LCD ISSUE

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100 Years of Commercial Liquid Crystals

- ***SID 2004 Preliminary Program***
- ***The History of Commercial LCs***
- ***Third-Generation Feedforward Driving***
- ***The Big-Screen-TV Market***
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The very existence of a liquid-crystalline state was hotly debated for 15 years until E. Merck produced extremely pure samples in 1904 that allowed the determination to be made beyond a reasonable doubt. The original bottles contain liquid-crystal materials that were listed in Merck's 1904 catalog. The polarizing microscope is the one Otto Lehmann used in developing his 1889 proposal that the two melting points of "liquid crystals" were due to the existence of a mesophase – a fourth state of matter. Naysayers said the second melting point was due to impurities, and the argument was not resolved until 1904.

Merck KGaA

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Information Display

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Two Russian Display Companies

Late last summer, following the FLOWERS 2003 conference, I visited two Moscow display companies in the company of Victor Belyaev (Director of the Russia Chapter of SID), who had made the arrangements and kindly helped with translation.

First, we visited the Moscow plant of Incotex, Ltd., one of three manufacturing plants owned by the company, and were escorted through the plant by General Director Yuri B. Sokolov and Deputy General Director Boris V. Kogan. Sokolov purchased the Soviet-era plant as a vandalized shell and has recreated it as a bustling facility. The plant formerly produced CRT television receivers under the Mercury brand, and "Mercury" can still be seen on the building. "Mercury is a bad name for a CRT-TV factory," Sokolov joked.

There is no CRT production now. The 14-year-old company makes its money by manufacturing digital cash registers (25,000 per month) and other office machines, and more than 32 types of electric power meters, and has sales and service companies throughout Europe. The company's product mix and high-quality/low-cost strategy is successful, and the main problem is expanding capacity without disrupting current production, Sokolov said.

During our tour through the multi-story building, Sokolov set a rapid pace; this was one day when I did not have to worry about how to get enough exercise. Our tour eventually took us to Incotex's plasma R&D facility because Sokolov is basing his plans for the next stage of the company's growth on plasma displays. But they were not the kind of PDPs I was expecting.

Incotex is primarily developing dc – yes, dc – plasma technology with relatively large pixels for indoor large-screen advertising and information applications. The displays will be made of 400 × 400-mm tiles and will have pixel sizes of 12 × 12, 6 × 6, and 3 × 3 mm. The developmental modules with 6 × 6-mm pixels were producing 150 nits, but Sokolov expects to increase the luminance to 600 nits in 2004. The company is not trying to keep its ambitions secret. At CeBIT 2003, it showed a 32-m^2 display, and it has an international patent portfolio of 25 patents so far.

Sokolov says the tiled dc-PDP technology is much less expensive than LED video panels for interior applications, so he intends to both compete with LEDs and provide a solution at a price point that makes large flat-panel displays feasible where they were not before. How much less expensive is an Incotex tiled PDP? Sokolov said that tiled displays with 12-mm pixels will be less than $1500 per square meter, and displays with 6-mm pixels will be about $2500 per square meter. This compares with LED screens of $14,000–15,000 per square meter for 12-mm pixels and $25,000–30,000 for 6-mm pixels, he said.

The company will also produce LED modules of its own for outdoor applications, and will use ac-PDPs for displays with 3 × 3-mm pixels. Sokolov is considering offering single PDP modules for point-of-sale terminals. "They're inexpensive enough," he said. Sokolov expects to be ready to go into production in 2004 and is looking for partners to help finance the scale-up.

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my turn

I Was There

by Bernie Lechner

As I write this column during the first week of December, Pearl Harbor Day approaches, again occurring on a Sunday, as it did in 1941. And I am reminded of a December 7th about 30 years ago, when, at lunch with some colleagues at RCA Laboratories, I started to reminisce and explain what I was doing on December 7, 1941 (at age 9, playing with my Erector Set while my parents listened to the New York Giants football game on the big RCA console radio in the living room), when suddenly I realized that none of my table-mates had yet been born on December 7, 1941. That was the first time I felt old.

So what has this got to do with information display? At SID 2003 in Baltimore last May, as I admired the beautiful pictures on the large LCD and PDP flat-panel displays, I thought back to the early work on these technologies and had a similar realization. Many of those attending the SID Symposium, including the speakers and committee members, had not yet been born when the initial work on LCDs and PDPs was being done in the 1960s, and certainly most of those attending SID 2003 had not been born when Jan Rajchman at RCA and Edgar Sack at Westinghouse developed concepts for the first flat-panel matrix displays in the 1950s.

Both Sack and Rajchman based their efforts on panels using ac-driven powder electroluminescent cells, as did I when I first worked on matrix displays in the early 1960s. Rajchman actually built a 1200-element (30×40) display. The EL panel had a diagonal of about 10 in. A two-aperture magnetic-core device, called a transfluxor, was associated with each pixel to provide for coincident X-Y selection and analog storage. Line-at-a-time addressing was employed, and live moving images were displayed from a modified vidicon camera. (If you are interested in the details, see the paper by Rajchman *et al.* published in the November 1958 issue of the *Proceedings of the IRE*. The IRE was the Institute of Radio Engineers, a predecessor to the IEEE. Also, see U.S. Patent No. 2,928,894.) I remember this display well. The driving electronics occupied a 6-ft. relay rack filled with lots of vacuum tubes and big power supplies.

I attended my first SID Symposium in 1964, and LCDs and PDPs were not yet on the agenda. But by 1970 they were. That is the year that evening panel discussions were first introduced as a feature of the SID Symposium. One of the evening panels in 1970 was entitled "Will Matrix Displays Replace Cathode-Ray Tubes?" My recollection is that the panel concluded that it would take about 5 years. As the 1970s progressed, the estimated time increased, reaching 10 years at one point. It has taken a lot longer, but LCDs and PDPs are now replacing CRTs in many applications, and CRT factories are actually being closed because of declining demand.

I feel very fortunate to have been there when the work on LCDs and PDPs started. It makes me appreciate all the more the importance of the early work and the magnitude of the effort that it took to bring us to where we are today. ■

Bernard J. Lechner *played major roles in the development of matrix addressing for FPDs (including LCDs) and HDTV. He was Staff VP of Advanced Video Systems at RCA Labs from 1983 to 1986. From 1994 to 2002, he was Chairman of the ATSC Specialist Group on Data Multiplex/Transport, which developed the Program and System Information Protocol for Terrestrial Broadcast and Cable Standard. (When you use the interactive electronic program guide, think of Bernie Lechner –* Ed.*) He is a past President of SID, as well as a Fellow of SID, SMPTE, and the IEEE; e-mail: tvbernie@att.net.*

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100 Years of Commercial Liquid-Crystal Materials

The very existence of LCs was hotly debated until, just 100 years ago, Merck supplied very pure samples that ended the debate – and eventually started a technological revolution.

by Werner Becker and Hans-Juergen Lemp

FRIEDRICH REINITZER was trying to analyze and describe vegetable ingredients, but cholesteryl benzoate was puzzling. The substance melted at 145°C to a milky fluid rather than directly to a clear liquid. Only when it was further heated to 179°C did this melt become clear and transparent.

Reinitzer, an Austrian botanist at the German University of Prague (Fig. 1), was puzzled: a substance with two melting points? In 1888, he contacted the German physicist Otto Lehmann (Fig. 2) at the Technical University of Karlsruhe to further evaluate this strange substance.

Lehmann was also unable to explain this phenomenon because it was generally accepted at the time that only three states of matter exist – namely, solid, liquid, and gas – and these substances were, as Lehmann put it, "apparently living crystals." But Lehmann solved the problem. In 1889, he proposed the liquid-crystalline state, or mesophase, as a new and distinct state of matter that could occur between the solid and liquid phases (Fig. 3).

This finding was a scientific sensation, and triggered a controversy within the scientific community. Many scientists suggested that Reinitzer and Lehmann had only observed an artifact caused by impurities. The German scientists Gustav Tammann, Walter Nernst, and Georg Quincke vigorously argued against the existence of a distinct liquid-crystal (LC) phase.

