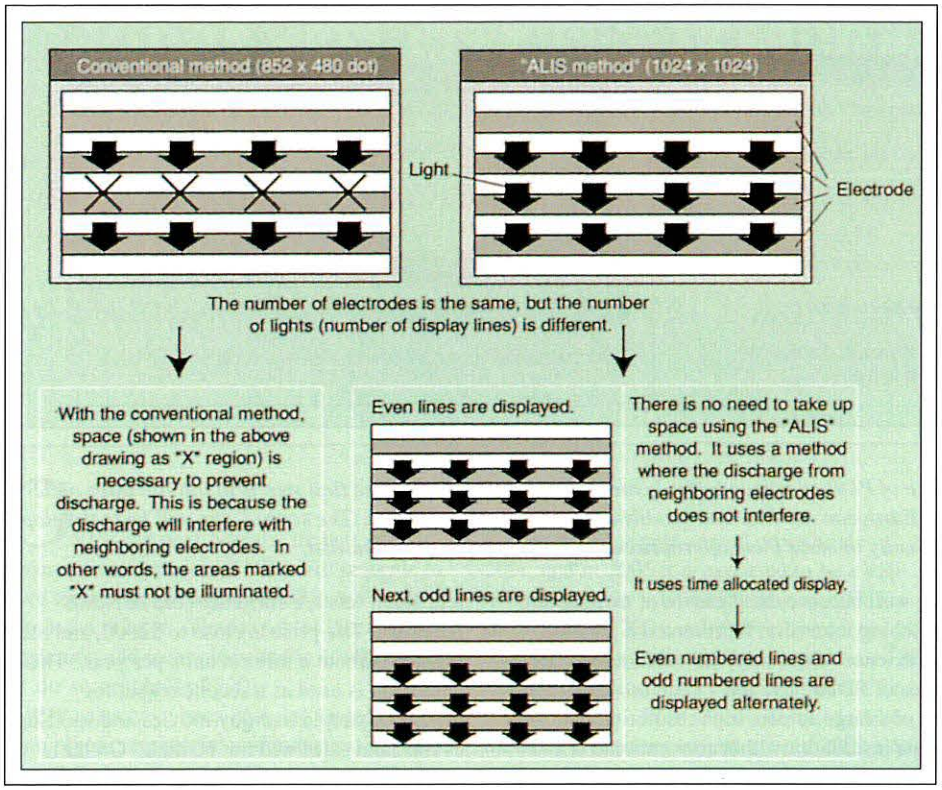

Fig. 4: *The ALiS alternate-line addressing method makes it possible to make a relatively small PDP that displays high-resolution images with high brightness.*

become apparent, we have developed a scenario to increase consumer use of PDP television in the home. The first step is to initiate PDP-television sales in the Japanese and European markets that readily accept high-end products. The initial target products for these markets will be 32–42-in. models. The second step will be to develop large 50–60-in. TV products when prices drop sufficiently to bring them in line for the North American market (Fig. 2). This global strategy plans for the wide acceptance of PDP television by carefully considering the market characteristics of each region.

The price of PDP television will be a problem. As PDP-module manufacturers, we at Fujitsu Hitachi Plasma Display, Ltd. (FHP) understand that television prices will be determined by our television-manufacturing customers. But if we can use technology and manufacturing savvy to provide our customers with modules that hit a size and value "sweet spot," we can help them sell PDP TVs at prices that consumers will be willing – even anxious – to pay.

Recently, we have developed 32- and 37-in. models that we believe define this "sweet spot" (Fig. 3). We were able to achieve high definition in a 32-in. PDP by using our unique drive technology known as the ALiS method (Alternate Lighting of Surfaces). Conventional drives require a space between neighboring discharge electrodes, whereas the ALiS method alternates the display times between odd lines and even lines so that no space is necessary, and it is thus possible to double the pixel density (Fig. 4). It was the ALiS method that allowed us to develop a 32-in. high-definition panel so quickly. The 32-in. ALiS model is able to produce a high luminance of 650 cd/m^2 without a fan.

