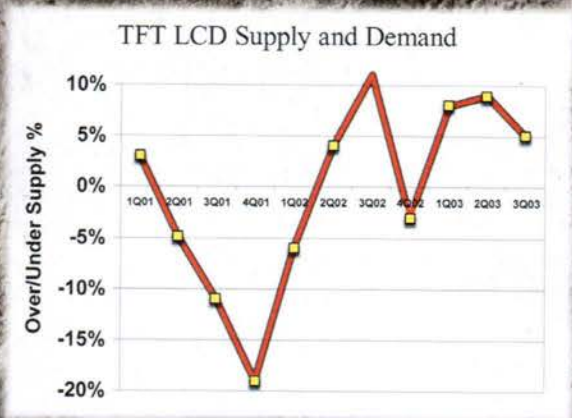
LIQUID-CRYSTAL-DISPLAY ISSUE

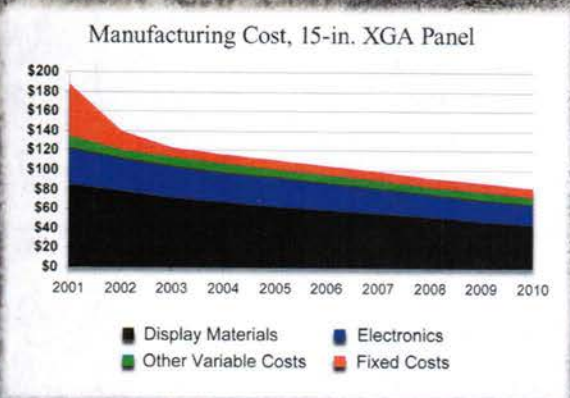
Information DISPLAY

February 2003
Vol. 19, No. 2

SID

Official Monthly Publication of the Society for Information Display





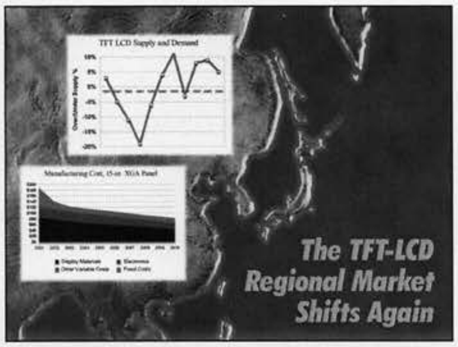
The TFT-LCD Regional Market Shifts Again

- **Measuring Reflective LCDs**
- **Bringing Backlights to the Fore**
- **LCD-Component Costs**
- **LCDs: Price and Demand**
- **SMAU 2002 Report**

Information
DISPLAY

FEBRUARY 2003
VOL. 19, NO. 2

For two quarters in 2002, Taiwan shipped more TFT-LCDs than either Korea or Japan. And with Korean and Taiwanese firms fighting a market-share war that is increasing manufacturing capacity dramatically and reducing manufacturing costs, it's once again a buyer's market for TFT-LCD modules.



iSuppli Stanford Resources

2 **Editorial**
A Visit to Kent
Kenneth I. Werner

4 **My Turn**
The Case for – and against – an Independent Test Facility for Projectors
Alfred Poor

14 **Reflections on Measurement Methods**
Although some issues remain, measurement methods for transmissive LCDs such as those used in desktop monitors are fairly well standardized, but a standard for reflective-LCD performance remains a challenge.
Michael E. Becker

20 **Bringing Backlights to the Fore**
The search is on to develop brighter backlights for LCD TVs and environmentally friendly mercury-free lamps – but the paths these developments take will not necessarily go in the same direction.
Shigeo Mikoshiba

26 **Managing the Cost of LCD Components**
Understanding how regional shifts in LCD production are affecting the component supply chain will help LCD makers do a better job of controlling component costs and weathering industry downturns.
Vinita Jakhanwal

32 **LCDs: Price and Demand**
The seesaw dynamics of the LCD market can be painful, but they are an important part of the engine that continues to drive the rapid expansion of LCD applications.
Sweta Dash

36 **SMAU 2002**
Bigger LCD monitors and TVs capture the glory, 15-in. LCD monitors begin to look passé – even in the cost-conscious Italian market – and CRTs refuse to go away.
Bryan Norris and Michelle Barnes

44 **SID '03 Hotel Reservation Information**

47 **Sustaining Members**

48 **Backlight**
Merger Mania: Yesterday, Today, and Tomorrow
David Lieberman

48 **Calendar of Display-Related Events**

For Industry News, New Products, Forthcoming Articles, and Complete, Continually Updated Conference Calendar, see www.sid.org.

Next Month in
Information Display

SID '03 Preview Issue
- SID '03 Preview
- Back to the Future
- Flexible Displays
- Color Conference Review
- Flat Information Display Conference Review

INFORMATION DISPLAY (ISSN 0362-0972) is published eleven times a year for the Society for Information Display by Palisades Convention Management, 411 Lafayette Street, 2nd Floor, New York, NY 10003; Leonard H. Klein, President and CEO. EDITORIAL AND BUSINESS OFFICES: Jay Morreale, Managing Editor, Palisades Convention Management, 411 Lafayette Street, 2nd Floor, New York, NY 10003; telephone 212/460-9700. Send manuscripts to the attention of the Editor, ID. Director of Sales: Joanne Morgenthal, Palisades Convention Management, 411 Lafayette Street, 2nd Floor, New York, NY 10003; 212/460-9700. SID HEADQUARTERS, for correspondence on subscriptions and membership: Society for Information Display, 610 S. 2nd Street, San Jose, CA 95112; telephone 408/977-1013, fax -1531. SUBSCRIPTIONS: Information Display is distributed without charge to those qualified and to SID members as a benefit of membership (annual dues $75.00). Subscriptions to others: U.S. & Canada: $55.00 one year, $7.50 single copy; elsewhere: $85.00 one year, $7.50 single copy. PRINTED by Sheridan Printing Company, Alpha, NJ 08865. Third-class postage paid at Easton, PA.

editorial

A Visit to Kent

Ohio isn't the center of too much these days, but it is the center of liquid-crystal research in the United States. It owes that honor to the Glenn H. Brown Liquid Crystal Institute (LCI) at Kent State University in Kent, Ohio.

The LCI was founded by Glenn H. Brown in 1965, and quickly sparked liquid-crystal-related research in the physics and chemistry departments. Grants from the U.S. Department of Defense (DoD) and the National Science Foundation (NSF) helped fund rapid growth and establish LCI as a major force in liquid-crystal research.

In 1983, Brown retired. J. William Doane replaced him as Director and had to face a serious challenge. LCI had been established as an institute to foster basic, collective research, but now the basic properties of liquid crystal were becoming understood and LCI needed a new mission. Doane decided to move the institute into the area of applied research and, in his words, have it "become more technologically oriented in order to attract funding." Doane recruited John West, and together they built a technological program centering on polymer-dispersed liquid crystals (PDLCs). In 1985, General Motors licensed the PDLC technology from LCI. The income from the licensing fees, and joint research projects with GM Research Laboratories and Hughes Research Laboratory, confirmed the success of the applied approach.

In the early '90s, with the support of the Governor of Ohio, the Ohio Board of Regents, and Ohio Senator John Glenn, LCI won an NSF grant to establish the Center for Advanced Liquid Crystalline Optical Materials (ALCOM), which became highly regarded and successful. Doane retired as Director in 1996, just as the new Liquid Crystal and Materials Sciences Building – which he had had a hand in designing – was completed. The new building is impressive, with 22,000 square feet of research laboratories, cleanrooms, a display-manufacturing line, classrooms, offices, and support facilities, for a total of 65,000 square feet. Included is the plush, 150-seat Samsung Auditorium, where I gave my invited seminar. (Giving the seminar was my excuse for visiting Kent and the LCI.)

LCI's current Director is John West, who received me graciously and is apparently well on his way to securing funding that will assure LCI's good health into the foreseeable future.

It is worth noting that LCI is a liquid-crystal institute, not a liquid-crystal-*display* institute. A substantial amount of display work goes on, of course, but other applications abound – from beam-steering to bacterial detection. The presence of LCI on the Kent State campus has stimulated liquid-crystal studies in more traditional divisions, such as the chemistry and physics departments and in the medical school.

Also important to the missions of LCI and ALCOM is the spinning off of technology companies. In what turned out to be a very busy day, I was able to visit only two of the 30 liquid-crystal-related companies in the area. The first was Kent Displays, which was founded in 1993 by Bill Doane and the financier William Manning (Doane is chief scientific officer). The company is well known for its continuing development and application of cholesteric liquid-crystal displays (Ch-LCDs), which are reflective, visible in bright sunlight, and bistable, with very low power consumption. While at Kent Displays, I saw a

continued on page 40

Information DISPLAY

Editor: Kenneth I. Werner
Managing Editor: Jay Morreale
Administrative Editor: Dian Mecca
Administrative Assistant: Ralph Nadell
Contributing Editors: David Lieberman, Bryan Norris, Alfred Poor,
Advertising Manager: Jay Morreale
Sales Manager: Joanne Morgenthal

my turn

The Case for – and against – an Independent Test Facility for Projectors

by Alfred Poor

One day – as I was looking over the latest press release trumpeting the launch of a new data projector boasting so many zillion "ANSI" lumens – I was struck by a vision. In order to get brightness specifications that buyers can trust, why not create an independent testing lab that will test new projectors and give them a "seal of approval" brightness rating? Wouldn't this be a great idea? And after some lengthy rumination, I answered myself with a clear and decisive No!

I confess that losing arguments with myself is not all that uncommon an occurrence. In this particular case, the issues are not as clear as they might first appear. As a result, I thought my reasoning might be of interest, or perhaps the starting point for further discussion.

An Independent View

The case in favor of creating such a facility is fairly straightforward, as the need can be stated quite clearly. Under the current circumstances, some manufacturers appear to be more conservative than others in reporting the light output of their projectors. This is based on my own luminous-output measurements of dozens of different projector models in recent years. I can see how the current situation could create problems for manufacturers: Do they risk giving up a competitive advantage to another company with more liberal testing procedures, or do they adjust their own specifications to match "industry practice"?

One way out of this box would be to create an independent facility in which all projectors are tested under the same conditions, using the same equipment, and following the same protocols. This effort could be funded directly by the industry; any manufacturer wanting the "approved" brightness specification would pay for the testing.

Pretty simple, right? Well, as with most simple solutions, I think it's probably wrong.

The Opposing Position

My opposition could be based on all the hurdles involved in setting up such a system. Engineering prototypes and pre-production samples rarely provide the same performance as the full-production units do, which makes it difficult to provide reliable measures in advance of the product launch date. And there is notable variation in the performance among individual production units, which raises questions about what represents an adequate sample. I will also mention that I have seen cases in other product categories in which manufacturers have been extra careful about the quality control of products provided for testing; some might even characterize their extra attentions as "tweaking."

However, all of these factors are beside the point. The main reason that we don't need independent testing of projector brightness is simple: it doesn't matter anymore.

The fact of the matter is that product improvements have overtaken the brightness issue. Current projectors are brighter overall, and for the most part are now "bright enough" for their intended applications. Back when lightweight projec-

continued on page 43

Society for Information Display
610 S. 2nd Street
San Jose, CA 95112
408/977-1013, fax -1531
e-mail: office@sid.org
http://www.sid.org

Reflections on Measurement Methods

Although some issues remain, measurement methods for transmissive LCDs such as those used in desktop monitors are fairly well standardized, but a standard for reflective-LCD performance remains a challenge.

by Michael E. Becker

TAKE a close look at two different reflective liquid-crystal-display (LCD) panels; which one shows the better contrast? It's a simple question, but one that proves to be difficult to answer. The way in which a panel is illuminated and observed has a major impact on the perceived visual results. At present, there is no broad agreement on how the illumination and measurement of reflective displays should be accomplished.

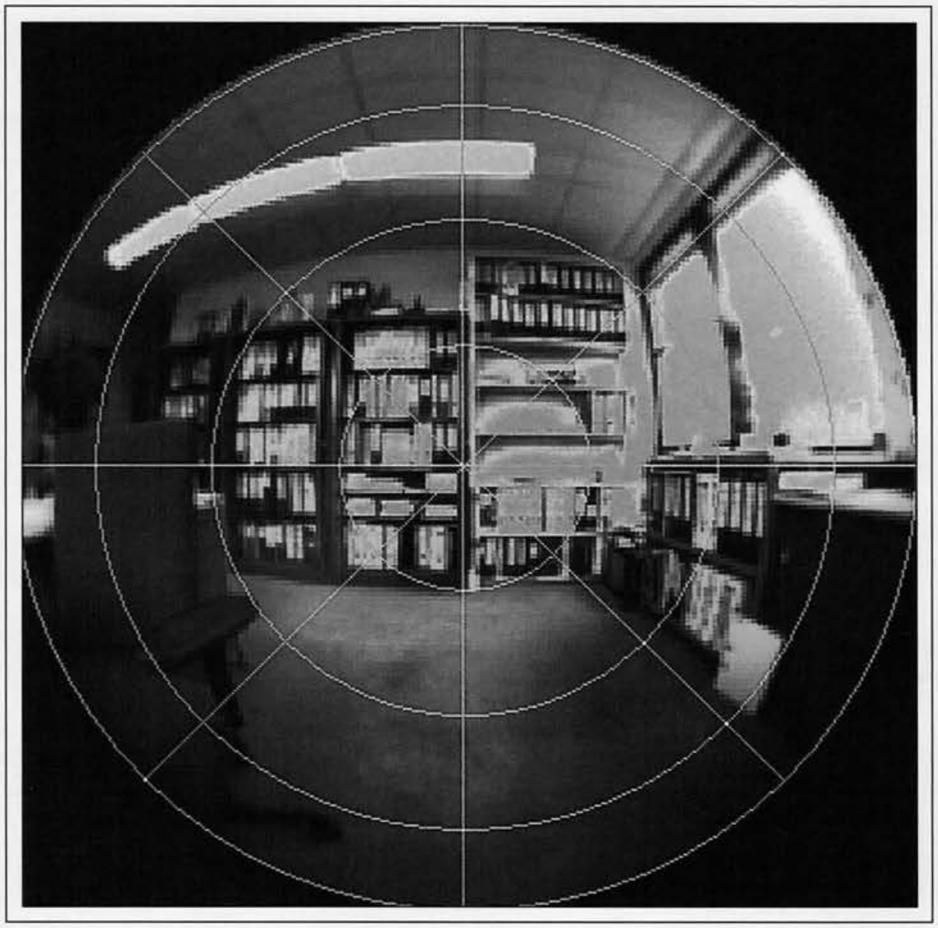
In 1976, G. G. Barna first proposed a method for illuminating reflective LCDs during measurement by using a glass hemisphere that produced a multidirectional illumination that approximated diffuse lighting. This concept evolved into a commercial product in Germany in 1985, but despite the available knowledge and instrumentation there still is no international standard for reflective-LCD panels.

In the December 1994 issue of *Information Display*, James Greeson contributed the article "Display Standards in Trouble." It seems that 8 years after the status analysis in the first paragraph of that article, little has changed for the better. But there is some cause for optimism.

Existing LCD Standards

After many years of cooperative and constructive discussions, the International Electrotechnical Commission (IEC) SC47C/WG2 has standardized simple approaches to measuring LCDs in the framework of IEC 61747: "Liquid crystal and solid-state display

Michael E. Becker, who has extensive experience in LCD metrology instrumentation, established Display-Metrology & Systems in January 2002. The firm is located at Marie-Alexandra Str. 44, D-76135 Karlsruhe, Germany; telephone/fax +49-721-981-2268, e-mail: m.Becker@display-metrology.com.



Michael E. Becker

***Fig. 1:** The directional luminance distribution in a typical office as "seen" by a desktop-computer monitor is shown here in a polar-coordinate system (maximum inclination $\theta_{max} = 80°$).*

0362-0972/03/1902-014$1.00 + .00 © SID 2003

devices." This standard comprises the following sections: Generic, Sectional, and Blank Detail Specifications; Visual Inspection; Environmental Endurance Test; Terminology and Letter Symbols; Essential Ratings and Characteristics; and, finally, the "Measuring Methods." This document, however, is restricted to transmissive LCDs.