Merck Gets Involved

In 1904, E. Merck, a successful pharmaceuticals and chemicals company with about 1000 employees in Darmstadt, Germany, helped to settle this scientific dispute by providing highly pure liquid-crystalline materials. Merck offered substances such as methyl-

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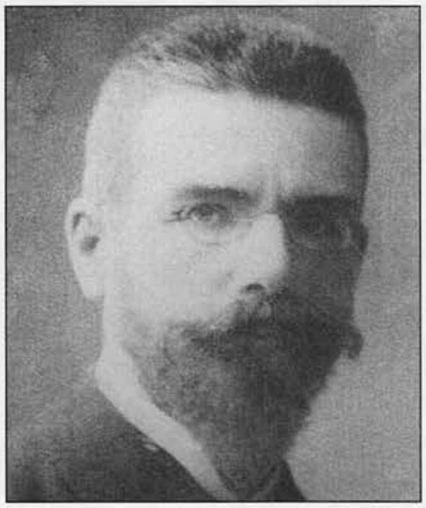

Merck

***Fig. 1:** The Austrian botanist Friedrich Reinitzer discovered the existence of LCs when he observed that cholesteryl benzoate melted at 145°C to a milky fluid, and only became transparent upon further heating to 179°C.*

Merck

***Fig. 2:** The German physicist Otto Lehmann proposed the liquid-crystalline state, or mesophase, as a new and distinct state of matter that could occur between the solid and liquid phases.*

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amino, dimethylamino, and trimethylamino oleate, and also acidum oleinicum purissimum. Later, the company also offered various cholesteryl esters, p-azoxybenzoate, p-azophenetole, p-azoxyphenetole, and p-azoxyanisole (Fig. 4). By investigating these substances, Lehmann and other scientists could finally confirm that the liquid-crystalline state forms a separate and distinct state of matter.

In the 1920s, the existence of a liquid-crystalline phase was generally accepted by the scientific community – with one exception. The famous physical chemist Gustav Tammann remained skeptical. It is reported that in a scientific plenary session he exclaimed, "Soft crystals do exist, floating ones may exist, but liquid ones? I tell you, no way!"

In 1923, the French mineralogist Georges Friedel established the names of the three liquid-crystalline phases as nematic, smectic, and cholesteric. At the University of Halle in Germany, Daniel Vorländer and his group intensively investigated the newly discovered LC materials as well. There was a great deal of interest in these substances, and many basic research efforts were made during the early decades of the 20th century.

Despite extensive basic research, technological applications for LCs were not identified. Therefore, by the mid-1930s, the scientific community gradually lost interest in LC materials. It was generally believed that the major scientific problems in this area had been sufficiently investigated and satisfactorily resolved. This was the beginning of a period of inactivity during which LC materials were widely considered to be an interesting, but essentially useless, laboratory curiosity.

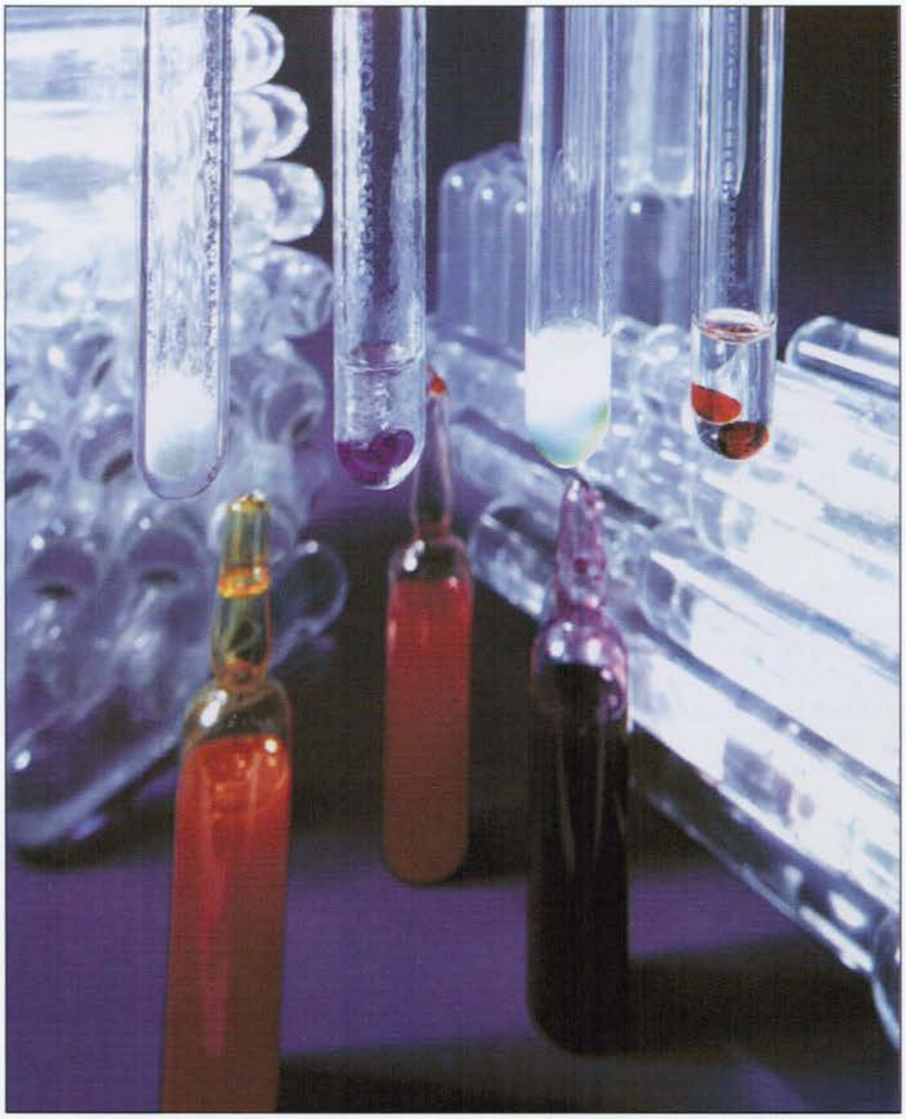
The Birth of LCDs

The revival of LC research was triggered by work done in the U.S. At the end of the 1960s, James Fergason of Westinghouse Electric Corp. in Pittsburgh, Pennsylvania, suggested the use of cholesteric LCs as temperature indicators. At about the same time, other U.S. scientists were developing other potential applications for LCs in analytical metrology, cancer diagnostics, and the non-destructive testing of materials. This marked the renaissance of LC research. The period of inactivity was suddenly over, and Merck resumed LC-materials research and development.

Some research groups focused on cholesteric LCs, others – like those of George Heilmeier (Radio Corporation of America) and James Fergason (Westinghouse Electric Corp.) – investigated possible applications for nematic LCs. In 1967, Heilmeier published his work on the dynamic scattering mode (DSM) in nematic LCs. Only one year later, he presented his first flat display employing LCs based on this effect.

Dynamic scattering had been discovered as early as 1963 by Richard Williams, but he said nothing about the significance of these patterns – also called "Williams domains" – for displays. Although Heilmeier's display required an operating temperature of 80°C, it was nevertheless considered a great breakthrough. The display was presented at the 2nd International Liquid Crystal Conference at Kent State University in 1968, where approximately 100 scientists discussed potential applications of LCs (Fig. 5). It was at this conference that the dream of a flat TV screen that could be hung on the wall like a painting was born.

Motivated by this conference, Merck intensified its efforts to synthesize new materials, now chiefly focusing on nematic LCs for dis-



Merck

Fig. 3: The suspended test tubes contain LC material in the solid, smectic, nematic, and isotropic states.

Merck

Fig. 4: Merck supplied original liquid-crystal substances in 1904 – a century ago.

play application. However, Merck also remained interested in cholesteric LCs, which were evaluated for use in thermometers, in the non-destructive measurement of temperature in various materials, and in infrared telescopes. Medical applications of cholesteric LCs, such as the diagnosis of vascular diseases and in mammography, were also considered.

Key Inventions in the 1970s

Liquid-crystal displays (LCDs) were initially based on effects such as dynamic scattering, deformation of aligned phases, and dichroism, but these displays did not find broad commercial use. The breakthrough was made in 1970–1971. Almost simultaneously, James Fergason, Martin Schadt, and Wolfgang Helfrich invented the twisted-nematic (TN) cell at the Liquid Crystal Institute at Kent State University in the U.S. and at Hoffmann-La Roche in Switzerland (Fig. 6). This invention triggered extensive R&D efforts in LC materials and LCDs all over the world.