A New Production Line

Because we firmly believe that we have accurately defined the "sweet spot" – the proper size, the appropriate price range, and the completion of the technology needed for the proliferation of PDP television in the home – we have aggressively supported our belief by establishing a new production line in a new building, Miyazaki Building 2. With 56,000 m^2 of floor space, the new building is much larger than the existing Miyazaki Building 1, with 18,000 m^2. The production capacity at Miyazaki Building 1 is 10,000 units per month (calculated on the basis of 42-in. units); production capacity at Miyazaki Building 2 was initially 30,000 sheets per month at the beginning of 2001. We plan to boost this to 60,000 sheets per month in 2002. At that point, the production capacity of both Miyazaki buildings combined will be 70,000 42-in. sheets per month.

Delivery of the production equipment for Miyazaki Building 2 began in October 2000, with the first mass production scheduled to start in January 2001. The investment was approximately ¥45 billion.

Because of the introduction of new process technology and multiple-yield cutting, the new line will provide cost reductions and a stable supply. The new line supports a glass-substrate size that allows 3-up production of 32-in. panels and 2-up production of 42- and 37-in. panels. It follows that if the production capacity of Miyazaki Building 2 is calculated in 32-in. units, it will be 1.5 times higher than when calculated in 42-in. units, and the stated initial capacity of 30,000 sheets per month increases to 45,000 sheets per month.

Assuming that PDP television will enter the home-television market as predicted, 2001 will be a turning point for the second-phase line at Miyazaki Building 2. ■

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PRECISION ON GLASS

Circle no. 15

continued from page 2

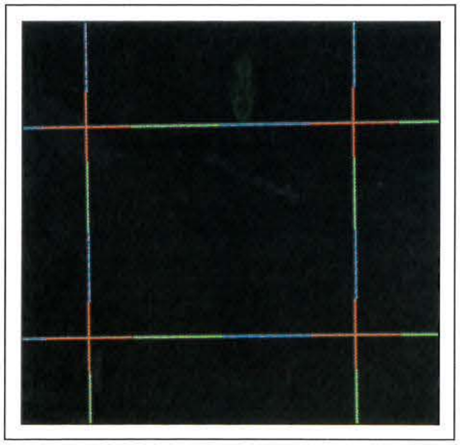
phase to remove complicated color and smearing artifacts. This was easily done with Compaq's three-button control panel used in conjunction with the OSD. Presumably, it is just this kind of adjustment that becomes unnecessary with the digital interface we were unable to use. But if the LCD required an adjustment to its pixel clock, Sony's high-resolution CRT required that moiré interference be tuned out. This, too, was easily accomplished.

So, now that we've set the pixel format of each display to SXGA and approximately equalized luminance and contrast, we would expect the flat-screen LCD to look much the same as the flat-screen CRT, right? Well, sort of.

To the User, What's the Difference?

First of all, the color balance is different. We set the CRT monitor to a white point of 9300 K, as indicated by the OSD. Without a point of comparison, this produces what seems like a reasonable white background for the word-processor "pages" on which I'm writing. When the LCD monitor is set to what *its* OSD says is 9300 K, it looks *very* blue. Setting it to 6500 K produces a reasonably neutral white that does not appear hugely different from the CRT's claimed 9300 K.

Although the highest white levels don't look very different on the two monitors, the situation changes dramatically when various gray-level patterns are examined in DisplayMate. From roughly level 192 (out of 255) on down, the CRT's gray levels look very "warm" – that is, brownish – while the LCD's gray levels are quite neutral. "Blacks" look very black on the LCD; they look like a very dark brown on the CRT.