The IEC TC 100 has generated an additional standard – IEC 61966-4: "Colour Measurement and Management, Part 4: Equipment using LCD panels" – that describes a metrology for electro-optic and electro-colorimetric characteristics, lateral variations of luminance and chromaticity, and variations of luminance and chromaticity with viewing direction. This document is also for transmissive LCDs.

The terms and definitions used by these two IEC standards unfortunately are not synchronized, and the measurement methods exhibit differences. As a result, trying to implement both standards can be confusing for the user.

The Video Electronics Standards Association (VESA) has developed its own Flat Panel Display Measurements (FPDM) standard; Version 2.0 was published in June 2001. Even though it does not explicitly address the subject of reflective LCDs, it is a valuable resource for all aspects of well-founded display metrology in theory and application – including various approaches to reflectance evaluation – and it surely is the most comprehensive and authoritative text on the subject currently available.

Metrology for Reflective LCDs

It is difficult to develop measurement procedures for displays that produce unambiguous and reproducible results. For the case of reflective LCDs, it is particularly hard because of the close coupling between the measuring apparatus – the illuminator and receiver – and the display to be measured. This dependence of the results on the instrumentation implies, for instance, that the contrast of a reflective-LCD device and its variation with viewing direction is not an intrinsic property of the device itself. It becomes a meaningful characteristic only when linked to well-specified conditions of the measurement apparatus and procedure. These "conditions to be specified" must be clearly identified in the standard.

The problems related to measuring the electro-optical properties of reflective LCDs have been known since the early attempts to characterize and optimize the variations of LCD contrast with viewing direction. In addition to G. G. Barna's work with "diffuse" illumination, another approach was implemented in Japan and later fixed in a national standard of the Electronic Industries Association of Japan (EIAJ) in ED-2523 MM "Reflective LCDs," published in 2001. This standard uses a directed beam source out of the specular direction of the receiver. As a result, variations of the optical properties of LCDs with viewing direction cannot be measured in a reasonable way.

The Barna and EIJA approaches make use of two extreme illumination situations – multi-directional "diffuse" and directed beam illumination – but the results obtained are still subject to superficial comparison and manipulation by commercial interests because the conditions under which the "numbers" listed in the data sheets have been generated often are not known, nor are the respective consequences and implications understood.

The results that are obtained with these two approaches show large differences, and the reasons for this have been analyzed in detail and were published in a series of papers presented at SID conferences in the early 1990s. The intrinsic variations of contrast with viewing direction can only be reproduced in the reflective mode of operation under multi-directional "diffuse" illumination.

CIE publication No. 38 (1977) provides a basic reference to the subject of measurement and evaluation of reflectance characteristics in general. This is a valuable guideline that seems to be unknown to many authors who work on and publish about the subject of reflective displays.

Metrology Standard for Reflective LCDs

Finally, there is a move to create a standard for reflective LCDs in Working Group 2 (WG2) of the IEC Technical Committee 47C (TC47C). This standard is supposed to cover the needs of display manufacturers in their research and development, engineers in integrating displays into electronic devices, and purchasing departments in acquiring those displays for the production line. The standard will provide

- Approaches for detailed characterization of the electro-optical properties of the sample LCD *vs.* viewing direction – such as the bidirectional reflectance distribution function (BRDF) – and other data (such as spectra) required for the subsequent numerical simulation of complex display systems.
- Realistic prediction of visual performance under actual illumination conditions.
- Procedures for testing conformity to product specifications, as required for acceptance screening.
- Applicability to all kinds of reflective displays.
- Applicability to a wide range of instrumentation, including goniometric and conoscopic devices.
- Applicability to a wide range of operator skills and laboratory budgets.
- Robustness, which includes easy alignment, low uncertainty, and low parameter sensitivity, which are required for good reproducibility.

Illumination Conditions

Stationary display devices, such as computer monitors that sit on a desk in a typical office environment, are relatively simple to analyze. We can check the illumination condition in this case by just "looking through the eyes of the monitor" with an appropriate electronic camera (Fig. 1). In the situation shown in the figure, the most dominant light sources are the windows (daylight) and the ceiling luminaires. Measured luminance varies between 100 cd/m^2 (ceiling areas and floor) and 30 kcd/m^2 (windows). With such an approach, and with additional spectral analysis, the illumination can be characterized as follows:

- Intensity (*e.g.*, luminance) and spectrum *vs.* direction of light incidence (θ_i, ϕ_i) and
- Temporal characteristics (short- and long-term variations) of intensity and spectrum.

This example illustrates that even a simple indoor scenario exhibits a wide dynamic range of intensity. The directional distribution is different from case to case, as are the sources and spectra, which can include daylight, incandescent lamps, discharge lamps, and others.

As complex as it may be for a stationary display, the situation becomes even more variable for portable devices. Neither the orientation of the display with respect to the light sources nor the direction with respect to the user can be generally defined. Users want displays in portable devices to perform well in all locations and under a broad range of illumination conditions – indoor, outdoor, clear blue sky, cloudy sky – that is beyond any narrow technical definition. Since the variety of real-life situations is much too large to be adequately covered by a single "typical case," we must consider which special illumination cases might be of most interest – given the final application of the product – even if they do not occur exactly in reality.

At one extreme – and one with distinct advantages, *e.g.*, the dynamic range of the

Fig. 2: *Four basic illumination geometries are shown in polar representations: (a) "directional" illumination at 30° with a fixed receiver (R); (b) multi-directional illumination shaded by the head (S_H) and shoulder and trunk (S_B) of an observer and fixed receiver (R); (c) multi-directional illumination with shade and gloss trap (S_1); and (d) multi-directional illumination with head shade (S_H) and gloss trap (S_1), both with variable receiver inclination for scanning of the viewing cone.*

detector – is illumination from a wide range of directions, which approximates "diffuse" illumination. This geometry, successfully used in the display industry for more than 20 years, yields lower contrast values than other non-diffuse illumination schemes, but seems to be closer to what we actually see.

The other extreme case is a directed beam that illuminates the sample from a given direction within a small solid angle. Suitable choice of the receiver direction (the direction of observation) can produce impressive contrast values.

And thus we come to the current dilemma in reflective-display metrology. We may choose between two illumination geometries: One provides a high contrast value for a specific viewing direction (with no variations included) and the other yields more moderate contrast values while allowing for detailed evaluation of variations with viewing direction.

The standard under development might do well not to exclude either of these extremes, and it should allow a much wider range of non-extreme cases. In a first section, it could include a limited number of useful configurations with one or more fixed receiver directions, such as illumination with ring-light, directed beam, "diffuse," and "shaped" illumination. In a second part, other schemes that allow scanning of the viewing cone for more detailed analysis must be included.

Specification of Illumination Geometries

To allow the illumination conditions in a test-and-measurement set-up to be applied to a wide range of application situations without sacrificing reproducibility, the illumination has to be specified in detail. This is achieved by measuring quantities such as luminance and spectra at the measuring spot on the sample as a function of the direction of light incidence.

The illumination from the perspective of the measuring spot can be described in polar-coordinate systems for several typical cases (Fig. 2). The sample is illuminated from the directions indicated by bright regions, with the dark regions representing shadow (no illumination). Configurations A and B measure the reflective LCD from fixed but selectable directions, while configurations C and D allow scanning of the viewing cone. There are many more possible combinations of illumination and receiver direction than shown here, and they should be allowed in the standard as long as they are well specified.

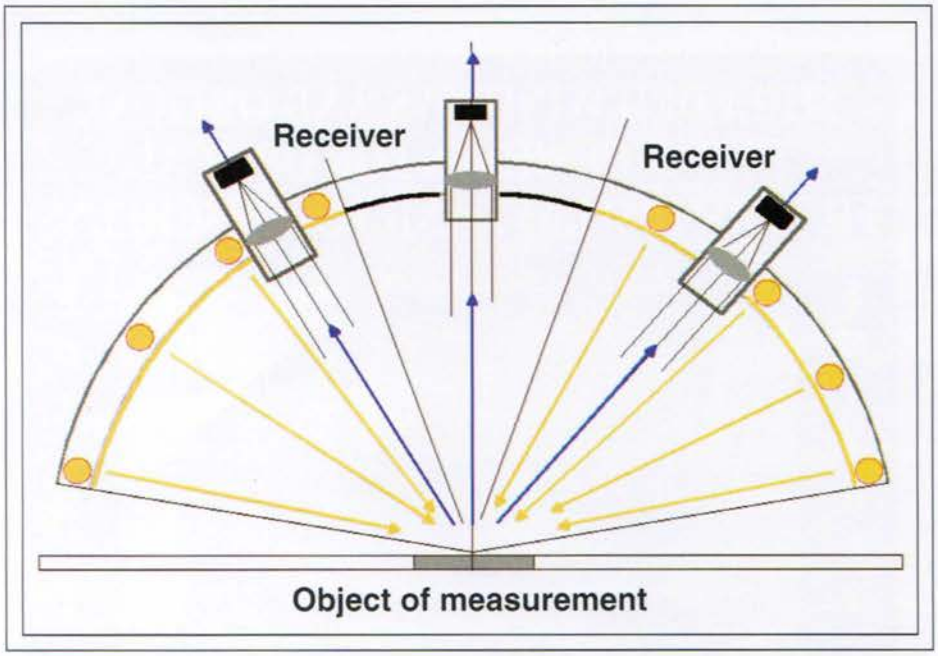


Fig. 3: *A double-layered dome centered around the measuring spot can provide a versatile set-up for illumination and detection when measuring the characteristics of a reflective flat panel.*

Configurations A and B use fixed receivers normal to the sample, with directional illumination in A and "diffuse" illumination between 35° and 70° approaching an extended ring-light geometry in B. In addition to the shadow cast by the head of the observer (S_H), the shadow of the observer's shoulders and trunk (S_B) is also included. The receiver (R) is assumed to be in the center of the head. The dimensions of the shaded regions can be adapted according to the distance from the display to the observer.

Configuration C shows "diffuse" illumination up to 70° and a receiver with a variable angle of inclination for motorized scanning of the viewing cone. The slit through which the receiver "looks" at the display extends to the far side of the hemisphere, where it acts as a gloss trap that suppresses unwanted reflections from the display surface. The width of this gloss trap can be adjusted to the width of the haze as shown by S_1 in configuration D.

A Flexible Solution

Implementing the principles just described produces a flexible concept and device that can be used to measure reflective-display performance across a wide range of different illumination and detection geometries. It can be used to recreate complex lighting conditions, such as those of the real-world office setting illustrated in Fig. 1. We can also map all light sources in the surroundings of the display into luminance sources on a hemisphere with the measuring spot in its center using a dome construction (Fig. 3).

In this double-layered dome construction, the outer dome is the carrier for the light sources and for the receivers, while the inner dome shapes the directional and lateral distribution of light by using either a scattering translucent material for homogenization of the light distribution or an absorbing material for generation of shadow regions. Clear transparent material is provided for discrete sources and for the receivers. A variety of light sources can be used, including incandescent bulbs, LEDs, or circular fluorescent tubes, or light can be supplied from remote sources *via* light-guiding fibers. This makes it possible to create the desired combination of light sources with different spectra and intensities.

The dome also can carry a multitude of receivers that are "looking" at the measuring spot on the sample from different directions. All receivers are connected to a special multi-channel spectrometer with simultaneous fast photometric detection, such as the Multi-Spect™ spectrometer from Display-Metrology & Systems. The light reflected by the object of measurement is analyzed in terms of luminance and spectral distribution for multiple viewing directions simultaneously. The short time required for one multi-directional spectral measurement makes this device well suited for acceptance screening of a large number of samples and for checking the conformity to product specifications under specific illumination conditions.

Setting the Standard

In order to effectively compare the performance of display devices, there must be a range of broadly accepted measurement conditions and procedures that are unambiguous and reproducible. International standards can provide these guidelines, and one is now under development for reflective displays. This category of displays has a number of special characteristics that make it especially difficult to make measurements that are significant and reproducible, and are at the same time reliable predictors of the end user's perception of the panel's displayed information. Such predictions will most probably require measurements under more than one illumination condition. The best measurement and evaluation testing methodology will be one that is flexible enough to address the wide range of environments where reflective panels are to be used, and yet be easy to describe accurately so that the test environment can be duplicated. The double-layered dome suggested here meets these requirements.

As consumer demand increases for portable low-power electronic devices, such as PDAs and mobile phones, we can anticipate both increased competition to provide the displays for these devices and increased sophistication on the part of product designers and consumers in terms of their expectations for display image quality. An international display standard can make the measurement and reporting of differences between these displays more accurate and reliable, which will help designers and end users make better buying decisions. ■

Bringing Backlights to the Fore

The search is on to develop brighter backlights for LCD TVs and environmentally friendly mercury-free lamps – but the paths these developments take will not necessarily go in the same direction.

by Shigeo Mikoshiba

BACKLIGHTS can not be seen, but if they were not there it would be very noticeable. They are an essential part of liquid-crystal displays (LCDs) used in desktop monitors and notebook computers, yet we rarely give them much thought. A typical active-matrix LCD panel absorbs as much as 96% of its backlight's output – even when displaying an all-white image. Thus, the backlight's luminance must be more than 20 times the desired luminance of the display.

At the same time, the backlight must be light in weight and compact so that it fits in the small housings that are the hallmark of LCDs. And for portable applications, the backlight must be highly efficient at converting electrical power into light so that maximum battery life can be delivered at minimum weight.

As if current demands weren't stringent enough, changes in the marketplace and customer expectations pose new challenges for LCD backlights. Many manufacturers have targeted the home-entertainment market and are developing large LCDs for television use (LCD TVs) that must be brighter than computer monitors. At the same time, environmental concerns about the mercury (Hg) used in current backlights are driving the research toward alternative materials.

Shigeo Mikoshiba is a professor of electronic engineering at the University of Electro-Communications, 1-5-1 Chofu-ga-oka, Chofu, Tokyo, Japan; telephone/fax +81-424-83-3294, e-mail: mikoshiba@ee.uec.ac.jp. Prof. Mikoshiba has extensive experience in the design of PDPs and LCD backlights, and is a Fellow of the Society for Information Display.

Television Requirements

Researchers are diligently seeking ways to improve LC-TV picture quality. Let us assume that a 20-in.-diagonal LCD-TV module – including a polarizer and a color filter – transmits 4% of the light from its backlight. If one wants to match the 800-cd/m^2 peak luminance that is typical for CRTs, then the peak backlight luminance must be 20,000 cd/m^2 (Table 1). The peak luminous flux must then be 7500 lm. If the lamp has a 40-lm/W efficiency, the average lamp power will be 47 W.

A blinking-backlight technique is sometimes used to improve moving-image quality. If the light-emission duty factor of the blinking is 1/8, then the peak luminous flux must be increased by a factor of 8, to 60,000 lm. This value, although instantaneous, is 20 times higher than that of the conventional 40-W lamp used for room lighting. Increasing light output 20-fold is a significant challenge.

Conventional LCD backlights generally use cold-cathode fluorescent lamps (CCFLs). As the gas in the CCFLs, mercury has superior luminance and efficiency characteristics, making it the gas of choice for conventional LCD backlights. A typical 400-mm-long 2.6-mm-outer-diameter CCFL has a luminance of 40,000 cd/m^2 and produces a flux of 300 lm. It would take six lamps behind a liquid-crystal panel to provide the average flux of 1900 lm

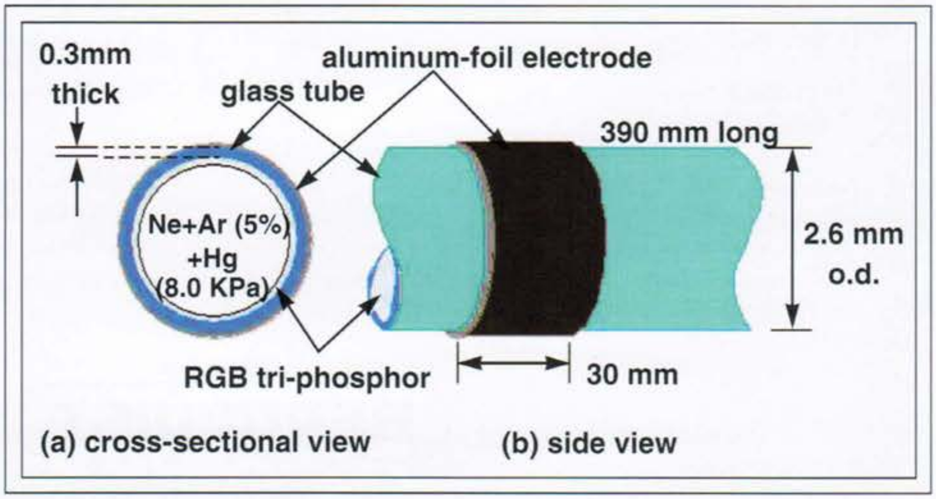


Fig. 1: A capacity-coupled Hg discharge lamp relies on aluminum foils as external electrodes.