George W. Gray (Hull University, England) and Merck were at the forefront of materials research at this time, and invented many stable, technically advanced LC materials, such as the substituted cyanobiphenyls and terphenyls. These compounds demonstrate a mesophase at room temperature and are thermally and chemically stable, so they enabled the manufacture of TN cells that met practical requirements.

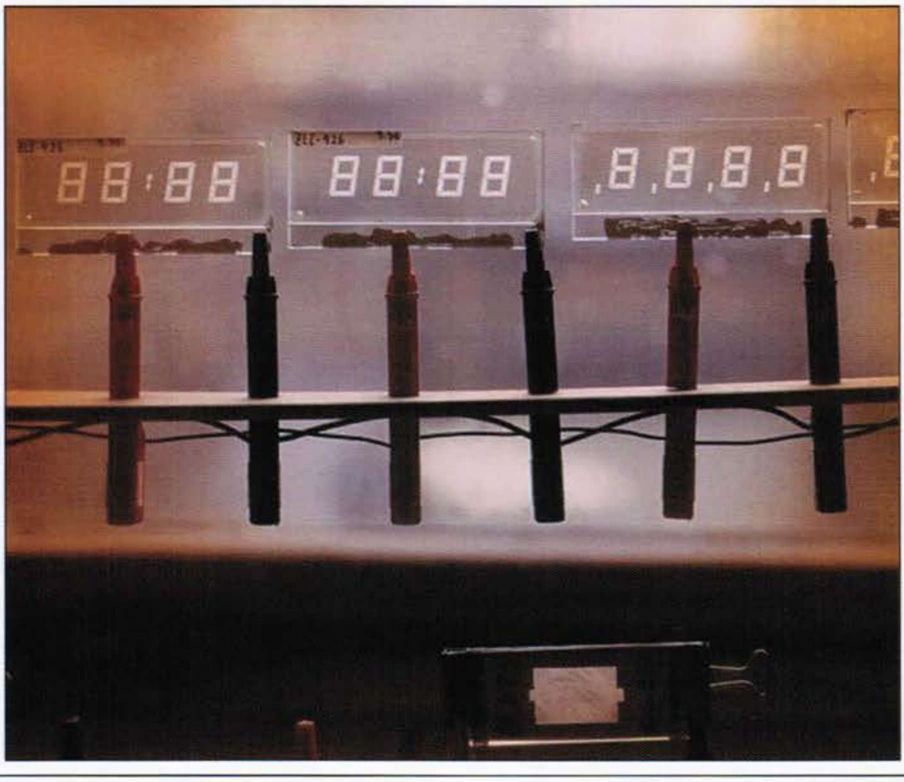
In 1976, the phenylcyclohexanes (PCHs) were invented at Merck by Rudolf Eidenschink and co-workers. These compounds exhibit a low viscosity and relatively low values of birefringence, thus enabling TN cells with shorter switching times. Other technically suitable LC materials were invented by research groups at Hoffmann-La Roche and BBC in Switzerland, at the University of Halle in Germany, and elsewhere around the world.

Advances of the 1980s and 1990s

In comparison to other displays, LCDs exhibit some unique advantages. First, they have a low power consumption, which is combined with low weight and no emission of radiation. Because of these advantages, LCDs replaced conventional display devices in many applications in the 1980s and 1990s. This unique combination of properties made possible completely new applications, such as portable PCs, mobile telephones, personal digital assistants (PDAs), and electronic toys.

LCDs have revolutionized modern communications because their light weight permits the construction of truly portable mobile telephones that make communication possible anywhere and at any time. LCDs thus permit more effective human interaction; they make our lives easier and have fundamentally changed the workplace environment.

This marked cultural change could not have occurred until the LC industry developed advanced LC mixtures and improved LCD concepts that could deliver improved performance and lower switching times. The devel-



Merck

Fig. 5: George Heilmeier's demonstration of a dynamic-scattering-mode (DSM) LCD in 1968 quickly stimulated other efforts. These DSM prototypes were made by Merck in 1971.

opment focused on LC materials that permitted the fabrication of LCDs with low power consumption, short switching times, and with contrast that did not vary greatly with viewing angle. These features are essential for advanced high-resolution LCDs – such as the supertwisted-nematic (STN) cell invented by T. J. Scheffer, J. Nehring, and others at BBC in Switzerland in 1981 – and, in particular, for active-matrix TN displays.

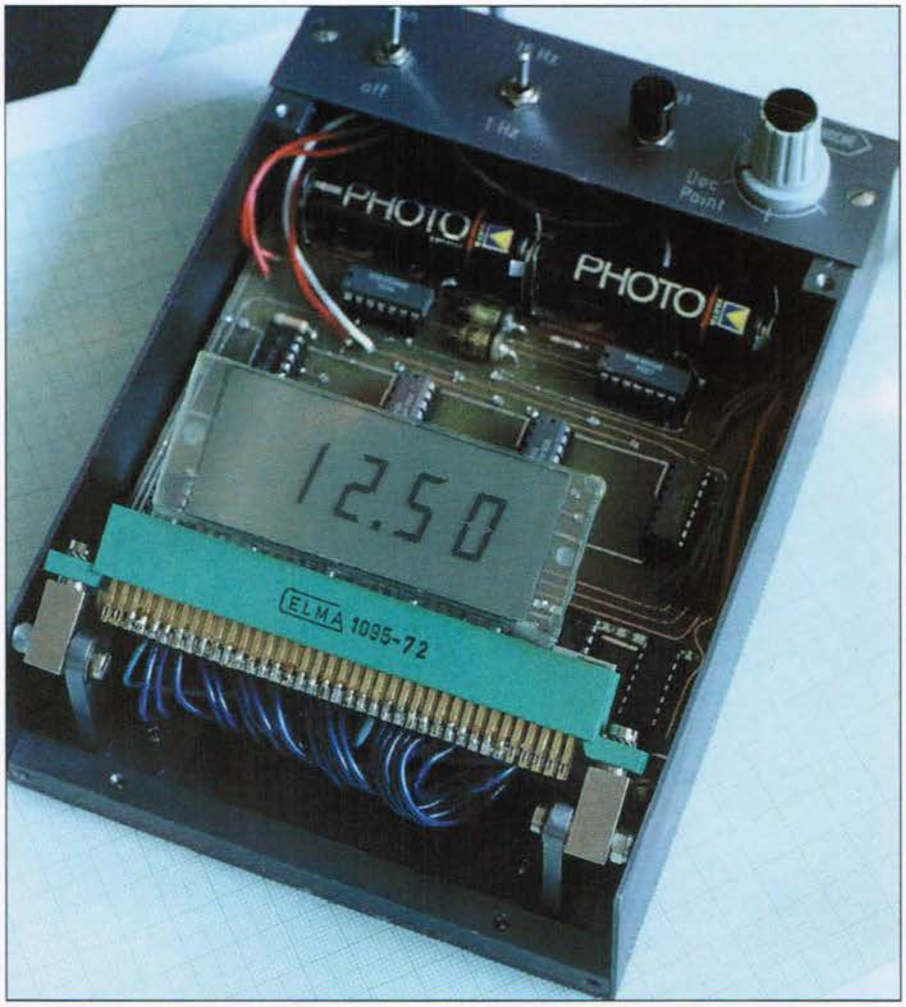
Improving AMLCDs

The 1990s saw Merck and its research partners invent two pioneering LCD technologies that improved the performance of active-matrix LCDs (AMLCDs). In 1992, Merck and the Institute of Applied Physics of Solid State in Freiburg filed a patent for in-plane-switching (IPS) technology. LCDs employing this technology are characterized by a particularly advantageous dependence of contrast on viewing angle, enabling a viewing angle of up to 170° to be obtained.

Another pioneering patent, for the multi-domain vertical-alignment (MVA) technology, was filed by Merck in 1997. MVA enables the manufacture of the very large LCDs required for applications including TV sets and computer-aided design (CAD). LCDs employing MVA technology are characterized by viewing angles up to 170°, high contrast, advantageous gray-scale and color properties, and very fast response times.