Ken Werner

Fig. 1: *We used DisplayMate's "static color registration pattern" to demonstrate the differences in how a one-subpixel-wide line is rendered by the Compaq LCD and Sony CRT monitors we evaluated.*

But all points do not go to the LCD. Virtually all high gray levels (at least through 253) are clearly visible on the CRT when shown against a white background (which is level 255) in an office with subdued natural lighting. The LCD monitor can not distinguish any level down to 225 from the white background – although, as you will see, this is something of an artifact produced by our setting the luminance so low and compensating to some extent with the contrast level. On the dark side, it is just possible to distinguish the LCD's level 20 against a black background (level 0), while the CRT's level 4 is clearly visible.

The LCD is sharper than the CRT. Although the Sony CRT's aperture-grille pitch of 0.22 mm – which may be the best ever for an off-the-shelf PC monitor – sounds better than the LCD's pixel pitch of 0.28 mm, this comparison is between apples and oranges. In a CRT, it is the diameter of the spot where the beam hits the screen that determines the smallest feature the tube can display. Even though Sony went to substantial pains to keep the spot small, developing a HiDensity™ electron gun and Enhanced Elliptical Correction System™ for this tube, the spot still covers more than one RGB phosphor triad.

Using DisplayMate's "static color registration pattern" (Fig. 1) and a 10X magnifier makes clear the differences in how a one-subpixel-wide line is rendered by the LCD (Fig. 2) and the CRT (Fig. 3). (The magnification in these photos is uncalibrated but is substantially more than 10X.)

For normal business PC applications, none of this matters much. One person in our office found the CRT's softer contours more pleasing on some medium-sized type fonts, while the LCD's sharper images made it possible to view some fonts a point or two smaller than was possible on the CRT.

The overall geometry on both of these monitors is superb. That's to be expected on the LCD, of course, but the CRT is just as good, maintaining its excellent rectangular geometry all the way into the corners. Together with the flat screens, this matters for graphical design (including ad and brochure layouts), CAD, and spreadsheets. Good geometry and a flat screen – whether on an LCD or a CRT – is a combination we would not want to give up.

Given their MSRPs, it is clear that both of these monitors were intended for demanding professional audiences, and both manufacturers made sure the basics were done to a high standard. Sony has its awe-inspiring rectangular geometry and spot size and uniformity. Compaq has very good viewing angles, no color inversion at large viewing angles (as indicated on the Brill–Kelley Color Inversion Target on the SID DTS 2000 CD-ROM), excellent backlight uniformity, and no visible mura or blotchiness on an evenly illuminated gray screen.

Many of the 24-bit color photos from the DTS CD-ROM look different on the two monitors as a direct consequence of the basic characteristics already noted. The LCD's small "spot" renders textures with greater clarity than the CRT. Combined with its tonal neutrality and subjectively much higher contrast ratio, many photos have much more impact and "presence."

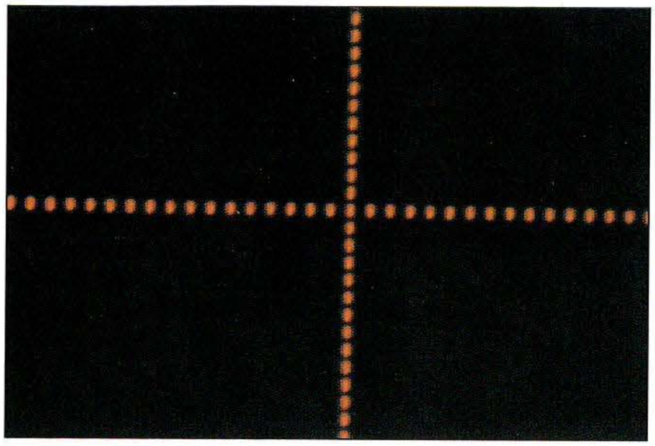
On the other hand, the LCD's inability to distinguish between gray levels close to white (as set up in the test so far) and close to black leads to a loss of highlight and shadow detail, and can make some highlights look harsh and unnatural.