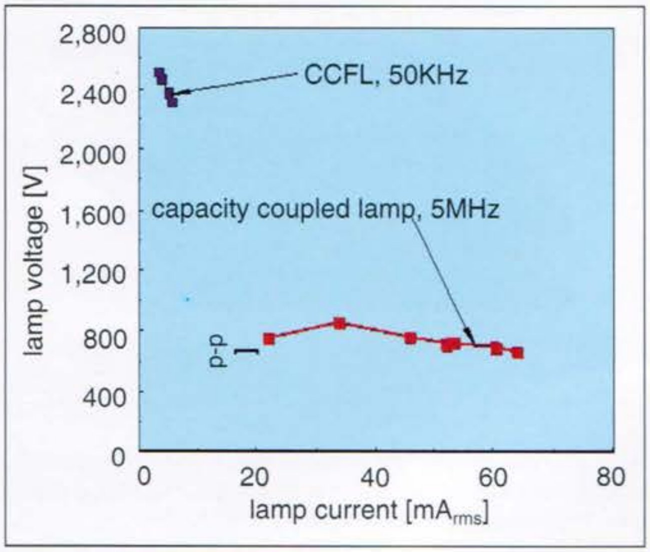


Fig. 2: A capacity-coupled Hg discharge lamp operates at a much lower voltage than that of a CCFL, but the current and drive frequency are much higher.

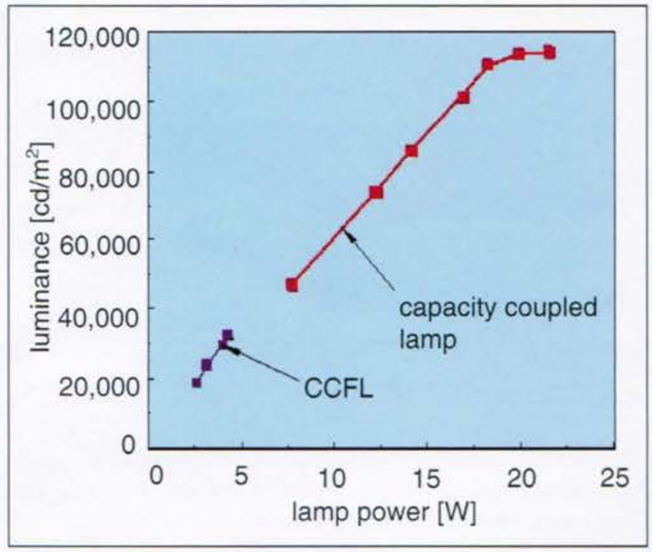


Fig. 3: The luminance–power curves for the capacity-coupled discharge lamp and CCFL lie along a single line.

that is required by our hypothetical 20-in. television. If the 1/8-duty-factor blinking backlight is considered, then the required number of lamps increases to 48, which is unrealistic.

Capacity-Coupled Hg Discharge Lamp

One of the methods of increasing the luminous flux is to increase the lamp luminance, which can be achieved by increasing the discharge current of a CCFL. One problem with this approach, however, is that it increases the sputter rate of the cathode inside the tube; the sputter rate is proportional to the current to the

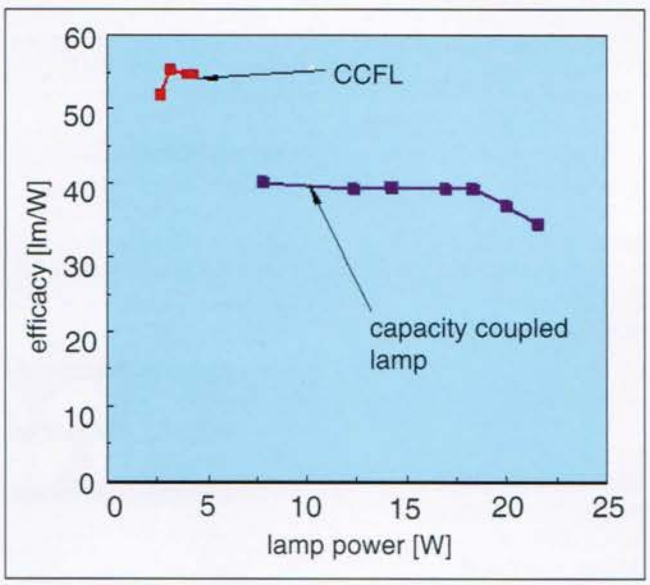


Fig. 4: Capacity-coupled lamps can operate at higher power than CCFLs, but the efficacy is lower. Drive frequencies are 5 MHz and 50 kHz, respectively.

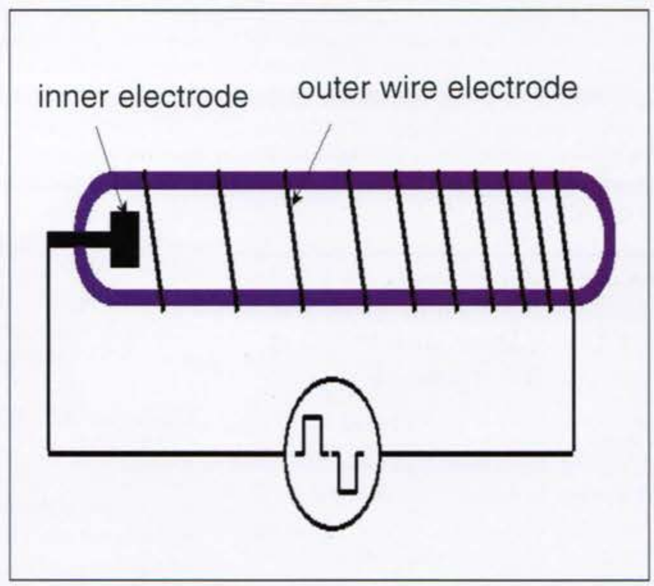
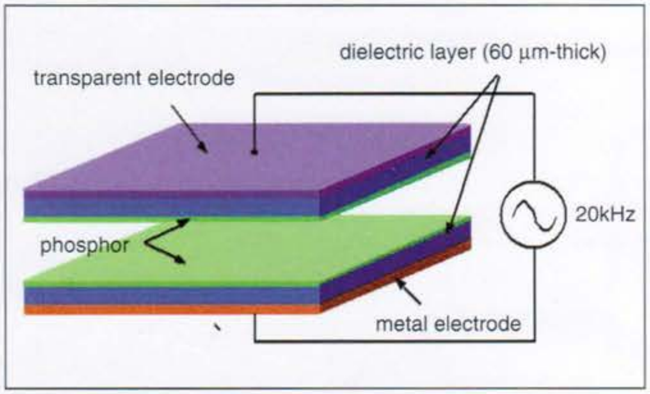


Fig. 5: This cylindrical Xe lamp design uses both an inner and an outer electrode. [Source: H. Noguchi et al., SID Intl. Symp. Digest Tech. Papers, *935–937 (2000).]*



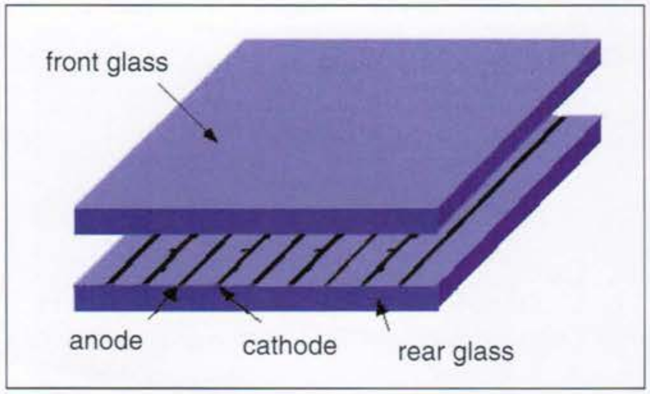


***Fig. 6:** A Xe barrier discharge lamp has two flat conductors covered by dielectric and phosphor layers. [Source: T. Urakabe* et al., J. Light & Vis. Environ. ***20,** No. 2, 20–25 (1996).]*

***Fig. 7:** One flat-Xe-lamp design uses alternating cathodes and anodes along the same surface. [Source: M. Ilmer* et al., SID Intl. Symp. Digest Tech. Papers, *931–933 (2000).]*

2.5 power. This results in a shortened lamp life. Lamp life can be extended despite the higher current by introducing a capacity-coupled discharge lamp (Fig. 1). Since the electrodes surround the discharge tube externally and are not immersed in the plasma, there is no ion bombardment and long lifetime can be expected.

The lifetime can be further extended by the application of a high-frequency field. Because of the alternating field, the number of ions impinging upon the wall is significantly reduced, with less sputtering of the glass wall. Also, the ionizing collision rate of electrons with neutral atoms increases, resulting in the efficient production of charged particles and hence reduced cathode fall. This reduces the ion energy in the cathode fall, resulting in even less sputtering.

Table 1: Requirements for LC-TV Backlights. A 20-in. Diagonal, 4:3 Aspect Ratio, and 25% APL Are Assumed

Item	Target
Peak/average luminance	20000–5000 cd/m^2
Peak/average luminous flux	7500–1900 lm
Dimming	5–100%
Lamp efficiency	40 lm/W
Peak/average power	190–47 W
Life	20,000 hours
Response	0.2 msec
Environmental issue	Hg free

Sample lamps of this design have a discharge tube that is 390 or 190 mm long, with an outer diameter of 2.6 mm. The tube contains a mixture of neon, argon, and mercury – Ne + Ar (5%) + Hg – at 8 kPa. Aluminum foils 30 mm wide are wrapped around the two ends of the tube to serve as external electrodes.

The capacity-coupled lamp can be driven with a voltage lower than that of a typical 50-kHz-driven CCFL (Fig. 2). Also, the capacity-coupled lamp can be driven with a discharge current that is an order of magnitude higher than that of the CCFL because there is no sputtering of the metal electrodes.

The luminance–power curves for the capacity-coupled and CCFL lamps lie on a single line (Fig. 3). A luminance greater than 100,000 cd/m^2 is obtained with the capacity-coupled lamp. The peak luminance and flux of the capacity-coupled lamp are 3.4 times those of the CCFL. The efficiency of the capacity-coupled lamp, however, is 63% that of the CCFL (Fig. 4).

Xenon for Backlights?

Backlights for TV applications should have a luminance response of 0.2 msec (Table 1). In an adaptive brightness intensifier, the average picture level of a TV field time is detected, and the luminance of the backlight is adjusted according to the level. By doing this, the ability to reproduce gray scale in dark images can be improved. Also, because the backlight does not have to operate at full power all the time, its power consumption is reduced.

Hg lamps need several minutes to reach their saturation level because the lamp temperature changes slowly. Accordingly, some means of luminance detection and adjustment is required if the adaptive-brightness-intensifier technique is adopted. If the lamp is dimmed to a low luminance level for a prolonged period, the lamp temperature drops and the Hg lamp will not operate efficiently. A xenon-based discharge is preferable for such a design. Usually Ne and/or Ar are added as buffer gases to reduce the firing voltage and to prolong lamp life. This has the added advantage of eliminating Hg from the lamp and avoiding its environmental problems.

But Xe can not be simply substituted for Hg as the gas. The Xe positive-column discharges tend to contract to form a narrow channel, but this can be eliminated if (1) the drive-voltage pulse width is shortened, (2) the

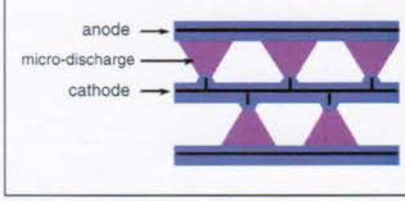


***Fig. 8:** The micro-discharge patterns in Xe barrier discharge lamps fan out from projections on the cathodes. [Source: M. Ilmer* et al., SID Intl. Symp. Digest Tech. Papers, *931–933 (2000).]*

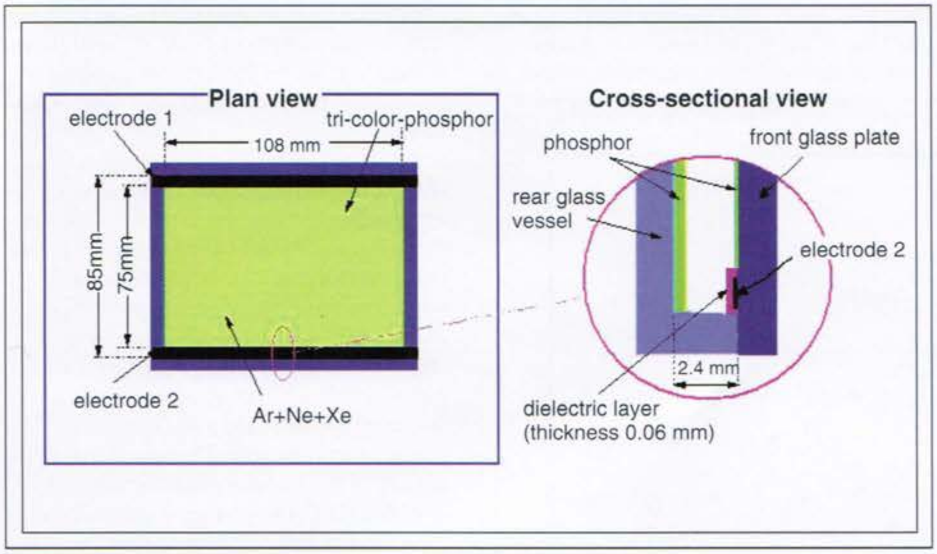


Fig. 9: *This Xe flat-discharge lamp has a simple structure. [Source: Y. Ikeda* et al., SID Intl. Symp. Digest Tech. Papers, *938–941, 2000).]*

rise of the pulse is increased, (3) the pulse interval is prolonged, and (4) the pulse voltage is reduced.

Cylindrical Xe Lamp

One design for a Xe lamp consists of an inner electrode positioned at one of the ends of a glass tube (Fig. 5). The second electrode is a wire coiled around the outer surface of the lamp. To obtain uniform luminance distribution along the tube axis, the space between the wire electrode varies according to the distance from the inner electrode. In order to avoid the contraction of the positive column, the lamp is operated with pulse voltages instead of a sinusoidal wave. The typical lamp luminance is 6000 cd/m^2 with a 6.5-W input.

Another type of cylindrical Xe lamp is 400 mm long with an outer diameter of 10 mm. A pair of 400-mm-long insulated electrodes run on the inner wall of the tube in the axial direction. Phosphor is coated on top of the dielectric insulating layer. In order to enhance illuminance in a preferred direction, a reflective coating is placed between the dielectric and the phosphor, leaving an open strip for the exiting light. An Xe excimer radiation of 172 nm then excites the phosphor.