History indicates that the development of LC materials has always been driven by the identification of new applications for LCDs. Today, the development of LC materials and tailor-made LC mixtures for various display applications proceeds at an ever-faster pace, reflecting the rapid technological progress in our age of globalization. The strong demand for innovation comes not only from end users, but also from industry, which wants to develop new markets by setting new trends.

Development is rapidly proceeding, for example, in the area of small- and medium-sized LCDs used in applications such as mobile telephones, PDAs, household equipment, and electronic games (Fig. 7). The next generation of mobile telephones – "smart phones" – includes models that are very small but equipped much like a personal computer. Automotive navigation systems are another example. They are still optional equipment in most automobile lines, but after further development we believe they will become standard for all vehicles.



ROLIC Research

Fig. 6: *This is the first twisted-nematic LCD prototype as presented to the Board of Directors of Hoffmann-La Roche by Martin Schadt and Wolfgang Helfrich in March 1971.*

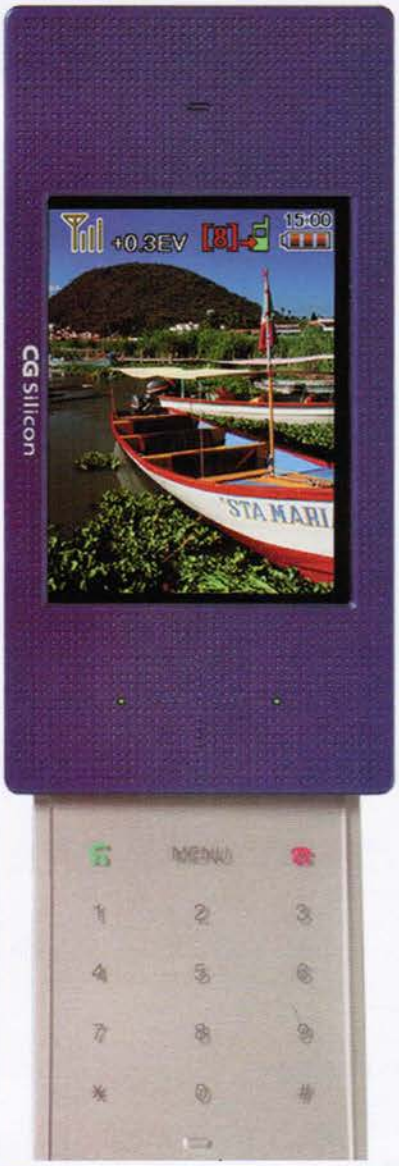
The Early Dream Comes True

Today, it is hard to imagine the working world without LCDs. They are used as monitors in PC workstations, in notebooks, and in control units for industrial manufacturing equipment. The market share of LCDs for PC-monitor applications for office and private use is increasing because of their superior properties and decreasing prices.

There is only one major market left for LCDs to conquer, and that is consumer TV. This application is still dominated by cathode-ray-tube (CRT) displays. But LCDs have already started to invade this area, and in a few years the dream of the early days in LCD history will come true: the wall-hanging TV will be produced in high volume. Since the prices for large-sized displays are now decreasing, LCD TVs will soon become affordable for everyone. It is predicted that LCD-TV-set sales will explode over the next 5 years – a boom that will be comparable only to that of mobile telephones over the past few years.

LCD TVs require specifically designed LC mixtures and advanced display technologies, such as IPS and MVA, which are now available to manufacturers of large LCD panels.

Over the years, a number of competing display technologies have been developed, including organic light-emitting diodes (OLEDs) and plasma-display panels (PDPs). Technologies that are less likely to become commercially important include electroluminescent (EL) displays, field-emission displays (FEDs), vacuum fluorescent displays (VFDs), and inorganic LEDs.



Sharp

Fig. 7 Advanced displays are now being designed for cellular telephones and other mobile devices.

From today's perspective, despite extensive R&D efforts devoted to alternative display technologies, it can be predicted that LCDs will remain the dominant display technology in most applications for many years to come. ■

Third-Generation Feedforward Driving

Motion-Adaptive CODEC Feedforward Driving (macFFD) retains the improvement in switching speed accomplished by previous generations of FFD, improves peak signal-to-noise ratio, and permits the use of low-cost frame stores that will reduce the cost of high-definition LCD TVs.

by Jun Someya

RECENTLY, television manufacturers have substantially increased the number of LCD TVs in their product lines, attracting customers because of the thin profiles and low power consumption made possible by LCDs. However, LCD TVs are not perfect. It is well known that the slow response time inherent in liquid crystals (LCs) causes moving images on LCD-TV screens to blur or smear.

Today, the problem of motion blur is gradually being solved by improvements in LC materials and panel structures and the adoption of an image signal-processing technique referred to as overdrive technology.

Designers began to use overdrive technology in a number of products because it can improve the response time – even in conventional LC panels. One variation of overdrive technology is the feedforward-driving (FFD) system, which we have studied extensively at Mitsubishi Electric Corp. and is the subject of this article.

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The Principle of FFD

When the amount of incoming image data to an LC panel changes, the luminance on the screen does not change correspondingly (Fig. 1). Figures 1(a) and 1(b) show the luminance profiles for an LC panel utilizing a conventional driving method when the amount of image data changes from d1 to d2 and from d1 to d3, respectively. Figure 1(c) shows the luminance profile when the amount of image data changes from d1 to d2 using FFD. In the diagrams shown in Fig. 1, time is plotted on the horizontal axis, while the vertical axis is calibrated in amounts of image data (d1, d2, *etc.*) and the luminance level (l1, l2, *etc.*) on the screen. When the amount of image data changes from d1 to d2 at time t1, the luminance changes from l1 to l2, but it takes until time t4 to do so because of the slow response time of the LC [Fig. 1(a)]. If a box having a luminance level of l2 moves from left to right on the screen, the displayed image will be as shown on the right-hand side of Fig. 1(a).

The illustration of the box is defined by time divisions t1–t6 that correspond to those on the graph. The part of the illustration labeled t3, for example, shows the luminance when the time interval t3–t1 has passed, following the change in the amount of image data from d1 to d2 at time t1. Similarly, Fig. 1(b) shows that the luminance attains a value of l3 at time t4 when the amount of image data changes from d1 to d3. In this case, we can see that the luminance passes through level l2 at time t2, which is one frame after the amount of image data changes.

This is an exciting observation because it means we can change the luminance from l1 to l2 within one frame time if we input the image data d3 for a period of one frame, and then return the input image data to d2 [Fig. 1(c)]. Thus, by comparing the old and new values of the amount of image data when it is changed, we can accelerate the luminance change by temporarily applying a high (or low) image-data level.

But nothing is free. FFD and the other overdrive techniques require a new frame memory because these technologies compare the amount of image data for the current frame with that of the previous frame. Such a frame memory involves a cost increase because pins must be added to the large-scale integrated circuit (LSIC) in order to control the LC; therefore, it is necessary to design a frame memory with fewer SDRAM units in order to apply overdrive to the product.

Reduction in Frame Memories

In this article, we discuss third-generation FFD technology. In first-generation FFD technology, which was described in paper 29.3 published in the *2001 SID International Symposium Digest of Technical Papers*, the frame memory consisted of a single SDRAM chip, which was made possible by reducing the amount of image data. We began studying new methods of memory reduction simultane-