Removing the Tethers

For the sake of a workable comparison, we did not allow either of these displays to operate at its best. The LCD was operated at far below its maximum luminance to match the CRT, and the CRT was operated at 1280 × 1024 to match the LCD instead of at 1600 × 1200 or 1800 × 1440 (its maximum).

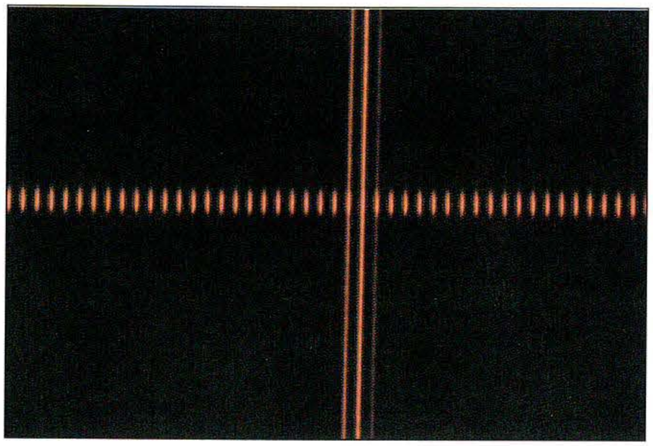
Setting the LCD to its maximum luminance – a claimed 200 cd/m^2 – made the white background of a word-processing page very bright and gave the LCD a few more visible gray levels on the low side (12 became barely visible against a black background instead of 20). At maximum brightness, we could now set the contrast to 50%, as shown on the OSD, which made high gray levels up to 253 become visible. Color photos benefited substantially, but narrow text fonts, such as Courier, became less pleasant to view against a white background.

Despite adding viewable gray levels on the extremes with our new TFT brightness and



Ken Werner

Fig. 2: The LCD presented monochromatic vertical and horizontal lines that were one subpixel wide. In most LCDs, subpixels are approximately three times as high as they are wide so that a complete RGB pixel is square. That means on this display, which has a 0.28-mm pixel pitch, this vertical red line is approximately 0.009 mm wide.



Ken Werner

Fig. 3: Although the spot size of the Sony CRT is relatively small, it still illuminates three columns of red subpixels in displaying a vertical red line. Since the pixel pitch is 0.22 mm, the red vertical line is roughly 0.44 mm wide.

contrast adjustments, subjectively, the CRT seemed to retain an advantage in subtlety of gray scale. This may not be significant in many applications, but the difference in viewing x-rays, for instance, is meaningful.

What happens when the CRT monitor is reset to 1600 × 1200 is subjectively less clear. The addressability improves but the spot size presumably does not. With the two monitors now driven by two different computers so they could be driven at different pixel formats simultaneously, the TFT presents images with noticeably more sharpness at 1280 × 1024 than the CRT does at 1600 × 1200.

A Tidy Conclusion?

Is there a tidy conclusion here? These are two excellent but visually different monitors. (I'm intentionally not worrying about the large differences in weight, size, and power consumption.)

Is there anything I'd like to "fix" on them? I'd like to see more brightness and contrast on the Sony CRT with no growth in beam spot size – an unreasonable request. There is nothing wrong with a bias to warm colors, but on this monitor it's excessive. Whether this was always the case, or whether it is something that has developed over time, I can't say. (The monitor has quite a few hours on it.) The colors could, of course, be adjusted individually to attain more neutrality.

A high-end 18-in. (viewable) monitor should really have more than 1280 × 1024 pixels. That was not a realistic proposition when the TFT8020 first entered Compaq's product mix. It is now, or will be soon.

At least one of these monitors has a white-point temperature that is wildly different from what is claimed on the OSD. That is not acceptable on monitors like these. Sony included a USB hub in the monitor base. Compaq includes a covered hole for a USB hub that is an extra-cost option. That seems like nickel-and-diming for this kind of monitor.