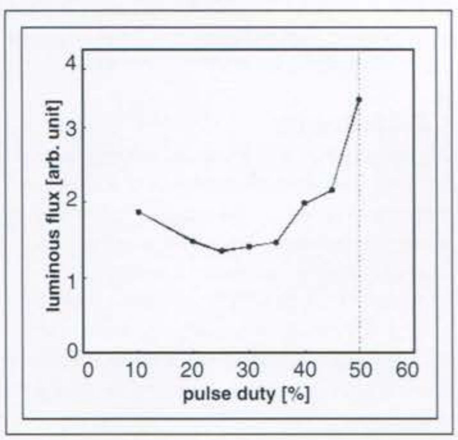


Fig. 10: *The luminous flux* vs. *pulse duty factor of a Xe lamp with a flat discharge shows an increase in flux as the pulse duty factor nears 50%.*

Flat Xe Lamps

Another way to increase the output flux is to increase the light-emitting area. The lamp can be made flat, with its active area as wide as that of the LC panel (Fig. 6). Xe micro-discharges are formed between two parallel-plane electrodes which are covered with dielectric layers. The two plates are spaced between 0.5 to 2 mm apart. The space is filled with either pure Xe or a Xe–Ne mixture at a pressure of 10–80 kPa. Xe-excimer radiation excites the phosphor on the dielectric layers. When the lamp is driven with a 20–30-kHz ac voltage of 1000 Vrms, many micro-discharges with a diameter of about 0.1 mm form in the gap between the two layers. A luminance of 3500 cd/m^2 with a luminous efficiency of 27 lm/W was obtained for a 3.5-in.-diagonal lamp.

Another type of flat Xe lamp has anodes and cathodes with projections (Fig. 7). The electrodes are covered with a dielectric layer and are separated by 10 mm. The space between the layers is filled with Xe at a pressure of 13 kPa to generate Xe-excimer radiation (Fig. 8).

Xe Lamps with Flat Discharges

Although the external configurations of the lamps of the previous section are flat, the discharges are not. There are a large number of tiny discharges in the lamps. It is possible, however, to design a lamp with a single flat discharge that occupies the entire volume of the lamp.

A 7-in.-diagonal Xe flat-discharge lamp (Fig. 9) consists of four parallel sections, each 175 × 27 mm. The discharge gap of 2.4 mm is kept constant across the lamp area by 12 spacers. The space is filled with a gas mixture of Ar + Ne (32%) + Xe (9%) at a total pressure of 30 torr. A mixture of three primary-color phosphors – $(Y,Gd)BO_3$:Eu for red, $LaPO_4$:Ce,Tb for green, and $(Y,Gd)(P,V)O_4$:Eu for blue – is deposited on both the front and rear substrates, except for the regions above the electrodes. The thickness of the phosphor layers is 0.01 mm for the front substrate and 0.1 mm for the rear substrate.

The lamp's two electrodes are driven with two trains of square pulses, which have an identical amplitude, width, and interval, but a 180° phase difference. The variation of output flux is a function of the drive-pulse duty factor (Fig. 10). The duty is defined as a ratio of the pulse width to pulse interval. When it

Table 2: Typical Performance of the Flat-Discharge Xe Lamp *vs.* the FPL 27

Item	Xe flat lamp	FPL 27 (JIS)
Gas	Ar + Ne (32%) + Xe (9%)	Ar + Hg
Active area	0.0256 m^2	0.035 m^2
Luminance	18,000 cd/m^2	14,300 cd/m^2
Luminous flux	825 lm	1500 lm
Illuminance (30 cm)	1700 lx	1350 lx
Efficiency	18.1 lm/W	62.5 lm/W
Lamp input power	40 W	24 W

is less than 50%, light is emitted at the leading and trailing edges of the pulses, resulting in four light emissions in a voltage cycle. With a 50% duty factor, the emission from the trailing edge of one of the pulse trains merges with the emission from the leading edge of the other pulse train. Although there are only two light emissions within a cycle, the total flux becomes higher, so the lamp efficiency increases as the pulse duty factor approaches 50%.

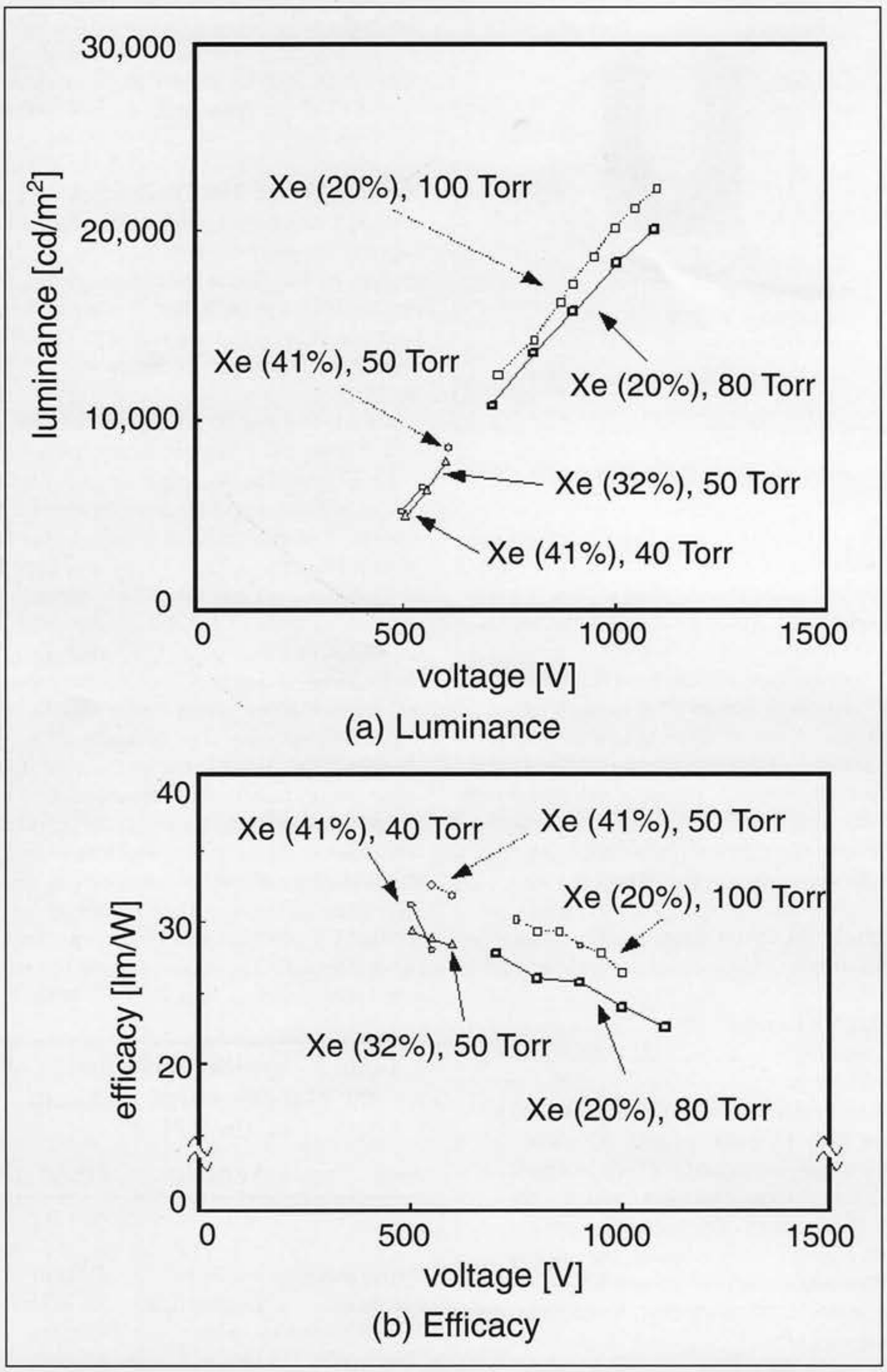


Fig. 11: *(a) Measured luminance and (b) efficiency of flat-discharge lamps show the effects of various Xe mixture ratios and total pressures. Xe partial pressure is 16 torr (solid lines) or 20 torr (broken lines).*

Test panels having a 0.5-in. diagonal and with various Xe mixture ratios were tested for luminance and efficiency (Fig. 11). The Ne concentration was kept constant at 30%. The pulse interval was 80 μsec for all cases. It was found that both luminance and efficiency increase with higher Xe partial pressure, regardless of the Xe percentage. With a Xe partial pressure higher than 20 torr, the discharge contracts and a flat uniform discharge is not obtained. The typical performances of the Xe lamp and a commercially available Hg fluorescent lamp (Japan Industrial Standard FPL 27) with comparable output characteristics show that the Xe lamp is brighter but not as efficient (Table 2).

It is easier to use Hg instead of Xe for flat-discharge lamps because the discharge contraction is less likely to occur for Hg. For the Xe lamps, luminance increases but the efficiency decreases as the drive voltage is increased because of an electronic de-excitation of the imprisoned Xe resonance atoms. For Hg lamps, however, both the luminance and efficiency increases with drive voltage because the lamp temperature – and hence the Hg vapor pressure – increases. The typical luminance and efficiency of the Hg flat-discharge lamps are 30,000 cd/m^2 and 50 lm/W, respectively. The peak luminance of the Hg flat-discharge lamps is three times higher than that of the Xe lamps, and the peak efficiency of the Hg lamps is 1.7 times that of the Xe lamps.

Eliminating Hg

Hg has superior electrical and optical characteristics for use in backlights, and Xe cannot compete with Hg in this respect. Nevertheless, strong temperature-dependency and environmental concerns encourage a shift to Xe, especially for LCD-TV backlights. Unless effective methods of treating Hg waste can be developed, the demand for alternative lamp designs capable of meeting the performance requirements will only increase. Initial test results indicate that while current Xe designs are not yet bright enough to replace Hg lamps in most applications, additional research should yield further improvements. ■

Managing the Cost of LCD Components

Understanding how regional shifts in LCD production are affecting the component supply chain will help LCD makers do a better job of controlling component costs and weathering industry downturns.

by Vinita Jakhanwal

MANUFACTURING large-sized thin-film-transistor liquid-crystal displays (TFT-LCDs) is a capital-intensive and time-consuming process. Because the LCD industry has been excessively dependent on a few applications, changes in market demand for those applications have had dramatic impact on the entire industry.

A basic problem for the industry has been that changes in demand often occur rapidly. But because of the capital-intensive and slow-to-react nature of TFT-LCD manufacturing, the supply side cannot be so nimble. The lag in information dissemination and the long lead times required for supply adjustments are the primary sources of supply-and-demand imbalances and are major causes of instability in the year-to-year profitability of TFT-LCD makers. And instability at the panel-maker level has a cascading impact on LCD-component suppliers. Understanding the differences in supply-and-demand cycles is necessary for reducing lag times and improving reaction times for both LCD and LCD-component suppliers.

The LCD industry is subject to extreme swings between oversupply and undersupply. During periods of oversupply, there is downward pressure on panel prices. When there is undersupply, the pressure abates and pricing power shifts to manufacturers, but the resulting price increases often dampen demand. Manufacturers can minimize the impact of price declines by introducing new higher-margin displays and by continuously striving to reduce the cost of manufacturing. One important way to cut manufacturing costs is to reduce the cost of components and raw materials, which can account for as much as 70% of manufacturing costs. Another is to invest in new production lines, which take advantage of newer equipment and have larger area capacity.

Vinita Jakhanwal is Senior Analyst for LCD Research at iSuppli/Stanford Resources, 20 Great Oaks Blvd., San Jose, CA 95119; telephone 408/240-1712, fax 408/360-8410, e-mail: v.jakhanwal@stanfordresources.com.

Ups and Downs

Between 1995 and 2001, the LCD industry experienced two complete supply-and-demand cycles. The first major supply-and-demand imbalance began in 1995 when manufacturers added too much capacity in response to excitement generated by the leading notebook-computer vendors. The market shifted gears in mid-1996, spurred on by lower prices and wider availability arising from the entry of suppliers in Korea. However, by the end of 1997, TFT-LCD supply exceeded demand and

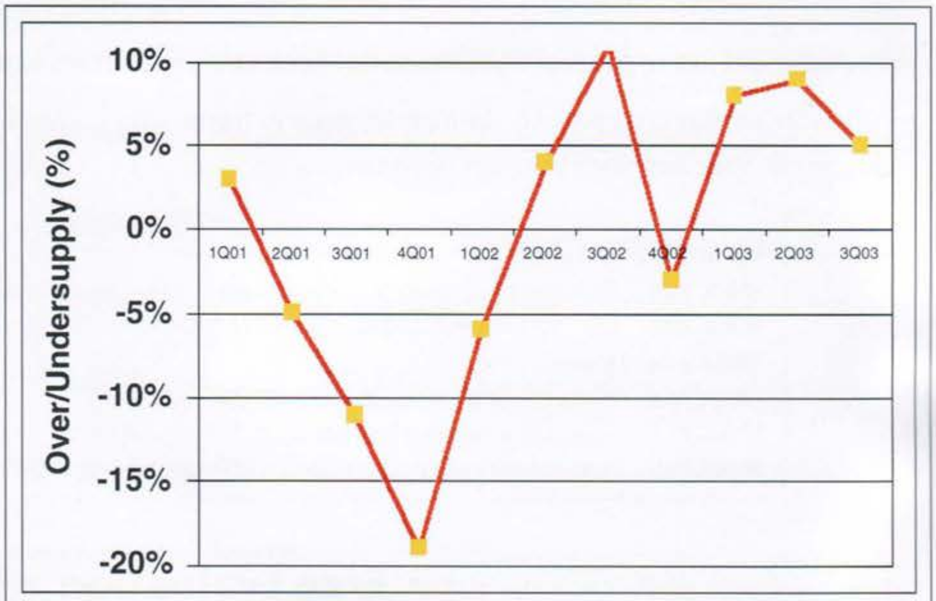


Fig. 1: TFT-LCD supply-and-demand balance, 2001–2003. (Source: Stanford Resources Global LCD Supply–Demand, Q3 2002.*)*

0362-0972/03/1902-026$1.00 + .00 © SID 2003

Table 1: New Investment Planned in Gen 5 and Gen 6 Fabs

	Country	Generation	Glass Sheet Size	Start Date	Starting Capacity
LG. Philips LCD	Korea	Gen 5	1000 × 1100	2Q02	30 K
	Korea	Gen 5	1100 × 1250	2Q03	30 K
Samsung	Korea	Gen 5	1100 × 1250	3Q02	30 K
	Korea	Gen 6	1370 × 1770	2Q04	30 K
AU Optronics	Taiwan	Gen 5	1100 × 1250	2Q03	60 K
Chi Mei	Taiwan	Gen 5	1100 × 1250	4Q03	30 K
CPT	Taiwan	Gen 5	1100 × 1250	2Q04	30 K
Hannstar	Taiwan	Gen 5	1150 × 1300	4Q03	30 K
Quanta Display	Taiwan	Gen 5	1100 × 1250	2Q03	15 K
NEC/SVA	China	Gen 5	1100 × 1250	2Q04	30 K
Sharp	Japan	Gen 6	1500 × 1800	2Q04	15 K
Hon Hai	Taiwan	Gen 5	1100 × 1250	2Q04	35 K

Source: Stanford Resources *Global LCD Supply Demand, Q3 2002.*

prices plummeted. Combined with the Asian financial crisis, these conditions prevented any significant capacity investment.

Responding to the lower prices, demand grew rapidly, and 1999 started with a sharp increase in pricing for all TFT-LCD panels. By 2000, Korean manufacturers had begun to add capacity and new Taiwanese suppliers had entered the market, and the TFT-LCD industry again faced an oversupply of panels. The trend continued even in the first half of 2001, when prices fell below manufacturing costs for many panels (Fig. 1). The rest of the year was followed by undersupply, particularly at year's end as monitor demand exceeded expectations.

By the second quarter of 2002, oversupply hit the industry, and continued through the end of the year – except for a seasonal demand boost at the end of the year. The oversupply is forecast to last through 2003 as three fifth-generation fabs come on line.

Manufacturers are planning to begin production at 12 new fifth- and sixth-generation fabs from the middle of 2002 to the middle of 2004 (Table 1). Most of the additional investment will come between 2Q03 and 2Q04. Due to market conditions in 2002, Taiwanese companies AU Optronics and Quanta Display may delay production in their Gen 5 fabs until late 2003 or early 2004, which could improve the supply balance. If this happens, there may be some tightness in supply in the second half of 2003.

Costing about $1 billion each, these fabs will add more than 2 million square meters of glass area in capacity in the industry, resulting in an oversupply through 2004. (Figure 2 shows the additional glass area capacity that will come on line from just the Gen 5 fabs.)