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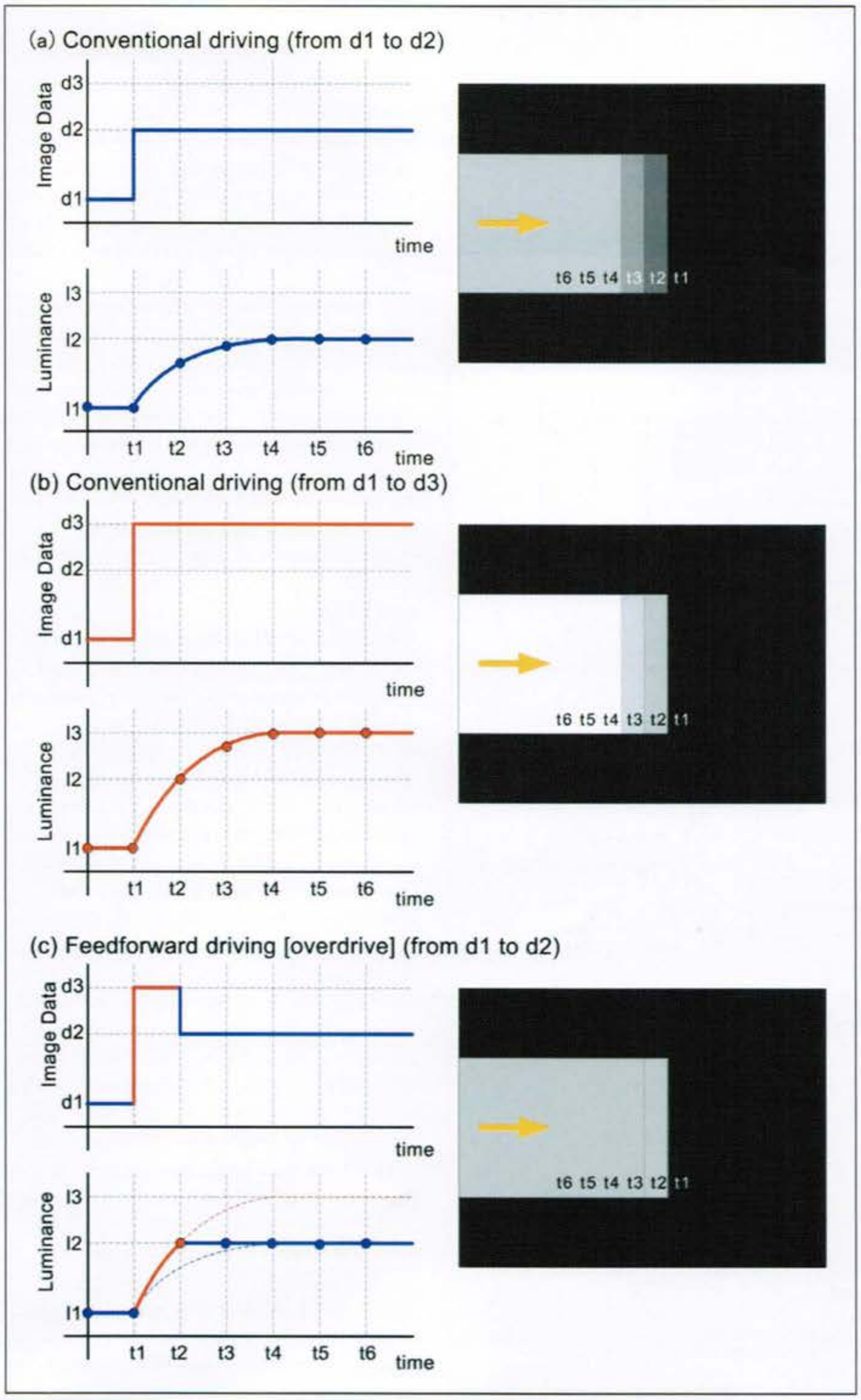
ously with the development of LSI for first-generation FFD because it was inevitable that the data quantization used in first-generation FFD would result in errors if overdrive was used [Fig. 2(a)]. Second-generation FFD uses image compression to reduce the amount of image data, and this approach is referred to as compression FFD (cFFD).



The two types of cFFD which we have developed are single (cFFD-S) and dual (cFFD-D). A cFFD-S system has a compression circuit located before the memory and a decompression circuit after the memory [Fig. 2(b)]. The cFFD-D system contains two decompression circuits; one supplies the output of the current frame and the other the output of the previous frame [Fig. 2(c)].

cFFD-S has a simpler circuit structure than that of cFFD-D, but a critical problem arises when a still image is supplied [Fig. 3(a)]. Block truncation coding (BTC), which has simple circuitry, is the image-compression method adopted in cFFD. Because BTC uses an irreversible compression system, its decompressed images always contain errors. Since cFFD-S uses the original image data for the current frame image, and uses the decompressed image for the previous frame image, the amount of data of the current frame differs from that of the previous frame because of the CODEC error involved in the decompressed image even if the image is static. More specifically, cFFD-S interprets the difference between frames due to the CODEC error as a temporal change in the image. As a result, images that contain no temporal changes undergo overdrive processing, which results in a noisy still image.

However, cFFD-D can cancel CODEC errors in still images owing to its two decompression circuits [Fig. 3(b)]. cFFD-D reconstructs the previous frame image from two decompressed images and the current image. First, the previous decompressed frame image is deducted from the current decompressed frame image to determine the difference in the image between frames. Second, the difference from the current frame image is deducted in order to reconstruct the previous frame image. Although these two decompressed

Fig. 1: *(a) When the amount of image data sent to a conventional LCD pixel is increased from d1 to d2, the luminance increases from l1 to l2, but takes about three frame periods to do so. (b) When the amount of data is increased from d1 to d3, the luminance takes three frame periods to rise to l3, but only one frame period to rise to l2. (c) This observation led to the creation of overdrive technologies, which temporarily apply an artificially high amount of image data to bring the pixel to its desired luminance more quickly.*

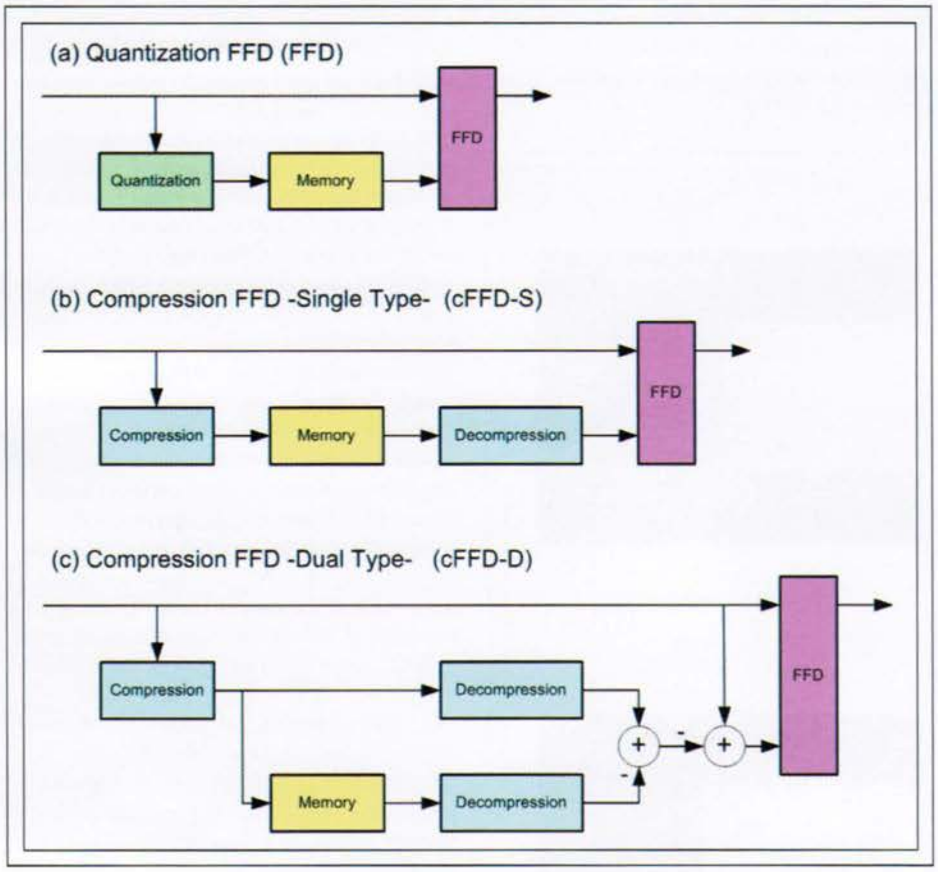


Fig. 2: (a) A block diagram of FFD and (b) and (c) two versions of cFFD are shown. FFD uses data quantization to reduce memory requirements. cFFD-S uses one decompression circuit while cFFD-D uses two.g