The Compaq monitor looked for a digital signal but didn't find it. We are guessing that the failure was in the little Matrox DVI daughter card, which looked as if it might have had a long history.

The most general short conclusion I can come up with is that monitors aren't commodities. For most applications, most buyers are not going to spend the time comparing two monitors that I spent – or that you spent if you have read this far. But using a few test patterns and images – such as a small selection of those found on the DTS CD-ROM – would sensitize buyers to the visual differences between monitors and help them select the monitors that best meet their individual needs.

– KIW

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

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continued from page 4

would start an Internet-based business and sell 27-in. name-brand television sets for $50 each to "establish a customer base and capture market share." Once we had this large customer base, we would then gradually raise prices to get to profitability. Of course, raising prices to $100, then to $150, and then to $200 would continue to prove that customers still flocked to our site. But to get to profitability, we would need to charge $300 or more. However, that is now the same price for which our customers can buy the set at any other dot.com site or traditional discount store. At that point, life for our dot.com company gets very challenging. While it was relatively easy to raise prices and thereby to reduce our quarterly losses from several hundred million dollars to maybe just 50 million or so, from there to profitability is like becoming a four-minute-mile runner. Only a few can hope to accomplish it. And the process is similarly asymptotic.

The traditional stores – especially the discount warehouses – may even have some inherent advantages. The customer does the work of picking the items from the shelves, the shopping cart and the car trunk are the no-cost shipping containers, the drive home provides transportation of the goods for free, and returning or exchanging a misbehaving product is easy. If companies providing home milk delivery services several decades ago couldn't stay in business, why should a dot.com grocery store have any more success today?

The story with new technology is similar. How many press releases have we seen of new display technologies that are going to "leapfrog" existing products? How many news reports have we read of great new and "revolutionary" displays based on a new type of light-emission or light-modulation capability – illustrated by a companion photo of a one-inch-square single-pixel display in a barely visible green or orange color? And how many announcements have we read of the great progress being made that, when *linearly extrapolated*, will soon lead to commercial success? To get from these early demonstrations to profitable products is again not too different from achieving that ability to run the four-minute mile. Many would like to do it, but few actually succeed.

I suppose that sometimes such high optimism is simply due to the exuberance (or lack of experience) of the participants, but just as often I suspect the drive behind such overly optimistic announcements is the need to meet investors' expectations or to try to live up to the early promises made to those investors.

Is there any hope for those of us who most likely will not be able to achieve the technological equivalent of the four-minute mile, and would prefer not to make such promises

to keep our careers on track? I believe there is. Instead of aspiring to run at a pace that is not realistic, why not accept a realistic goal of running five (or maybe even ten) miles at a seven-minute-per-mile pace? That is still darn good and way above what most people are able to do. And if it can be sustained for many years, then that can be a path to long-term success and survival – a sustainable and profitable business.

Therefore, suppose we retain our enthusiasm, and seek to develop innovative new display technologies, but insist on being more realistic about how much immediate market impact those technologies will have. Any new technology needs time (typically more than ten years) for all the details to be worked out for full performance capability to be developed and for reliability to be proven – especially if new materials are involved. Thus, an entry point needs to be found where modest production volumes are acceptable and where it is not necessary to immediately compete with well-established technologies such as CRTs and LCDs. One market segment where such an opportunity currently exists, for example, is in electronic advertising.

Perhaps it will continue to be necessary to dangle the promises of leapfrog technologies and revolutionary breakthroughs in order to attract investors' attention. However, within the display community, we can temper these claims with the balanced perspective of knowing how technologies really develop and how they eventually lead to successful products – and to profitable businesses.