Gen 6 lines will not start production before 2Q04. If both lines come on line as planned, there could be oversupply throughout most of 2004. Television will emerge as a driving application, but it will likely be 2005 before demand is significant enough to absorb an appreciable amount of the new capacity.

The new fab investments will also require supporting investments from component suppliers, without which there will be delays in ramp-up. Gen 5 glass requires pristine surfaces, and there is an increased risk of glass damage when handling large substrates. Glass substrates are now available with low density, low thermal expansion to improve chip-on-glass bonding, high thermal conductivity to minimize thermal breakage, and high silica content for high chemical durability and improved scoring and separation. Gen 5 factory layouts are moving away from the use of automatic guided vehicles (AGVs), using only cassettes to move glass. Gen 6 fabs will also do away with the cassettes by adopting single-glass handling.

Because most Japanese firms have refrained from making capacity investments, Taiwan and Korea have rapidly gained panel-production market share in recent years. Japan accounted for 44% of the large-sized

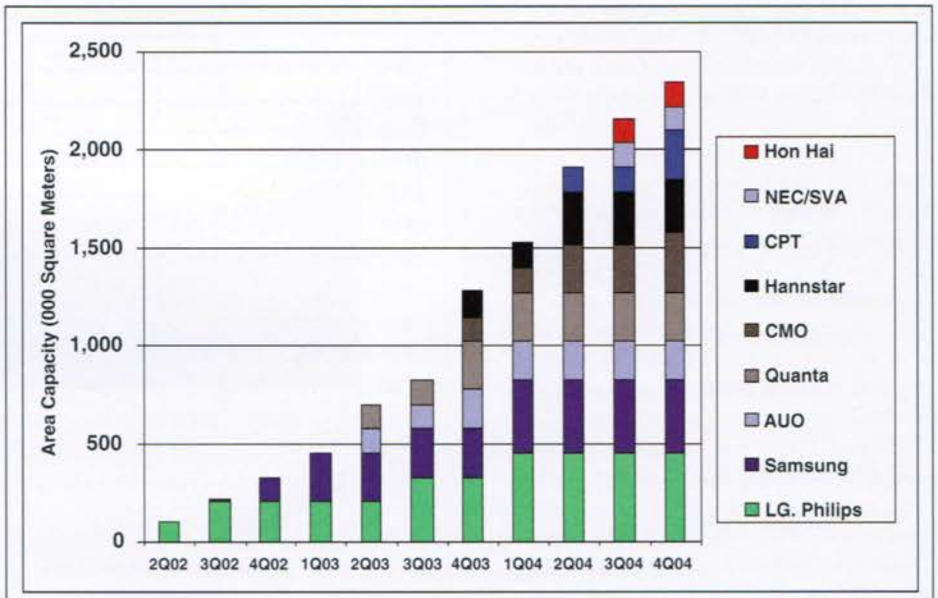


Fig. 2: New glass-area LCD capacity to be added, by company, 2002–2004. (Source: Stanford Resources Global LCD Supply–Demand, Q3 2002.*)*

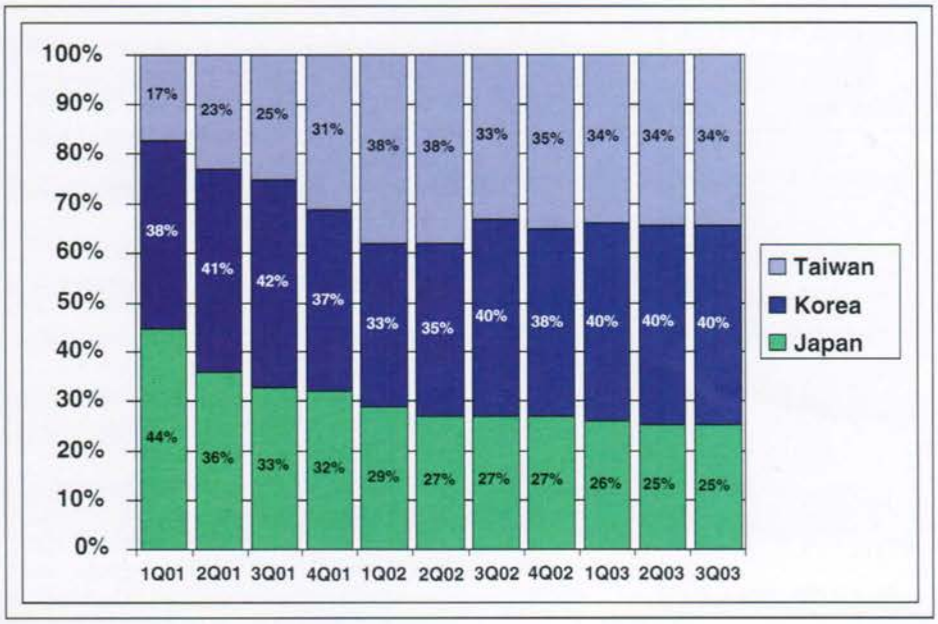


Fig. 3: TFT-LCD market share by region, 2001–2003. (Source: Stanford Resources Global LCD Supply–Demand, Q3 2002.*)*

panels produced at the beginning of 2001. By the end of 2003, it will account for only 25% of production (Fig. 3). Taiwan has five large LCD manufacturers, and during the first half of 2002 emerged as the leading supplier. There are only three manufacturers in Korea, but the fabs in Korea are bigger and more productive. After leading for most of 2001, Korea has reemerged as the leading supplier of TFT-LCDs with the start of Gen 5 production at LG.Philips LCD and Samsung Electronics.

The Component Industry

The best way for panel makers to weather downturns in the industry is to keep manufacturing costs low. When prices fall in oversupply situations, lower manufacturing costs will help in maintaining at least some margin of profit on panels, although there have been periods of negative margins, most recently in mid-2002.

Purchased components and raw materials account for the largest part of manufacturing costs, contributing over 70% of the cost of the goods sold (COGS) (Fig. 4). In 2002, the total manufacturing cost of a typical 15-in. panel was $140, of which display materials and electronics cost $110. After depreciation and gains from yield improvements are factored in, further reductions in manufacturing costs must come from reduced component costs, especially those with high conversion costs such as glass, color filters, polarizers, and drivers (Fig. 5). To reduce component costs, it is necessary to make capital investments in state-of-the-art component factories located near the display fab.

Like the panel industry, the component industry has been concentrated in Japan. However, with the shift in the panel-production base to Korea and Taiwan, component supply has been migrating to these countries, too, although slowly. In contrast to the situation with panels, Japanese companies still hold leadership positions in a few component industries – but they are steadily losing market share.

Taiwan and Korea have opted for the cluster type of component manufacturing and have been developing indigenous component sourcing to reduce their dependence on imports from Japan. This produces the following benefits:

- Shorter cycle time for new product development,
- Quicker response to market conditions, avoiding inventory build-ups, and
- Reduced transportation costs.

Color Filters

Color filters are the most expensive component in LCD panels. A new development is to apply the color filters directly onto the TFT backplane, which is called "color filter on array." This approach utilizes the resin as part of the TFT insulating layer, resulting in increased aperture ratio, reduced cost, and process simplification. Color-filter manufacturers are responding to the demand of Gen 5

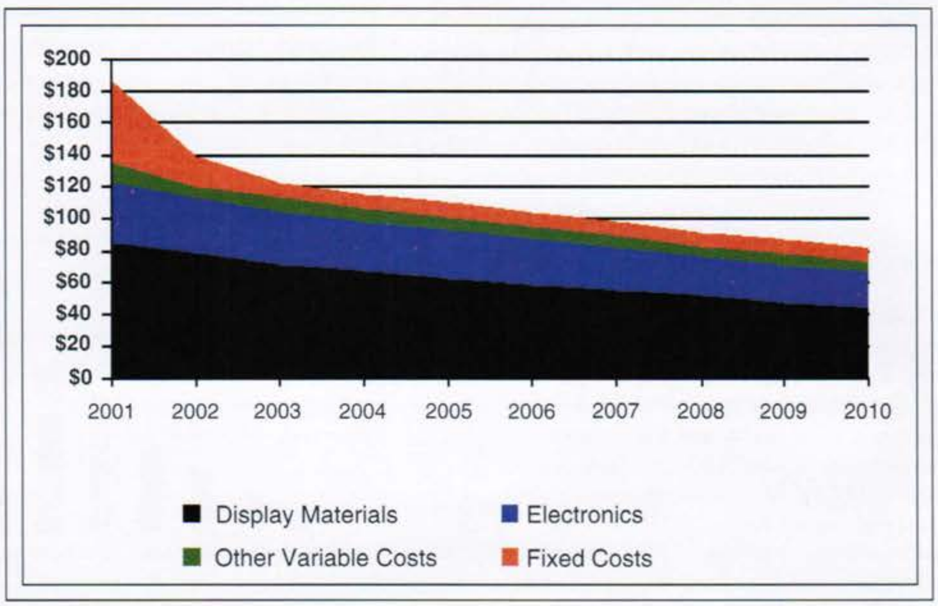


Fig. 4: Manufacturing cost of a 15-in. XGA panel, 2001–2010. (Source: Stanford Resources Display Manufacturing Cost Models, 2002.*)*

panel fabs by investing in many new Gen 5 color-filter lines (Table 2).

Color-filter production is still dominated by Japanese manufacturers Toppan Printing and Dai Nippon Printing (DNP). Together they are planning Gen 5 lines in Taiwan and China. Japanese color-filter manufacturers entered into joint ventures with Taiwanese companies, thus adding them to the global supply chain. Sintek Photronics of Taiwan has a partnership with DNP. A similar technology arrangement exists between AMTC of Taiwan and Toppan. Cando bought a 50% stake in New STI of Japan. Large expansions of production lines in Taiwan helped lower the price of color filters by more than 20% in 2001. Taiwan now sources almost 60% of color filters locally.

Backlights

Backlights are the second most expensive component. Most large LCDs use cold-cathode fluorescent-lamp (CCFL) backlights. Notebooks use one tube, monitors use two or more, and TVs use several.

There are several key components that must be assembled into a backlight: inverter, tubes, diffusers, light guide, prism sheets, brightness-enhancement film, and other films. Japan is still a leading supplier of inverters, diffuser films, and tubes. But the assembly of backlight units is moving out of Japan as the domestic panel industry stagnates.

Korea sources more than 90% of backlight units domestically. Samsung Electronics, LG.Philips LCD, and HYDIS have been increasing purchases from Kuho Electric, Wooree ETI, and Clean Creative, while moving away from Japanese suppliers Harrison Toshiba Lighting (HTL) and Sanken Electric. Optoma, K-Bridge, and Forhouse meet most of the Taiwanese demand with facilities within the Chi Mei and CPT fabs. Radiant is a large supplier to AU Optronics and CPT. Backlight prices have fallen 20% over the last 2 years.

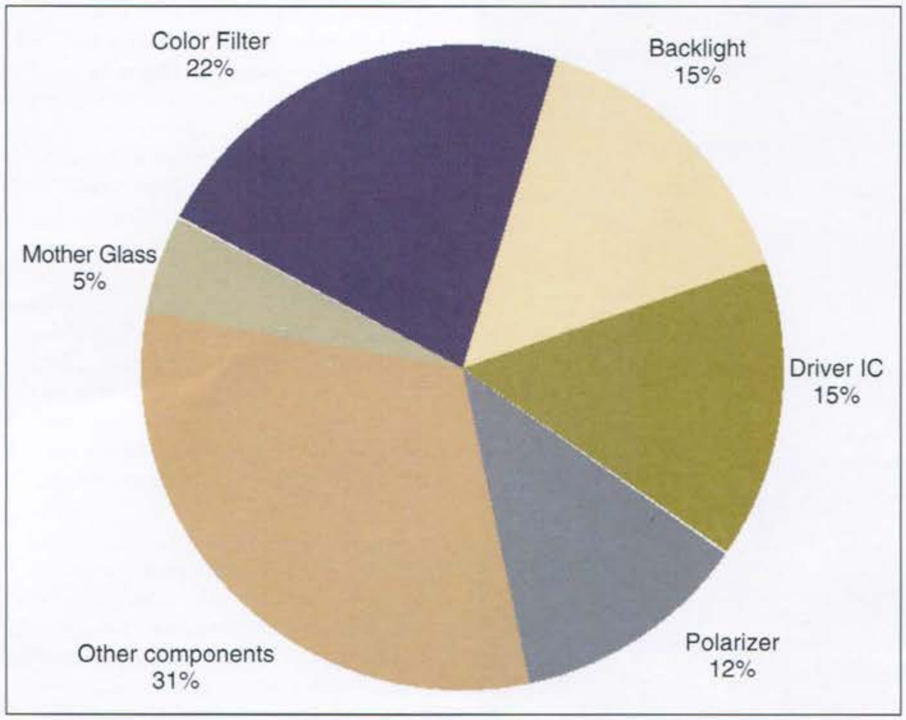


Fig. 5: TFT-LCD component costs as a percentage of cost of goods sold (COGS). (Source: Stanford Resources Display Manufacturing Cost Models, 2002.*)*

Table 2: New Investment in Color-Filter Fabs

Company	Location	Generation	Substrate Size	Capacity	Start Date	Partnership
Sintek	Taiwan	Gen 5	1150 × 1300	60	4Q03	Hannstar & DNP
	Taiwan	Gen 5			3Q03	CPT
Toppan/ AMTC	Taiwan	Gen 5	1100 × 1250	80	2Q03	
	Shanghai	Gen 6			2005	
	Shanghai	Gen 4	730 × 920/ 680 × 880	100	2003	
CMO	Taiwan	Gen 5				DNP
Cando	Taiwan	Gen 4	730 × 920/ 680 × 880	60	1Q03	New STI
Hitachi	Japan	Gen 4	730 × 920		3Q02	

Source: Stanford Research *Global LCD Supply Demand, Q3 2002.*

Other Components

Almost half of the Taiwanese polarizer demand is met locally by Optimax. It plans to set up a joint venture with Japan-based Sanritz to begin volume production in China. The local supply of polarizers is approaching 50% in Korea. LG Chem has successfully developed TFT-LCD polarizer products and is supplying them to LG.Philips LCD, replacing Japan's Nitto Denko, Sanritz, and Sumitomo. Shinwha OPLA and Ace Digitech, which initially produced only TN/STN-LCD polarizers, have now developed TFT-LCD polarizers.

Japanese manufacturers NEC, Hitachi, and Sharp still lead in the driver-IC market, but Novatek, Winbond, and other Taiwanese companies are ramping up production to meet emerging demand. Samsung and Hynix Semiconductor have captured majority market share in South Korea's TFT-LCD driver-IC market and plan to enter overseas markets in 2003.

Corning has glass-smelting furnaces in Korea (a joint venture with Samsung) and Taiwan. It recently announced plans for expansion at its Taiwan factory to enable Gen 5 production.

LCD supply chain

Vertically Integrated Factories

LCD-manufacturing operations require adequate supplies of high-quality components on a timely basis. Most manufacturers purchase components based on order forecasts from their customers – forecasts that are made a quarter in advance but updated monthly.

Due to the tremendous pressure on panel prices, manufacturers are striving to reduce manufacturing costs by sourcing a greater portion of their components from local suppliers. To further reduce costs, many Taiwanese companies are inviting component suppliers to set up production lines inside or in and around the new factories. The impact of improvements in component supply can be seen in decreasing component prices (Table 3).

The Taiwanese Government has helped display-related companies establish fully developed vertically integrated industrial clusters. More than 20 component companies are located in the Tainan Industrial Park, supplying glass substrates, optical masks, color filters, and other related products.

Chi Mei Optoelectronics sources most of its components within 50 km of its factory in Taiwan. In-house production accounts for 80% of color filters, and 95% of backlights are sourced from third-party vendors with production units inside its fab. Chi Mei has invested in the company from which it sources 30% of its backlight requirements. All glass-substrate requirements are outsourced to a company in the same cluster.

AU Optronics sources only 25% of color filters locally, but has decided to invest in a color-filter line for its Gen 5 fab. Similarly, Hannstar – which sources 22% of color filters locally – and CPT both plan to contract with DNP and Sintek Photronics to set up production lines for color filters and other key components inside their Gen 5 factories.