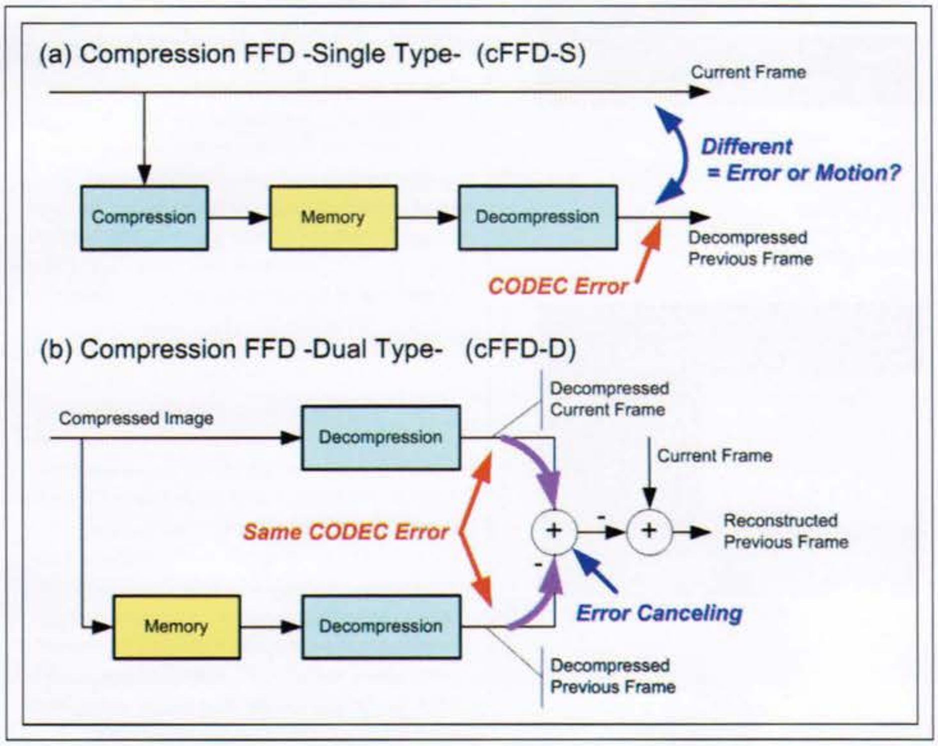


Fig. 3: (a) A cFFD-S system cannot differentiate CODEC errors in a still image from those in a moving image. (b) A cFFD-D system cancels CODEC errors in still images.

images involve CODEC errors, as is the case with cFFD-S, these errors cancel each other when the previous decompressed frame image is deducted from the current decompressed frame image because these errors have the same value when the image does not change at all. This is why a cFFD-D system has two decompression circuits, and it is also why we decided to use cFFD-D in our second-generation FFD.

In comparing the two generations, we noticed that cFFD-S has fewer errors than cFFD-D if the image is changing. Errors generally tend to increase because different errors are contained in the two decompressed images of cFFD-D when the image is changing. So, we investigated possible methods for switching between cFFD-S and cFFD-D according to whether or not the program contains a changing image in a particular time interval.

macFFD

We needed a method to create the previous frame image in a way that depends on the degree of image change. Such a method was devised and is called Motion-Adaptive CODEC Feedforward Driving (macFFD) (Fig. 4). macFFD is achieved by adding a selector to a cFFD-D system. This selector switches between the reconstructed previous frame image, which is used as the previous frame image in cFFD-D, and the decompressed previous frame image, which is used as the previous frame image in cFFD-S, according to the degree of temporal change of the image. Because the temporal change of the image has already been obtained when calculating the reconstructed previous frame image using cFFD-D, the selector can be controlled based on this value. Therefore, with the addition of only one small circuit to the cFFD-D system a performance improvement can be obtained (Fig. 5).

The figure compares the peak signal-to-noise ratios (PSNRs) of cFFD-S, cFFD-D, and

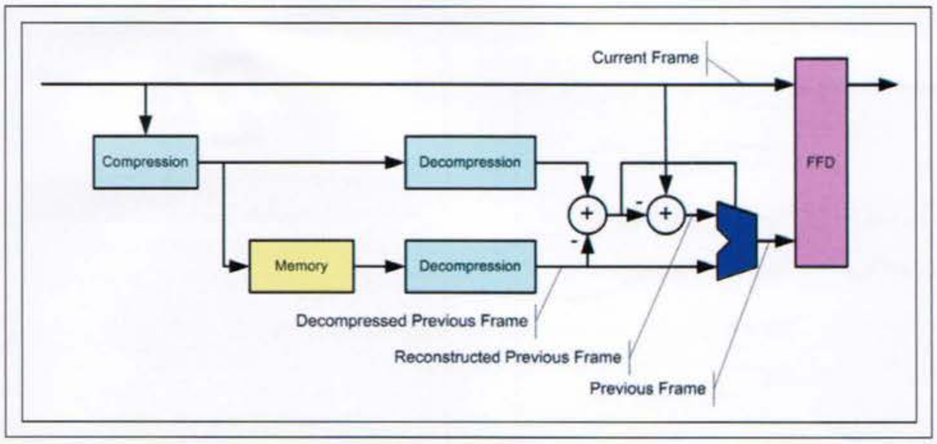


Fig. 4: Motion-Adaptive CODEC Feedforward Driving (macFFD) creates the previous frame image in a way that depends on the degree of image change.

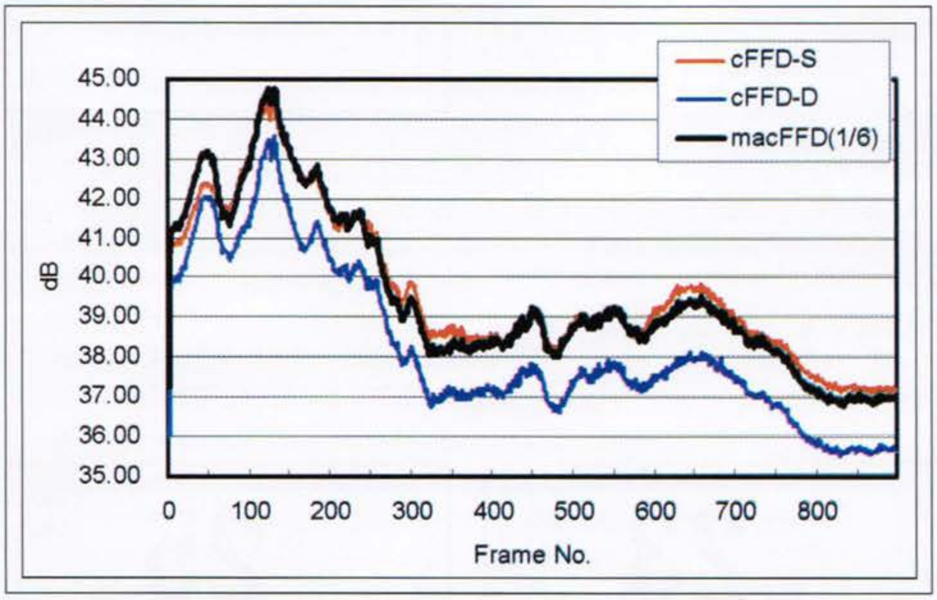


Fig. 5: macFFD improves images by providing a higher peak signal-to-noise ratio (PSNR).

macFFD over 900 frames of image data from ITE Test Materials for Standard-Definition-Television No. 3 (Woman with Birdcage) using a BTC compression ratio of 1/6. The PSNR of macFFD is almost the same as that of cFFD-S and is higher by 1–2 dB for all picture frames. The size of this improvement is modest but worthwhile when the small scale of the added circuits is taken into account. However, for HDTV, the benefits of macFFD become much greater.

macFFD in HDTV

Overdrive technology, which started with FFD, requires a frame memory that memorizes a frame of an image. To reduce system cost, it is necessary to minimize the number of DRAM chips that constitute this frame memory. The number of DRAMs necessary for the frame memory is determined not only by the amount of image data but also by the data-transfer rate (which in turn is determined by clock frequency and bus width) between the DRAM and LSIC.

The LC panels used in TV sets contain varying numbers of pixels, but let us discuss a structure that implements FFD using a single DRAM in an HDTV LC panel having the highest number of pixels (1920 × 1080). Table 1 compares the memory composition and performance of macFFD structures, which use BTC, to an FFD structure that uses data quantization for implementation of an overdrive LC panel for HDTV. Three types of macFFD structures are shown in the table.