Should you wish to support or challenge my comments with your own experiences in introducing new display technologies, I would very much like to hear from you. You can reach me by e-mail at silzars@attglobal.net or president@sid.org, by telephone at 425/557-8850, by fax at 425/557-8983, or by mail at 22513 S.E. 47th Place, Sammamish, WA 98075. ■

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SID 2002 honors and awards nominations

Once again, on behalf of the SID Honors and Awards Committee (H&AC), I am appealing for your active participation in the nomination of deserving individuals for the various SID honors and awards. The SID Board of Directors, based on recommendations made by the H&AC, grants all the awards. To begin with, these awards include four major prizes that are awarded to individuals, who are not necessarily members of the SID, based upon their outstanding achievements. The **Karl Ferdinand Braun Prize** is awarded for ***"Outstanding Technical Achievement in Display Technology."*** Scientific and technical achievements that either cover a wide range of display technologies or the fundamental principles of a specific technology are the prime reasons for granting this prize to a nominee. The **Jan Rajchman prize** is granted for ***"Outstanding Scientific and Technical Achievement or Research in the Field of Flat-Panel Displays."*** This prize is specifically dedicated to those individuals who have made major contributions to one of the flat-panel-display technologies or, through their research activities, have advanced the state of understanding of one of those technologies. The **Johann Gutenberg prize** is awarded for ***"Outstanding Technical Achievement in Printing Technology."*** This prize is specifically devoted to those who have excelled in the field of hardcopy printing. Each of these above-mentioned prizes carry a $2000 stipend sponsored by Thompson Consumer Electronics Inc., the Sharp Corporation, and the Hewlett-Packard Company, respectively. The fourth major society prize, the **Lewis and Beatrice Winner Award,** is awarded for ***"Exceptional and Sustained Service to the Society."*** This award is granted exclusively to those who have worked hard over many years to further the goals of the Society.

The **SID Fellow Award** is given each year to a number (up to 0.1% of the membership in that year) of **SID members** in good standing for at least five years at the time of the nomination, who have demonstrated ***"Outstanding Scientific or Technical Engineering Achievements in the Field of Displays over a Sustained Period of Time,"*** and who are recognized as significant technical contributors to knowledge in their area(s) of expertise by SID members practicing in the field. For this rea-

SID honors and awards nominations

Nominations are now being solicited from SID members for candidates who qualify for SID Honors and Awards.

- FELLOW. Conferred annually upon a SID member of outstanding qualifications and experience as a scientist or engineer in the field of information display, and who has made a widely recognized and significant contribution to the advancement of the display field.
- JAN RAJCHMAN PRIZE. Awarded for an outstanding *scientific* or *technical* achievement in, or contribution to, research on flat-panel displays.
- KARL FERDINAND BRAUN PRIZE. Awarded for an outstanding *technical* achievement in, or contribution to, display technology.
- JOHANN GUTENBERG PRIZE. Awarded for an outstanding *technical* achievement in, or contribution to, printer technology.
- LEWIS & BEATRICE WINNER AWARD. Awarded to a SID member for exceptional and sustained service to SID.
- SPECIAL RECOGNITION AWARDS. Granted to members of the technical, scientific, and business community (not necessarily SID members) for distinguished and valued contributions to the information-display field. These awards may be made for contributions in one or more of the following categories: (a) outstanding technical accomplishments; (b) outstanding contributions to the literature; (c) outstanding service to the Society; (d) outstanding entrepreneurial accomplishments; and (e) outstanding achievements in education.

Nominations for SID Honors and Awards must include the following information, preferably in the order given below.

1. Name, Present Occupation, Business and Home Address, Phone and Fax Numbers, and SID Grade (Member or Fellow) of Nominee.

2. Award being recommended:
   Fellow*
   Jan Rajchman Prize
   Karl Ferdinand Braun Prize
   Johann Gutenberg Prize
   Beatrice Winner Award
   Special Recognition Award

*Fellow nominations must be supported and signed by at least five SID members.

3. Proposed Citation. This should not exceed 30 words.

4. Name, Address, Telephone Number, and SID Membership Grade of Nominator.

5. Education and Professional History of Candidate. Include college and/or university degrees, positions and responsibilities of each professional employment.