LG.Philips LCD's and Samsung Electronics's Gen 5 fabs are vertically integrated – including color filters – to optimize not only the process flow but also save on transportation costs for raw materials. Hitachi's 730 ˘ 920 (V3) fab in Mobara is a fully automated fab, including a color-filter line.

There is room for further reduction in LCD manufacturing costs. Some of it will be a result of more-efficient LCD production processes in higher-generation fabs, but most of it will come from better management of component and raw-material supplies. ■

Table 3: Component Price Decreases (%)

Price Decreases (%)

	2000 – 2002	2002 – 2005
Color filter	30	45
Column drivers	39	45
Backlight	19	30
Polarizer	6	18

Source: Stanford Resources *Display Manufacturing Cost Models, 2002.*

Please send new product releases or news items to Information Display, c/o Palisades Convention Management, 411 Lafayette Street, 2nd Floor, New York, NY 10003.

LCDs: Price and Demand

The seesaw dynamics of the LCD market can be painful, but they are an important part of the engine that continues to drive the rapid expansion of LCD applications.

by Sweta Dash

THE liquid-crystal-display (LCD) market has experienced dramatic growth over the past decade, although there have been periodic imbalances in supply and demand, and is expected to continue on this growth path throughout the next decade. The technology behind the LCD continues to evolve each year, driven by a desperate need to reduce cost and improve profitability, as well as to compete with established technologies, such as the cathode-ray tube (CRT), and emerging technologies, such as plasma-display panels (PDPs) and organic light-emitting diodes (OLEDs).

Market Growth

From 1990 to 1995, the worldwide LCD market quadrupled in value from $1.8 billion to $7.2 billion, and more than tripled over the next 5 years, reaching $22.4 billion in 2000. iSuppli/Stanford Resources forecasts that the market will more than double from 2000 to 2005, reaching $46 billion (Fig. 1). Looking to the 2005–2010 timeframe, we see the probability of revenue growth in the 50–60% range; some suppliers expect more than 100% growth, resulting in $100 billion in LCD revenues by 2010. They are hoping to achieve this through investment in sixth, seventh, or even higher generation fabs and expanding the application markets to television and new mobile products.

Sweta Dash is Director of LCD & Projection Research at iSuppli/Stanford Resources, Inc., 20 Great Oaks Blvd., Suite 200, San Jose, CA 95119; telephone 408/240-1708, fax 408/360-8410, e-mail: s.dash@stanfordresources.com.

Growth in the LCD market from 1990 to 1995 can be attributed to portable computers. LCD revenues from portable-computer applications increased from 31% in 1990 to 66% in 1995, and they continued to be the major revenue contributor through 2000, even though their market share declined to 41%. By 2005, their share will decrease to 21% (Fig. 2).

Desktop-monitor applications started gaining importance in the late 1990s. From 2.5% of the total revenues in 1997, their market share increased to more than 21% in 2000. By 2005, desktop monitors will account for nearly 40% of the total LCD revenues (Fig. 2). Compared to the desktop monitor, LCD TVs accounted for less than 2% of the total LCD revenues in 2000. Suppliers are hoping that it will be the next significant application area for LCDs, and expect it to be a major contributor to LCD revenues by 2010.

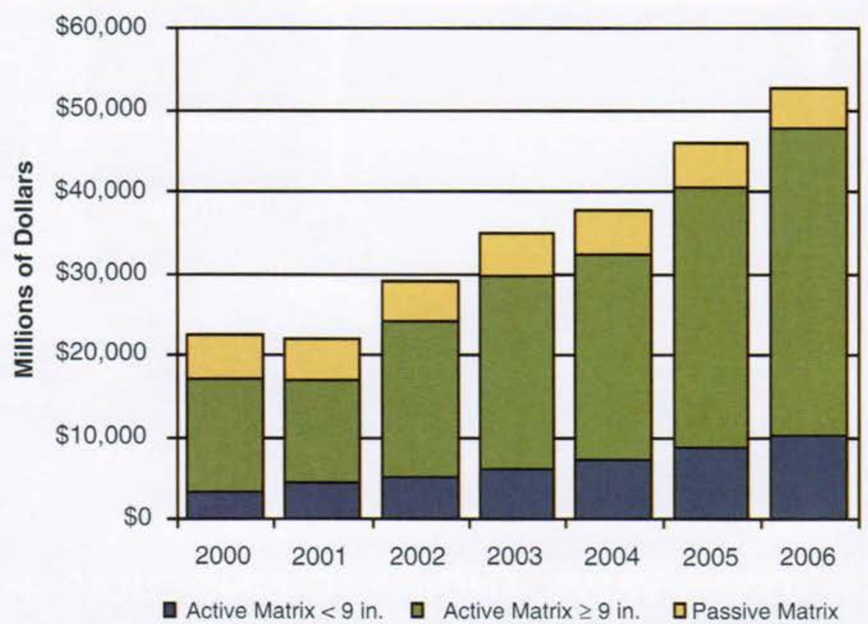


Fig. 1: *Worldwide LCD revenues by technology, 2000–2006. (Source: iSuppli/Stanford Resources* LCD Market Tracker, Q2 '02.*)*

0362-0972/03/1902-032$1.00 + .00 © SID 2003

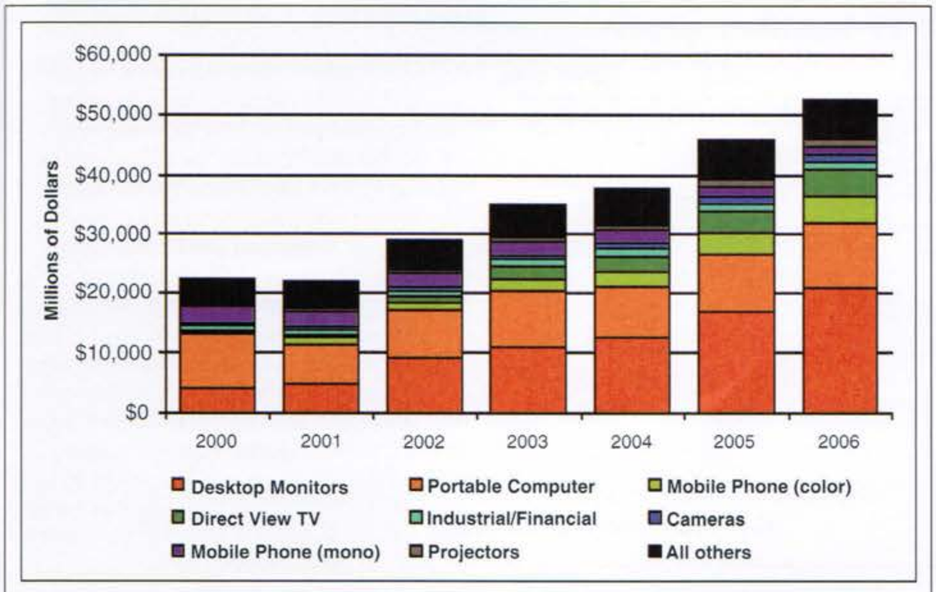


Fig. 2: Worldwide LCD revenues by application, 2000–2006. (Source: iSuppli/Stanford Resources LCD Market Tracker, Q2 '02.)

Mobile-phone handset displays – both color and monochrome – increased their LCD market share from 1995 to 2000 because unit demand grew rapidly and the adoption of color increased. By 2001, handsets accounted for 17% of total LCD revenues.

The growth in the portable-computer market during the early 1990s was enabled by the growth of thin-film-transistor (TFT) active-matrix technology. Active-matrix LCDs (AMLCDs) accounted for less than 14% of total LCD revenues in 1990, which increased to 55% in 1995 and nearly 76% in 2000. Active-matrix technology is expected to account for nearly 95% of total LCD revenues by 2005 (Fig. 1).

Future revenue growth in active-matrix products will not keep pace with unit growth because of continued price pressure. In addition, the active-matrix product mix is shifting towards smaller sizes because of the increased use in mobile phones, PDAs, digital cameras, automotive navigation, entertainment, camcorders, and handheld games. In 2001, 26% of the active-matrix revenues came from screen sizes less than 9 in. on the diagonal, a share that will decline slightly by 2005 to 21%. Revenue from panels larger than 9 in. on the diagonal will grow rapidly because of the increasing screen sizes used in monitors (17, 19, 20 in., and above) and TVs (larger than 20 in.), accounting for 79% of active-matrix revenues in 2005.

STN: exSTNct?

In 1990, more than 98% of portable computers used supertwisted-nematic (STN) LCDs in both monochrome and color; this share fell to 63% in 1995. By 2001, these passive-matrix displays disappeared from the portable-PC market. Mobile applications, such as handheld PCs/PDAs and mobile phones, originally used only monochrome STN-LCDs. The first mobile phone with a color STN-LCD was introduced at the end of 1999, and the first active-matrix mobile phone, using TFT or thin-film-diode (TFD) technologies, were introduced in 2001 for the Japanese marketplace.

Manufacturers are just starting to introduce color STN and color TFT-LCD panels in Europe and America. The falling TFT-LCD panel prices which are the result of stronger competition and the use of Gen 3 fabs will combine with the increased functionality and greater use of digital cameras, cellular phones, and PDAs to accelerate the shift to TFT-LCD technology in the future. Passive-matrix unit and revenue growth will lag behind because of pressure from active-matrix LCDs and OLEDs. Mobile phones using passive-matrix color LCDs will be the only major growth area for the next few years. However, TFT-LCDs will become the dominant technology in mobile handsets and handheld computers.

The LCD Supply Cycle

The dominance of TFT-LCDs in the flat-panel market and the dependence on computer applications has resulted in periodic imbal-

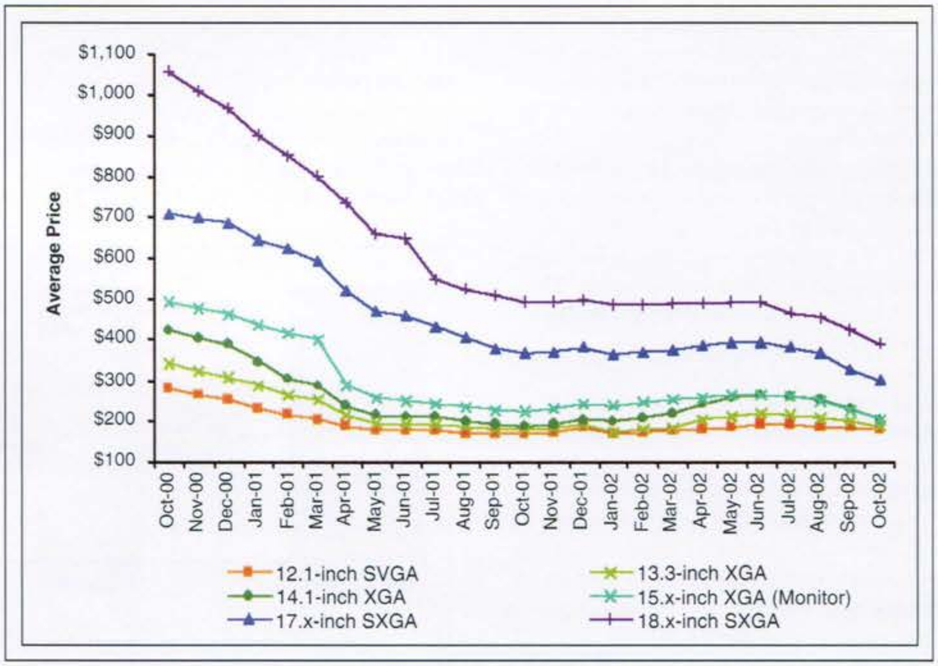


Fig. 3: Price trends for Large TFT-LCD Panels, October 2000 to October 2002. (Source: iSuppli/Stanford Resources LCD Price Trak.)

Table 1: Manufacturers' LCD-TV Technology Targets

Application	Feature	2002	2005–2006
Notebook (15-in.)	Weight (g)	550–650	≤450
	Thickness (mm)	6–7	5
	Power consumption (W)	4.5–5.5	≤4
	Pixel format (mainstream)	XGA	UXGA
Monitor	Brightness (nits)	<300	450
	Viewing angle (°)	≤150	≥170
	Pixel format	XGA	≥SXGA
TV	Brightness (nits)	500	700
	Contrast ratio	500:1	1000:1
	Response time (msec)	<15	<7
	Color gamut (compared to CRT TV)	70%	90%

Source: iSuppli/Stanford Resources LCD Market Tracker, Q2 '02

ances between supply and demand of large (greater than 9-in. on the diagonal) TFT-LCD panels. These economic cycles have a significant impact on LCD revenues. During times of tight supply, prices generally remain stable or increase, giving a big boost to revenues, while prices fall sharply (often to below manufacturing costs, as occurred in 2001) during the down cycle. This has serious consequences for the market size and profits earned by suppliers. Although, overall, prices have trended strongly downward over the last 2 years, these cyclical variations have been significant (Fig. 3).

While painful, downturns have helped the industry to expand into new applications markets, not only by forcing manufacturers to offer lower prices but also through improving technology to meet new requirements. The downturn experienced in 1995 resulted in a shift to TFT-LCD technology for portable computers. It also led to a rapid shift to larger panel sizes (from 8 to 9 and then 10 in.), higher pixel formats (VGA and SVGA), lighter weight, lower power consumption, increased luminance, and narrower bezels. The down cycle of 1998 drove LCDs into the desktop-monitor market. The monitor market grew nearly sixfold from 1997 to 1998 (from 268,000 units to 1.5 million). Lower prices in 1998 also fueled its growth in 1999, and produced a shift to even larger sizes (15 and 16 in.) and the development of wide-viewing-angle (more than 150) products using film-enhanced TN, in-plane switching (IPS), and multiple-vertical-alignment (MVA) modes.

In the 2001 down cycle, the desktop-monitor market share increased from 6 million to more than 15 million units and the 15-in. became the mainstream size, with growth in 17-, 18-, and 20-in. sizes. With increased demand for multimedia capabilities, suppliers are trying to increase brightness and decrease response times in desktop monitors and notebook computers. Many large TFT-LCD suppliers are paying more attention to specialized markets, such as the industrial and medical segments, to increase profitability. That has spurred the development of monochrome high-resolution TFT-LCDs, such as 21.3-in.-and-larger panels with 5 million pixels for medical diagnostic applications.

Many suppliers are also focusing on mobile displays, which is resulting in lower prices and improved performance for small TFT-LCDs. Small TFT-LCDs for PDAs are now shifting to VGA format from QVGA format. The down cycles continue to help expand the applications market and initiate technology developments to meet new requirements.

During the next down cycle in 2003, the monitor market is expected to receive another boost in unit sales and shift to 17–19-in. sizes. At the same time, pixel formats will move to SXGA (1280 × 1024 pixels) and even UXGA (1600 × 1200 pixels) for high-end models, from mostly XGA (1024 × 768 pixels) at present. By 2005, 17-in.-and-larger monitors will account for more than half of the monitor market. In the notebook-computer market, there will be increased movement toward 15-in.-and-larger (15.5-, 15.7-, and 16-in.) sizes, particularly in the consumer market.

In 2005, the 15 in. size will most likely be dominant in the notebook-computer market. Some suppliers are even considering 17-in. wide-format displays for notebooks.

The market will also shift toward higher pixel formats such as UXGA, higher luminance (at least 200 nits), response times below 25 msec, and wider viewing angles. By 2005, more than 81% of notebook-computer shipments will be in SXGA+ (1400 × 1050 pixels) and UXGA format. The shift to larger panel sizes will contribute to the dominance of the UXGA format by 2006.