The first one uses a standard SDRAM with a data-compression ratio of 1/6. In this case, the SDRAM has a bus width of 16 bits, and the frequency of the data transfer is 75 MHz. The second and third macFFD types are comprised of a standard SDRAM of 32-bit width and a DDR-SDRAM of 16-bit width, respectively, both having a data-compression ratio of 1/3. The SDRAM with a 32-bit width has a data-transfer rate of 75 MHz, and the DD-SDRAM has a rate of 150 MHz. Quantization (last column in Table 1) is used to reduce the data by 1/3 in order to compare performance. The PSNR values of the 32-bit-width SDRAM and the DDR-SDRAM are higher than those of quantization FFD by 10 dB or more, and they have the same data volume as quantization FFD. Furthermore, for macFFD with a data-compression rate of 1/6, the PSNR is improved by approximately 8 dB.

When we examine the plot of PSNR *vs.* the number of frames of ITE No. 3, an improvement of about 15 dB can be seen in some of the segments of the macFFD (1/3) curve compared with the quantization-FFD (1/3) curve

Table 1: Memory Structure and Performance of FFD Techniques for HDTV

Method	macFFD	macFFD	macFFD	Quantization
Reduction	1/6	1/3	1/3	1/3 (3:3:2)
Data size	7.91 Mbit	15.82 Mbit	15.82 Mbit	15.82 Mbit
Frame memory	SDRAM	SDRAM	DDR-SDRAM	DDR-SDRAM
	16-bit width	32-bit width	16-bit width	16-bit width
Data rate	75 MHz	75 MHz	150 MHz	150 MHz
PSNR	39.53 dB	42.74 dB	42.74 dB	31.14 dB

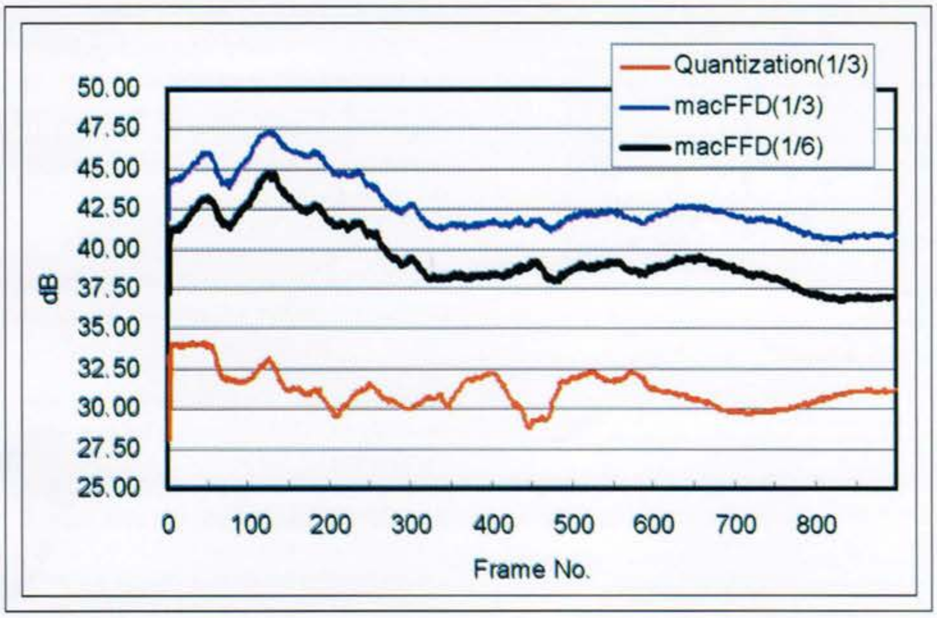


Fig.6: In either form, macFFD is a more-efficient method of memory reduction than quantization FFD when structuring an overdrive method for HDTV.

(Fig. 6). Even the macFFD (1/6) curve, with 1/6 data reduction, shows an approximately 8-dB improvement compared with the quantization-FFD (1/3) curve. macFFD is therefore an efficient method of memory reduction in either form. Thus, we can select either a 1/3 data-compression method with the emphasis on performance or a 1/6 data-compression method to reduce costs when structuring an overdrive using macFFD for HDTV.

Future Plans

An LSIC for second-generation FFD (cFFD) has been developed. Today, LC panels containing this LSIC are shipped on a regular basis, and some personal computers, LC TVs, and other end products containing the LSIC are also on the market. The macFFD technology discussed in this article will undergo further technological reviews before a final evaluation using practical hardware. When the evaluation is complete, a plan for LSIC development will be discussed.

Meanwhile, Mitsubishi is planning to license this technology to external institutions and companies; procedures and formalities are being discussed. The memory-reduction method in which the image-compression technology is applied, as used in cFFD and macFFD, is applicable to memory reduction in overdrive techniques other than FFD. Therefore, we are also discussing the licensing of the memory-reduction technique on its own. Some companies have already inquired about this technology, and negotiations are under way. ■

Big-Screen-TV Competition Heats Up

In 2007, the industry could easily sell 40 million TV sets with screen diagonals over 30 in. and 18 million sets with diagonals over 40 in. But will they turn a profit?

by Chris Chinnock and Chuck McLaughlin

BIG-SCREEN-TV TECHNOLOGY is now in the first stage of a revolution. This segment was once dominated by cathode-ray-tube (CRT) technology, but direct-view liquid-crystal-display (LCD) and plasma-display-panel (PDP) technologies, as well as high-temperature polysilicon (HTPS) LCD, digital-light-processing (DLP), and liquid-crystal–on–silicon (LCoS) technologies, are now beginning to displace CRT-based TV sets. More importantly, these new technologies will not only replace the CRT, but greatly expand the big-screen-TV market. How big it will become and which technologies will do well are the key questions that will challenge the industry.

A Dynamic Market

The results at the retail level are clear. In 2003, Gateway's introduction of a $3000 PDP TV spurred sales and price-cutting by competitors, and further confirmed consumer perception that plasma is the next big thing in TV technology.

LCD-TV sets surged into the market, selling mostly in sizes under 20 in. at high price points and causing almost every consumer-electronics company – and now information-technology (IT) companies as well – to scramble to establish a line of TV sets intended to grow to 30 in. and beyond very quickly.

Front-projection technology, once the domain of the wealthy, is starting to attract less-affluent buyers. So-called "cross-over" projectors that are sold through business and IT channels are already ending up in the homes of consumers. Some cost as little as $1000 and are the cheapest way to obtain a 100-in. image.

In the rear-projection-TV segment, micro-display-based sets are starting to displace CRT-based sets. In fact, manufacturers were caught off guard by the surprising strength of sales in this new category. Now they are scrambling to ramp up production to meet a demand that is 3–5 times what they anticipated.

In addition, new sales channels for buying big-screen TVs are emerging to challenge the traditional electronics/appliance retailers. Personel-computer makers Dell and H-P are following Gateway's lead. Electronics mass retailer Good Guys was swallowed up by IT channel seller CompUSA. Professional and high-end home-projection installers are all eyeing the exploding home-entertainment market. Chinese companies, who will make an increasing number of big-screen-display systems, are also planning to invade U.S. markets with branded products of their own.

A Turbulent Market

Some of the drivers and factors that are creating a turbulent TV market include the rapid adoption of DVDs for movies, the conversion from analog to digital TV, and the convergence of technologies that support PC monitors, business projectors, and big-screen displays. Some factors will induce consumers to buy big-screen TVs, while other factors will cause an expanding array of TV sets to enter the market at ever lower price points.

DVDs are creating a great demand for big-screen displays. A large number of consumers want wide-aspect-ratio sets that match the format of many DVD movies, so they are buying new sets. But do consumers have enough disposable income to fuel a big wave of new TV purchases? This is not clear because consumers may have to re-allocate money planned for other purchases to buy an expensive big-screen display.

The conversion to digital TV is well under way worldwide. Recent developments in the U.S. are now adding new momentum to the move to high-definition TV (HDTV). These developments include an agreement for cable companies to carry HDTV programming as well as an expanding line-up of content coming *via* broadcast and satellite. Nearly all prime-time programming is now broadcast in high definition. As was confirmed at the recent HDTV Forum, the "lack of content" argument that has hurt sales expansion seems well on the way to being resolved.

On the technology front, the stars are now aligning to enable multiple technologies to penetrate into the big-screen-TV segment. For example, market growth in the business-projector segment slowed in 2002, so manufacturers are turning to new opportunities in the TV industry. This is driving a wave of front-projection models that are business-projector derivatives, plus a new class of video-optimized models at every conceivable price point. Similar projection engines are

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also being used to create microdisplay-based rear-projection televisions.