6. Professional Awards and Other Professional Society Affiliations and Grades of Membership.

7. Specific statement by the nominator concerning the most significant achievement or achievements or outstanding technical leadership which qualifies the candidate for the award. This is the most important consideration for the awards committee, and it should be specific (citing references when necessary) and concise.

8. Supportive material. Cite evidence of technical achievements and creativity, such as patents and publications, or other evidence of success and peer recognition. Cite material that specifically supports the citation and statement in (7) above. (Note: the nominee may be asked by the nominator to supply information for his candidacy where this may be useful to establish or complete the list of qualifications).

9. Endorsements. Fellow nominations must be supported by the endorsements indicated in (2) above. Supportive letters of endorser will strengthen the nominations for any award.

Send the complete nomination – including all the above material by **October 12, 2001** – to Andras I. Lakatos, Honors and Awards Chairman, Society for Information Display, 610 South 2nd Street, San Jose, CA 95112 USA; e-mail: sidawards@sid.org.

son, five endorsements from SID members are required to accompany each Fellow Award nomination. Each Fellow nomination is evaluated by the H&AC, based on a weighted set of five criteria. These criteria and their assigned weights are creativity and patents, 30%; technical accomplishments and publications, 30%; technical leadership, 20%; service to SID, 15%; and other accomplishments, 5%. When submitting a Fellow award nomination, please keep these criteria with their weights in mind.

The Special Recognition Award is given annually to a number of individuals (membership in the SID is not required) of the scientific and business community for distinguished and valued contribution in the field of displays. These awards are given for contributions in one or more of the following categories: (a) ***Outstanding Technical Accomplishments,*** (b) ***Outstanding Contributions to the Literature,*** (c) ***Outstanding Service to the Society,*** (d) ***Outstanding Entrepreneurial Accomplishments,*** and (e) ***Outstanding Achievements in Education.*** When evaluating the Special Recognition Award nomination, the H&AC uses a five-level rating scale in each of the above-listed five categories, and these categories have equal weight. Nominators should indicate the category in which a Special Recognition Award nomination should be considered by the H&AC. More than one category may be indicated. The accompanying nomination should, of course, stress accomplishments in the category or categories selected by the nominator.

While individuals nominated for an award may not submit their own nomination, nominators may ask a nominee for information that will be used in his/her nomination. The selection and nomination process is relatively simple, but requires that you and perhaps some of your colleagues devote some time to preparation of the supporting material that the H&AC needs in order to evaluate each nomination for its merit. It is not necessary to submit a complete publication record with a nomination. Just list the titles of the most significant half a dozen or less papers and patents authored by the nominee, and list the total number of papers and patents he/she has authored.

The selection of nominations for SID honors and awards is a highly selective process. Each year only about 30% of the nominations are selected to receive one of the awards. Some of the major prizes are not awarded every year due to the lack of sufficiently qualified nominees or, in some cases, because no nominations were submitted. On the other hand, once a nomination is submitted, it will stay active for three consecutive years, and will be considered three times by the H&AC. The nominator of such a nomination may improve the chances of the nomination by submitting additional material for the second

or third year that it is considered, but such changes are not required. If a nomination is not awarded an award over this three-year period, the nominee will not be considered again.

Since 1997, nominations can be entered through the Internet simply by logging in at www.sid.org. At the SID Web site click on ***Awards.*** This action opens the Honors and Awards section of the SID site. Then click on ***Award Nominations*** found at the top of the page, *i.e.,* the display screen, to open the Nomination Form. The SID H&AC encourages the use of this electronic version. Volunteer labor is used to process all the nominations. Electronic filing saves a lot of administrative work, and helps with reducing the workload on our volunteers. In 2000, all award nominations were submitted over the Internet. But we will still accept hardcopy nominations. The associated text box appearing in this column contains a complete description of each of the prizes and awards, along with a detailed description of the information that is asked for in support of each nomination. *Please note that with each **Fellow Award nomination,** only five written endorsements by five SID members is required.* These brief endorsements – *a minimum of 2–3 sentences* to a maximum of one-half page in length – *must state why, in the opinion of the endorser, the nominee deserves to receive the Fellow Award. Identical endorsements by two or more endorsers will be automatically rejected* (no form letters, please). Please send these endorsements to me either by e-mail (preferred) or by hardcopy to the address stated in the accompanying text box. Only the Fellow Award nominations need these endorsements.