Strong competition and the frequent oversupply conditions that force panel suppliers to

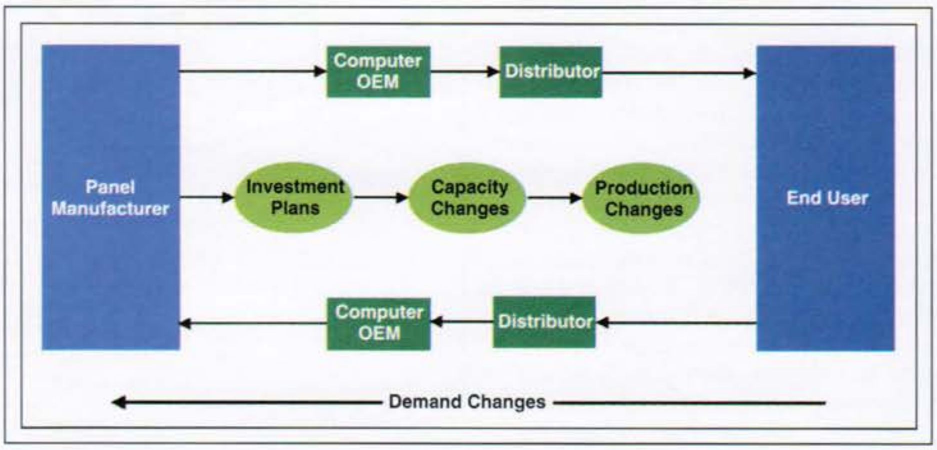


Fig. 4: *TFT-LCD supply-and-demand cycle. (Source: iSuppli/Stanford Resources.)*

sell at below-cost pricing also help to develop new markets. This trend will probably help develop the LCD-TV market, especially during 2005 and 2006. Suppliers are trying very hard to bring response times to below 15 msec, from 25 to 30 msec today, to improve video quality, which is a major deficiency of LCD panels compared to CRTs or plasma panels. Many suppliers have already demonstrated 11-msec response times, and are hoping to break the 10-msec barrier in the future. LCD TV has the advantage of lower power consumption compared to that of CRTs and plasma panels.

In 2001, large LCD TVs accounted for slightly more than 700, 000 units, with only 3% of the market in sizes over 15 in. Within the next 5 years, the LCD-TV market will grow rapidly. By 2005, about 63% of the market will be larger than 15 in., with most above 20 in.

Manufacturers are already showing 40-, 42-, and 46-in. LCD-TV panels in wide-XGA (1280 × 768 pixel) format, with a contrast ratio of 800:1 and response times less than 12 msec, and have ambitious technology targets for the near future (Table 1). Manufacturing costs for such panels are expected to fall when production moves to Gen 6 or Gen 7 fabs.

The shift to larger panel sizes is the cause of moving to newer-generation fabs for TFT-LCD manufacturing. In the early 1990s, the industry had mostly first- and second-generation fabs. Third-generation fabs came on line in the late 1990s (for portable applications); 3.5- and fourth-generation fabs in the early 2000s (for portables and monitors); and fifth-generation fabs in 2002, 2003, and beyond (for large monitors and TVs). Suppliers have announced plans for sixth-generation (1500 × 1800 mm) and seventh-generation (1800 × 2000 mm) fabs for very large TVs (30-in., 40-in., and larger panels) in 2004 and beyond.

Supply-and-demand imbalances for large TFT-LCD panels are due to over-investment by LCD suppliers and to over-dependence on a few key applications. But most importantly, the lag time between a change in demand and change in supply creates imbalances in the industry.

Changes in demand often occur rapidly, but because of the capital-intensive (more than $1 billion) and time-consuming ramp-up process of TFT-LCD manufacturing (12–15 months from the establishment of a fab to full production), long lead times are required for supply adjustments (Fig. 4). When demand for monitor panels increases, manufacturers increase panel prices in response to the tight supply situation. There is a lag time between the increase in panel price and the increase in system price, usually one to two quarters.

After the increase in system price, the demand will react to it, depending on price elasticity; the more elastic the demand, the more impact the price increase has on it. There is also a lag between changes in demand and inventory build-ups. Once inventories are built up, panel demand decreases. But by that time, LCD-panel suppliers have already started investing in new capacity. By the time the new capacity becomes available, demand has already fallen off. That creates the imbalance and results in oversupply. With an increased number of applications in the future, the revenue impact during downturns may be reduced.

The cycles of rapid growth and slowdown during the last decade have resulted in rapid technology improvements and a wider range of products and applications in the LCD industry. In the future, competition will come not only from within the industry but also from other technologies, such as plasma and OLED. Technological developments, new applications, a shift to advanced-generation manufacturing, lower manufacturing costs, and improved performance will all help the LCD market to continue in its dynamic growth pattern throughout the next decade. ■

show report

SMAU 2002

Bigger LCD monitors and TVs capture the glory, 15-in. LCD monitors begin to look passé – even in the cost-conscious Italian market – and CRTs refuse to go away.

by Bryan Norris and Michelle Barnes

FAR LARGER than Las Vegas's diminished Fall Comdex and the second-largest IT show in the world, SMAU 2002 was held from October 24–28, 2002, at its usual "Fiera" Milan venue during a time of some depression in the Italian IT industry. An Italian IT growth figure of only 1.2% for 2002 was being predicted by the European Information Technology Observatory (EITO); third-quarter desktop-PC shipments were down 13% year-on-year; and the Q3 monitor market was down 10%.

It was therefore not surprising that exhibitor numbers at SMAU were considerably lower than in 2001, and, judging by the proliferation of small "rest areas" in most halls, many suppliers had withdrawn at the last minute. (The booths of the 2500 exhibitors covered a floor area of 80,000 m^2, as opposed to the 3000 in 2001 that covered an area of 106,000 m^2.) But there was a new addition to the show this year: the SMAU Shop! Italian retailer ***Media World*** had taken 2400 m^2 of "shop space" in Hall 21 for "over-the-counter" selling.

Many displays exhibitors decided not to attend this year's SMAU, including the international suppliers ***Acer***, ***BenQ***, ***Fujitsu Siemens***, ***Sony***, ***ViewSonic***, and ***Waitec***, and the Italian company ***Nortek***. And, since distributor ***Fraelpoint*** was another absentee, there was no grand showing of ***AOC*** monitors. ***Daewoo*** was also missing, having recently decided to move out of monitors. (Italy was Daewoo's largest market for displays in Europe.) Furthermore, large multi-product suppliers ***NEC*** and ***Samsung***, who have normally taken a separate stand for their monitors, economized this year by showing all their IT products together – and in locations a long way from the normal displays area.

Show-Stopping LCDs

But the display suppliers who did make it to Milan put on a grand viewing. Naturally, in this day and age, their main aim was to pro-

__Michelle Barnes__ and __Bryan Norris__ are partners and co-founders of Bryan Norris Associates, Consultants to the Displays Industry, 7 Biddenham Turn, Bedford MK40 4AT, U.K.; telephone +44-(0)-1234-26-7988, fax +44-(0)-1234-26-2345, e-mail: m_barnes@kbnet.co.uk. Mr. Norris is a contributing editor to Information Display. *Dr. Barnes is a periodic contributor.*

GDS

Fig. 1: *The Global Display Solutions (GDS) Group was offering its new 30-in. (actually, 29.53 in.) LCD public-information display (PID) with an extended 3-year warranty, thanks to an MTBF greater than 45,000 hours.*

0362-0972/03/1902-036$1.00 + .00 © SID 2003

Byran Morris

Fig. 2: *Samsung's SXGA 19-in. 191N slim-line LCD, seen alongside their 18-in. 181T, was launched at a price intended to pose a direct challenge to existing 18-in. models.*

mote their LCD monitors rather than their CRT models. And the LCDs keep getting bigger. At the time of the show, some of ***Samsung***'s 40- and 29-in. LCD TVs (the LW40A13W and LW29A13W) were already selling in Europe as monitors, the "real" monitor-only versions not being available until Q1 '03. Joining these king-sized displays was ***NEC***'s 30-in. LCD monitor, the LCD 3000, for its "first showing in Europe" at SMAU. This has an SXGA (1280 × 768) IPS panel, 170° viewing angle, and a contrast ratio of 450:1. The "3000" is well-suited to information-display purposes because its weight is just 17.5 kg, it is compatible with a very long cable length, and it has an energy consumption of only 170 W – around 30% less than similarly sized plasma models. (Are we seeing the writing on the wall for plasmas under 50 in.?) The local players were also showing off their 30-in. LCD public-information-display (PID) monitors. Milan-based ***Sambers*** had added a 30-in. PID unit, fitted with an embedded PC, to its professional and industrial line-up of ***Hantarex*** LCD monitors (15-, 18-, and 22-in.). And Cornedo-based ***CA&G***, now part of the ***Global Display Solutions (GDS) Group***, was offering its new 30-in. (29.53 in., actually) LCD PID with an extended 3-year warranty, thanks to an MTBF greater than 45,000 hours (Fig. 1).

GDS/CA&G also reported that its new 23.1-in. LCD on display, the MOLVL2310T, had recently been launched. On one of the few remaining large and colorful stands, ***LG*** showed a prototype of its 30-in. LCD amongst its large range of LCD, CRT, and plasma models. The SXGA L3000A is due for release in the first quarter of 2003.

Larger TFTs Ready for Center Stage

In the *southern* European countries, 15-in. TFT-LCD monitors still form the largest sector of the LCD market. But in an effort to escape the 15-in. price war and to achieve a profit margin, the suppliers exhibiting at SMAU were heavily promoting their larger screen sizes. (Two weeks earlier at the Orbit/Comdex show in Basel, Switzerland, exhibitors made it very clear that few buyers in the Swiss marketplace were now satisfied with a 15-in. LCD screen; and, as for CRT monitors, forget it!) Even in Milan, the 17-in. was being promoted as the basic office screen size; the 18- and 19-in. models were being aimed at the multiple-window enthusiasts; and the 20/21-in.-and-over units were being pushed at niche-application desktop users.

The expectation that the 17-in. LCDs would become the general workhorse of the future had led all suppliers to introduce 17-in. "fill-that-gap" models, despite the limited sources of 17-in. TFT panels. ***LG***'s new 17-in. models – such as the new silver slim-bezeled L1710B with USB port and DVI-I – were thought likely to use LG.Philips's own TFT panels as these became available. (LG's production of LCD monitors for the European market is located in Wales.) On the ***Philips***

Bryan Norris

Fig. 3: LG's latest 18.1-in. LCD, the 1810B, had only recently been released, which earned it a prominent display position on LG's stand at SMAU.

stand, the data sheet showed that its 17-in.-LCD range included four silver-and-black models, but the six-unit wall demonstrations inevitably consisted of 18-in. displays.

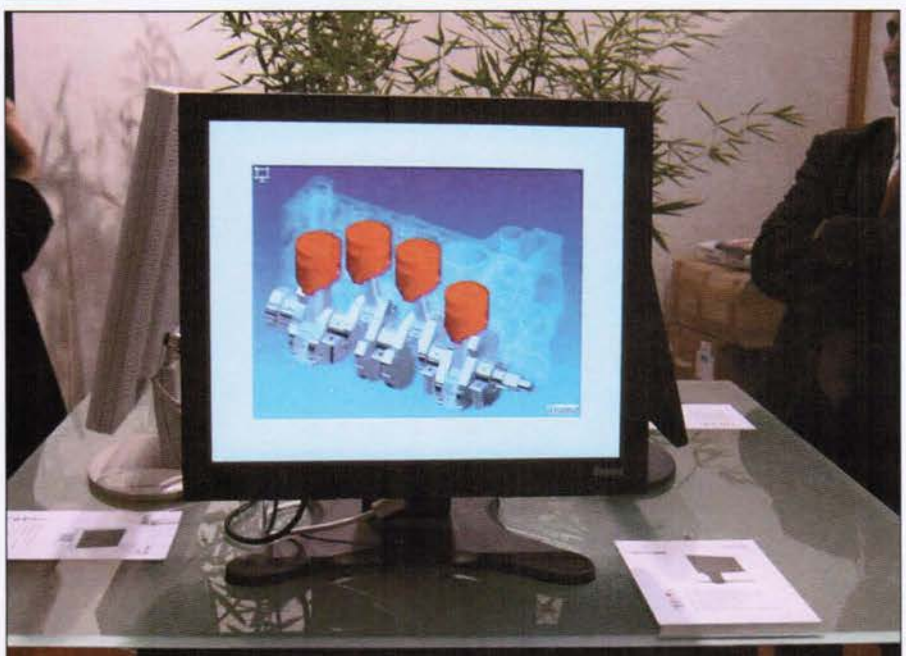
The ***Hitachi*** monitor range, promoted on the stand of its distributor, ***ECC Elettronica***, also included four 17-in. models, but the company generally concentrates on the 18.1-, 19-, and 20.1-in. screen sizes. ***Hyundai***'s monitors were all prominently exhibited on the stand of exclusive distributor ***DHI***. The company had a new L70B monitor in its range of 15–18-in. silver- or white-bezeled ImageQuest LCD models. And ***iiyama***'s silver-and-blue AS4316UTC was listed as "nuovo/new."

NEC's new LCD1700NX SXGA model, with a 170° viewing angle, was promoted with ***Portrait Displays***' "Liquid View" software, which "allow[s] the user to select more readable (larger) fonts and text without changing the on-screen resolution setting." (With LV software, the use of digital smoothing for alternative resolutions *via* a scaling chip becomes unnecessary.) ***Sharp*** also had a "fill the gap" 17-in. LCD, the LL-T17A3H, scheduled for sale in January 2003. However, since this unit was displayed with other models fitted with Sharp's own magnificent panels, such as the recently introduced 18-in. 1803H, one could deduce from the poorer picture quality that the 17-in. panel was from another maker.

Samsung unveiled the SyncMaster 172W LCD – its "first Wide Monitor" 17-in. model – at SMAU, which joins the dozen "conventional" 17-in. LCDs in the Samsung range. The 172W has SXGA resolution, a luminance of 450 nits, and a contrast ratio of 400:1; and its 15:9 format "makes it ideal for watching DVDs, moving images, or PowerPoint presentations," and allows users to view two Word pages on a single screen at 75% of full size. But Samsung's biggest promotion was for the new slim-line LCD range (first seen at the Swiss Comdex/Orbit show) – the 151N, 171N, and 191N. The SXGA 19-in. 191N was launched at a price intended to pose a direct challenge to existing 18-in. models (Fig. 2). LG's latest 18.1-in. LCD, the 1810B, had only recently been released and thus warranted a prominent display position (Fig. 3).

NEC was showing off its newly styled LCD and CRT models, which have a "black case surrounding a silver bezel." As well as looking très chic, the silver bezel bordering the screen allows the products to meet the strict TCO '99 requirements, which they couldn't do with a completely black surround. (TCO '99 is still important to Nordic and Germanic end users.) NEC Italy was expecting that its new 18-in. LCD, the 1860NX, would soon join the 19-in. 1920NX, which had been on the market for a few weeks and was prominent in their booth.

iiyama was showing off its new 19-in. LCD, the black-only SXGA AS4821D-BK, which boasts a 170° viewing angle and dual DVI-I input (Fig. 4). Also promoted on iiyama's booth were the CeBIT-award-winning 20.8-in. AQ5311DBK, which uses the IBM QXGA (2048 × 1536) panel, and the 22.2-in. AQ5611DBK with QUXGA (3840 × 2400) resolution. Both units had just entered the market, at €6400 and €8400, respectively.



Bryan Norris

Fig. 4: *iiyama was showing off its new 19-in. black-only SXGA AS4821D-BK LCD, which boasts a 170° viewing angle and dual DVI-I input.*

CRTs Still on the Scene

The three exhibitors that appeared most happy to promote their latest CRT models were ***Hyundai***, ***NEC/Mitsubishi***, and, on the ***Unibit*** stand, ***ProView***. Hyundai is one of the few suppliers still heavily pushing its CRT monitors, both the conventional models and the stylish two-color flat-screen "Q" range. The Q units are very compact because of the unique way in which the (Samsung) DynaFlat X™ tubes are housed; the 17-in. model is the physical size of a conventional 15-in. model. NEC/Mitsubishi also had a new range of out-of-the-ordinary CRT monitors on show. The 17-, 19-, and 22-in. "SB" models are fitted with SuperBright (three-mode) Diamond-Tron™ MM tubes, which give enhanced performance with no increase in power consumption. On distributor ***Bit International***'s stand, it was clear that the company now sold ***CTX*** monitors rather than, as previously, those from ***Relisys***.

New to SMAU

Two monitor companies exhibiting for the first time at SMAU were Neso and neovo, both from Taiwan. ***Neso***, whose advanced Sony Trinitron®-tubed CRT models were displayed at CeBIT – see *Information Display* (August 2002) for a description and photo – brought only its LCD monitors to SMAU. These included two futuristic prototype models, one like a shell in appearance and the other similar in shape to ***Sharp***'s Aquos LCD TVs; but photographs were not allowed.

(Neso recently became part of the enormous ***GBM*** group, whose GNR brand of monitors started selling in Europe in Q3, initially in the U.K. market.) Meanwhile, neovo had recently opened an office in Italy, so its black-glass-fronted LCDs were expected to become well-known there before long. On its stand – which had been booked too late to appear in the show guide – neovo demonstrated its 17-, 18-, and 19-in. models. ***3C Computer*** had recently become an outlet for neovo, and reported that its first shipment of neovo monitors had all been sold within a week.

Two other unusual brands at the Milan show, both offered by ECC Elettronica, were ***Focustek*** (a German producer with 15- and 17-in. LCD monitors) and ***Aluc***, a label of Taiwanese company ***Ennyah***. And back at SMAU after a year's sabbatical was local PC assembler ***ICS Olivetti***. Its Olivetti-branded monitors were reported to be made by CA&G, and consisted of basic 15- and 17-in. LCD models plus 15-, 17-, and 19-in. CRTs.

Do Trade Fairs Have a Future?

Visitors at SMAU 2002 numbered over 450,000, up 11% from 2001, so the organizers reported that this "confirmed the success of the 2002 event." However, 9-11 had meant that 2001 numbers were down significantly. The 2002 turnout was actually disappointing, given that visitor attendance back in 2000 was around the half-a-million mark. In an effort to discourage non-professional visitors from attending the show on its "professional" days (Thursday, Friday, and Monday), the week-end entrance fee was reduced from €15 to €10. But, judging from the hordes of young-sters and school parties there on the Friday, an extra €5 is nothing to an IT junky. And when the final figures were in, only 40% of the SMAU 2002 visitors had attended "for business reasons."

With exhibitor-stand space in 2002 down by over 30% compared with 2000, many companies had obviously decided that the huge expense of a large stand, particularly in terms of manpower, couldn't be justified in these days of the Web site.

A few weeks after SMAU 2002, Deutsche Messe, Hannover, organizers of the world's biggest IT show, announced that CeBIT 2004 would revert to its former 7-day format, from the 8-day show it became in 2002.

So, has the IT trade fair had its glorious day? We hope not because the atmosphere, excitement, and noisy bustle of the large trade exhibitions give business meetings an extra dimension. We look forward to the 2003 SMAU show, which will take place earlier than usual, from October 2–6, 2003. ■

SID '03
May 18–23, 2003
Baltimore, Maryland

editorial

continued from page 2

new single-layer black-and-white cholesteric-display prototype with excellent contrast ratio. The black (actually a very dark blue-purple on this unit) was very dark, and the white was quite bright and had no obvious color cast.

Because the thick layer switches more slowly than thinner layers, a new dynamic addressing scheme has been developed that switches in only about half a millisecond per line. That implies a 300-msec switching time for an SVGA display, which would be fine for e-books – the application for which the display was primarily designed.

Another idea – patent recently applied for – makes use of the fact that in a reflective cholesteric display the light that is not reflected passes through the cholesteric layer and is absorbed by a dark pigment – or partially absorbed to make, for instance, a white-and-green display. The patent describes a structure in which the light is absorbed not by a pigment but by a photocell layer beneath the cholesteric layer. Under the proper circumstances, this would produce a self-powering display.

I also visited AlphaMicron, Inc. (AMI), and was taken on a flying tour by CEO/CTO Bahman Taheri. Taheri told me that AMI has done something that no other company has ever done – applied an LC material to doubly curved surfaces.

The technology, called Variable Attenuation Liquid Crystal Device (VALiD), was developed with the U.S. Air Force to make variable-transmittance visors for pilots which would switch from a light to a deep tint virtually instantaneously. (The original intent was to use these visors in conjunction with head-mounted displays that projected onto the visors.) AMI's solution to the Air Force's problem uses guest-host mixtures of dichroic dyes and liquid-crystal hosts, which switch at low voltages with a millisecond response time. The guest-host mixture is sandwiched between two conductor-coated polycarbonate substrates.

But a funny thing happened between AMI's offices in Kent and the flight line – the fashion eyewear industry came calling. The ability to make doubly curved polycarbonate sunglasses (and ski goggles and helmet visors) with lenses in many colors and capable of switching from a light to dark tint rapidly at low voltage is something the fashion and sports eyewear industry has been seeking for a long time. The only problem was that Air Force pricing was out of the question. A development program ultimately dropped costs to the point at which lenses can probably be sold for about $10, which is in the eyewear industry's window. (That doesn't mean that the sunglasses that can be bought from companies such as Luxotica will cost anywhere near $10, of course.) Look for products to start rolling out in a couple of years.

The next step is to make the technology work with prescription lenses. "We can do that," said Taheri. Development work is proceeding now. For more information on these interesting applications, check www.alphamicron.com.

Among the many things I did not get to see was the work going on at the medical school at Kent State to use liquid crystals to make small detectors for various disease-causing bacteria. I would be very pleased to have another excuse to visit Kent, Ohio.

AlphaMicron, Inc.

AlphaMicron, Inc., a company spun out of Kent State's Liquid Crystal Institute, has figured out how to apply guest-host liquid crystal to doubly curved plastic substrates. The original application was for rapid-switching visors for Air Force pilots, but the fashion eyewear industry is also interested now that AlphaMicron has been able to reduce costs substantially.

In the Magazine

After 10 years, Aris Silzars is retiring the column he has written for *Information Display* under the names "Display Continuum" and, more recently, "A View from the Hilltop." The many fans of Aris's column won't have to go "cold turkey." Aris is posting some new essays on his Web site, www.displayconsulting.com. In recent months, Aris's column has been alternating with "My Turn," a column presenting a variety of opinions from those in the international display community. "My Turn" will now appear every month.

– 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).

Please send new product releases or news items to Information Display, c/o Palisades Convention Management, 411 Lafayette Street, 2nd Floor, New York, NY 10003.

sustaining members

Acheson Industries, Inc.
Ad-Vance Magnetics, Inc.
Advance Reproduction Corp.
Aerospace Display Systems
AMJ Industries, L.L.C.
Amulet Technologies
Applied Concepts
ATI Technologies, Inc.
AU Optronics Corp.
autronic – Melchers GmbH

Brewer Science, Inc.
Brimar Ltd.

Candela Instruments
Cando Corp.
Canon, Inc.
CELCO
The Cherry Corporation
Chi Mei Optoelectronics Corp.
Chunghwa Picture Tubes, Ltd.
Ciba Specialty Chemicals
ClairVoyante Laboratories, Inc.
Clinton Electronics Corp.
Corning Incorporated
Corning Japan K.K.
CYRO Industries

Data International
Delphi Automotive Systems Singapore
DisplaySearch
Dontech, Inc.
DuPont Displays

E-Ink Corp.
ELDEC Corp.
Electro-Plasma, Inc.
Elo Touch Systems, Inc.
Endicott Research Group
ERSO/ITRI

Futaba Corp. R&D Center

GDS
Gebr. Schmid GmbH & Co.
Gennum Corp.
GPO Corp.

Hannstar
Hitachi, Ltd.
Hoya Corp., USA
Hunet, Inc.

iFire Technology
IMT Masken und Teilungen AG
Incom, Inc.
Industrial Electronic Engineers, Inc.
Info Incorporation
Innova Electronics, Inc.
Instrument Systems
Integrated Technology Express, Inc.
Interface Display & Controls, Inc.
Intevac, Inc.
iSupply/Stanford Resources

Japan Patent Office

Kent Displays

LCD Lighting, Inc.
Lexel Imaging Systems, Inc.
LG.Philips LCD

Micronic Laser Systems AB
Microvision, Inc.
Mitsubishi Electric Corp.
Myson Century, Inc.

National Semiconductor Corp.
NEC Corp.
Nippon Seiki Co., Ltd.
Noritake Itron Corp.

OCLI — A JDS Uniphase Company
OES/ITRI
Optrex America
OSRAM GmbH

Phosphor Technology Ltd.
Photon Dynamics
Photo Research
Pioneer Electronics (USA), Inc.
Planar Systems
Plasmaco, Inc.
Polar Vision, Inc.
Polytronix, Inc.

Quanta Display, Inc.
Quantum Data Inc.

Reflexite Display Optics
ROLIC Research Ltd.
ROLIC Technologies, Ltd.

Sarnoff Corp.
Schott Corp.
Sharp Corp.
SI Diamond Technology
Silicon Optix, Inc.
Silver Cloud Manufacturing Co.
Sony Chemicals Corp. of America
Sony Corp. Research Center
Supertex, Inc.
Symbol Technologies, Inc.

Tannas Electronics
Thomas Electronics, Inc.
Three-Five Systems, Inc.
Tiun Yuan Technology Co., Ltd.
TLC International
Toppoly Optoelectronics Corp.
Toshiba America Electronic Components, Inc.

Unaxis Balzars, Ltd.
UNIGRAF
Universal Display Corp.
USA EELY-ECW Optoelectronics, Inc.

Video Electronics Standards Association
Viratec Thin Films, Inc.
Vishay–Dale Electronics, Inc.
VON ARDENNE Coating Technology

Westar Corp.
WINTEK Corp.

ZBD Displays, Ltd.

index to advertisers

Absopulse Electronics, Ltd. **41**
Astro Systems **12**
Avery Dennison Microreplication **7**
The Bergquist Company **19**
Bi-Search International **8**
CyberTouch **30**
DisplaySearch **23**
Eldim **31**
Elo TouchSystems **10**
Ergotron **6**
Eyesaver International **43**
Jepico America **25**
Klein Instruments **35,43**
Kristel Corp. **31**
Photo Research **C2**
Polar Vision **39**
Quantum Data **5**
Radiant Imaging **9**
Shielding Express **18**
Silver Cloud Manufacturing Co **41**
Society for Information Display **46**
Solomon Systech **18**
3M Optical Systems **C3**
Unaxis **41**
Unigraf **42**
VESA **3,C4**
Westar Display Technologies **11**

Business and Editorial Offices
Palisades Convention Management
411 Lafayette Street, 2nd Floor
New York, NY 10003
Jay Morreale, Managing Editor
212/460-8090 x212 Fax: 212/460-5460
jmorreale@pcm411.com

Sales Office – Europe
George Isaacs
12 Park View Court
The Paddock, Eaton Ford
St. Neots, Cambridgeshire
PE19 7SD U.K.
Phone/Fax: +44-(0)-1480-218400
george@gandg.demon.co.uk

Sales Office – Japan
Ted Asoshina
General Manager
Echo Japan Corp.
Grande Maison Room 303
2-2, Kudan-Kita 1-chome
Chiyoda-ku, Tokyo 102-0073 Japan
+81-3-3263-5065
Fax: +81-3-3234-2064
echoj@bonanet.or.jp

Sales Office – U.S.A.
Palisades Convention Management
411 Lafayette Street, 2nd Floor
New York, NY 10003
Joanne Morgenthal, Sales Manager
212/460-8090 x211 Fax: 212/460-5460
jmorgenthal@pcm411.com

Sales Office – Korea
Jung-Won Suh
Sinsegi Media, Inc.
Masters Tower, Room 2410
553, Dowha-dong
Mapo-ku, Seoul 121-040 Korea
+82-2-313-1951/2 Fax: +82-2-312-7335
sinsegi@sinsegimedia.info

Sales Office – Taiwan
Michael Young
Trade Media Representative, Inc.
3F, No. 140, San Min Rd.
Taipei, Taiwan, R.O.C.
+886-2-2763-2438
Fax: +886-2-2545-7868
mediarep@seed.net.tw

backlight

Merger Mania: Yesterday, Today, and Tomorrow

by David Lieberman

This past September, Matsushita Electric Industrial Co., Ltd., and Toshiba Corp. announced their intention to create a joint venture by the end of March 2003 that will in effect merge the two companies' CRT businesses. The announcement was just the latest in a slew of recent events in an era of repositioning among Asian display companies – and the end is nowhere in sight. Joint ventures, spin-outs, mergers, partnerships, strategic investments, and the rest are the order of the day as vendors strive to share the burden of investment and risk in an increasingly competitive and increasingly uncertain display business environment.

The new 60% Matsushita, 40% Toshiba CRT joint venture continues a merger of the companies' display interests that began in 2001. In February of that year, the two announced their intention to form a venture – 40% owned by Matsushita and 60% by Toshiba – to manufacture low-temperature-polysilicon (LTPS) LCDs in Singapore. Toshiba had invested about ¥38 billion in 2000 to install a new LTPS production line at its Fukaya Operations, on top of the roughly ¥30 billion it had already sunk into LTPS facilities, the total of which slightly exceeded the company's sales of LTPS products in FY 2000.

With the new LTPS joint venture, incorporated in April of 2001, Toshiba gained a partner in bankrolling its LTPS expansion to the tune of an expected ¥123 billion by the end of FY 2002. The first wholly owned Japanese active-matrix-LCD operation outside of Japan, the AFPD Pte., Ltd., LTPS venture began operation in April 2003. The venture enjoys the considerable LTPS expertise of Toshiba, a technology pioneer and the first display vendor to make a major push in this arena, as well as Matsushita's fast-response LCD technology, which should considerably enhance LTPS for video applications and possibly enable field-sequential color. But between the concept and the reality, Matsushita and Toshiba tied a much tighter display knot than ever before.

In October of 2001, the two companies made two significant announcements: first, the establishment of a 50/50 joint venture dedicated to the procurement of materials and components for their respective CRT operations in an effort to reduce costs and improve procurement efficiency through higher-volume purchasing clout; and second, the complete merger of their businesses in LCDs and "next-generation displays" (*i.e.*, OLEDs) in yet another joint venture that would eventually be named Toshiba Matsushita Display Technology Co., Ltd., with 60% belonging to Toshiba and 40% to Matsushita.

The new merged LCD operation, incorporated in April of 2002 with an initial capitalization of ¥10 billion, has taken over all of its parents' LCD operations: passive LCDs; amorphous-silicon active-matrix LCDs, including TFPD Corp., formerly Display Technologies Inc., a joint venture between Toshiba and IBM which was dissolved in 2001; and LTPS active-matrix LCDs, including the new Singapore operation, which will operate as a wholly owned subsidiary. By some accounts, the new venture becomes the third-largest LCD manufacturer in the world. Withheld from the merger was Matsushita's PDP operation, Matsushita Plasma Display Panel Co., Ltd., itself a joint venture with Toray Industries, Inc.

continued on page 42

calendar

The Third International Display Manufacturing Conference & Exhibition 2003. Contact: SID HQ, 408/977-1013, fax -1531, e-mail: office@sid.org.
February 19–21, 2003 Taipei, Taiwan

FPD Expo Taiwan 2003. Contact: Sue Chung, 408/943-7961, e-mail: schung@semi.org.
February 19–21, 2003 Taipei, Taiwan

SID 2003 International Symposium, Seminar, and Exhibition (SID '03). Contact: SID HQ, 408/977-1013, fax -1531, e-mail: office@sid.org, www.sid.org.
May 18–23, 2003 Baltimore, Maryland

The 8th Asian Symposium on Information Display (ASID '03). Contact: Southeast University, Electronic Engineering Dept., Nanjing, Jiangsu, 210018 China, telephone/fax +86-25-3363222, URL: www.asid03.seu.edu.cn.
August 17–20, 2003 Nanjing, China

The 12th International Symposium on Advanced Display Technologies & Flowers, 2003. Contact: SID HQ, 408/977-1013, fax -1531, e-mail: office@sid.org.
August 25–27, 2003 Moscow, Russia

The 23rd International Display Research Conference (IDRC '03). Contact: Ralph Nadell, PCM, 212/460-8090 x203, fax -5460, e-mail: Rnadell@pcm411.com.
September 15–18, 2003 Phoenix, AZ ■