All 2002 award nominations are to be submitted by October 12, 2001. We strongly encourage the submission of nominations *via* the Internet as described above. Or you may e-mail your nomination directly to *sidawards@sid.org.* If that is not possible, then please send your hardcopy nomination to the address appearing in the associated text box.

The Honors and Awards section of the SID Web site contains all this information along with the names of previous award winners.

Last year the H&AC received a good selection of well-qualified nominees for the Fellow and Special Recognition Awards, but there were very few nominees for most of the major awards. I am especially appealing to you and urge you to nominate worthy candidates for all the major prizes as well as candidates for the Fellow and Special Recognition awards.

As I state each year: "In our professional lives, there are few greater rewards than recognition by our peers. For an individual in the field of displays, an award or prize from the SID, that represents her or his peers worldwide, is a most significant happy and satisfying experience. In addition, the overall reputation of the society depends on who are the individuals who are in its 'Hall of Fame.'

When you nominate someone for an award or prize, you are bringing happiness to an individual and his or her family and friends, and you are also benefiting the society as a whole."

Thank you for your nomination in advance.

– Andras I. Lakatos, Chairman
SID Honors & Awards Committee

5 **01**

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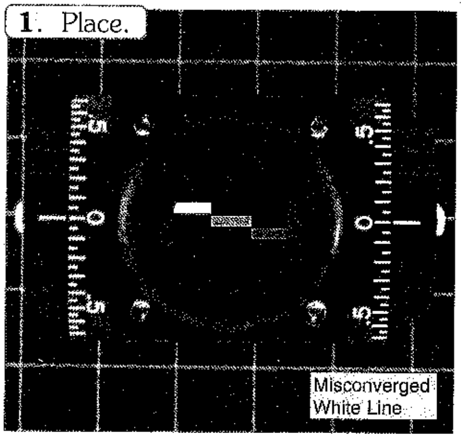

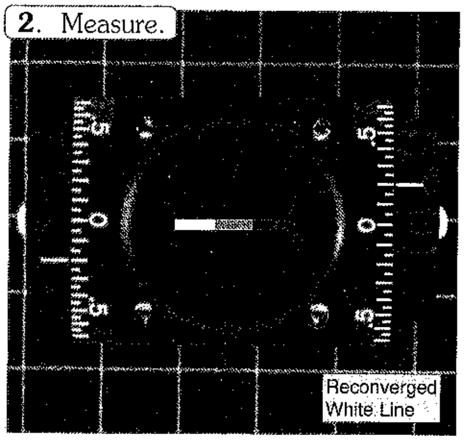

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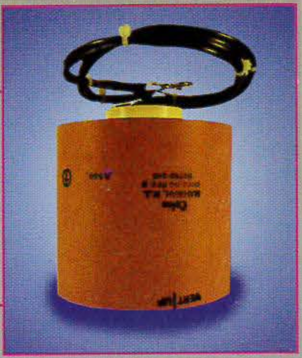

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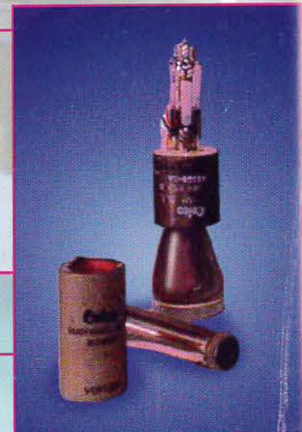

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