Meanwhile, manufacturers of direct-view LCDs continue to invest in next-generation fabs that can process ever-larger panels, enabling the cost-efficient production of TV-sized displays. Having conquered the notebook and PC-monitor segments, these companies now have their sights set on TVs.

Similarly, makers of plasma panels are expanding beyond their base in professional display markets and heading into homes, leveraging investments in new fab capacity.

Forecast: Uncertainty

The success of all these technologies is both good news and bad news. The good news is that sales are up and growing quickly. And most analysts expect that a number of factors will converge over the next 10 years to propel sales of big-screen displays to new heights in terms of units.

The bad news is that it may be a challenge for anyone to make any money in this business. With prices, alliances, technology, and sales channels changing so rapidly, today's leader could become an also-ran in a heartbeat. It is a jungle out there!

What we are seeing is the maturation of the display industry. Exploding demand, rapidly expanding competition, severe price pressure, profit squeezing, and consolidation are phenomena that industries such as the PC, disc drive, DRAM, and others have faced before. Some companies will react in time to survive, but others will not.

Despite this challenging environment, there is unbridled enthusiasm within the analyst community for big-screen-TV growth, with each analyst tending to be most bullish on a favorite technology. About 4 million TVs with screens larger than 40 in. were forecast to be sold in 2003. Summing up the more optimistic estimates from the analyst community places the 2007 market for greater-than-40-in. displays at more than 20 million units. Will consumers buy five times as many of these big-screen displays in 2007 as in 2003?

Big-screen-TV forecasts by product technology indicate there is optimism everywhere. Forecasts of sales of rear-projection TVs by 2007 vary between 4 and 8 million units. To that, add front-projection TVs with forecasts of 1–4 million and plasma big screens at 6–7 million, and it is not hard to forecast more than 18 million units for the greater-than-40-in. sets. If direct-view-CRT TVs and LCD TVs greater than 30 in. are included, an estimate of the market size could quickly rise to 40 million units in 2007. Most of that volume would be in the 30–39-in. range, with prices for LCD TVs approaching $1000 as Gen 5, 6, and 7 fabs flood the market.

The problem with these forecasts is that they are supply-side driven, with little in the way of demand-side surveys and analysis. It is a case of "if we build them they will sell" optimism, which may or may not be founded in reality. (Yes, they will sell, but will it be at prices that force consolidation and cripple profits?)

To help understand how this market will change over the next few years, Insight Media and McLaughlin Consulting Group have teamed up to produce a forecast for the entertainment segment as well as several other microdisplay-based market segments.

For displays over 30 in., the forecast predicts that

1. Direct-view CRT sales will peak in 2003–2004 at 11.5 million units and decline to 8.5 million units by 2007.
2. Plasma-TV sales will grow from 700,000 in 2003 to 4.5 million by 2007.
3. LCD-TV sales will rocket from 400,000 in 2003 to 16 million in 2007.
4. LCD TVs will dominate the under-40-in. market, and rear-projection TVs will own the segment above 50 in., with tough competition in the 40-in. range.

CRT sales will be hurt by the thin form factor of flat-panel alternatives, as well as their excellent image quality, hang-on-the-wall capability, and attractiveness. Despite being considerably more costly than CRTs, plasma displays and LCDs will see their sales skyrocket as huge fab investments drive prices down at a rapid rate. The average selling price of all plasma TVs in 2007 will be about $2500, while LCD TVs will be about half that. Granted, most PDP TVs will be 40 in. and larger while most LCD TVs (in this forecast) will be in the 30–39-in. range. Nevertheless, the forecast predicts the sale of 2 million LCD TVs with diagonals greater than 40 in. in 2007.

Predicting the prospects for the projection segments of the entertainment market is challenging. Therefore, we offer two scenarios – optimistic and conservative – focused primarily on the opportunities for microdisplay-based systems.

The optimistic forecast assumes that microdisplay-projection TV is competitive, and branders and integrators will successfully build consumer enthusiasm (Fig. 1). As a result,

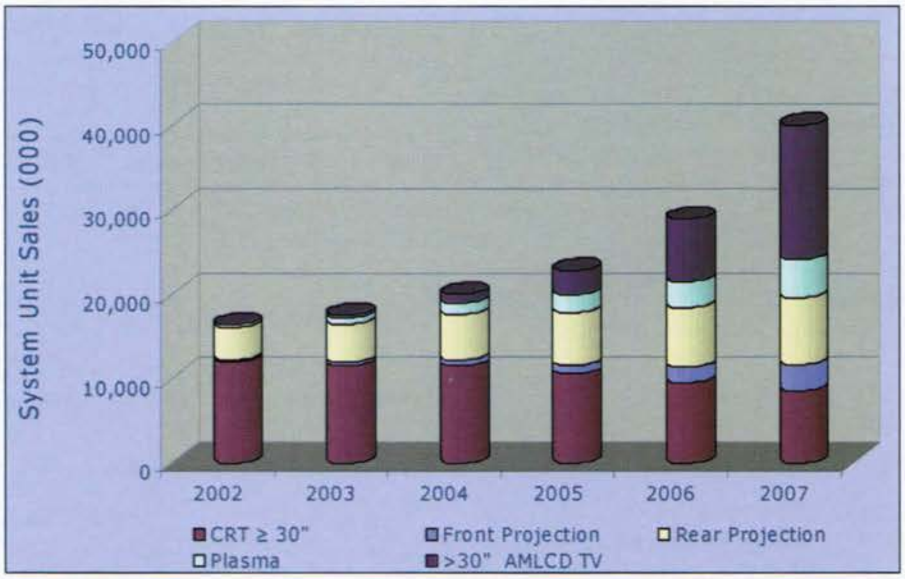

Fig. 1: Market forecast for big-screen televisions, incorporating the optimistic assumptions for microdisplay-projection sets.

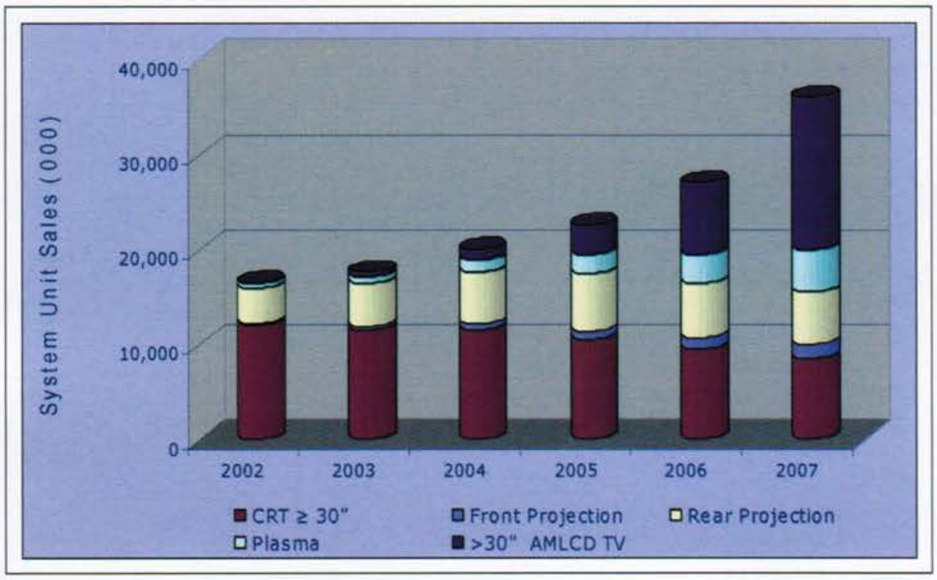

Fig. 2: Market forecast for big-screen televisions, incorporating the pessimistic assumptions for microdisplay-projection sets.

1. Rear-projection TV will hold its own and effectively compete against flat-panel big screens, growing to 8 million units in 2007, about twice current levels.
2. Microdisplay rear-projection technology will progressively displace CRT rear-projection TVs from the market, gaining a 65% share of the rear-projection-TV market by 2007.
3. Low-priced front-projection TVs optimized for home-TV viewing will catch on, and unit sales will hit 3 million by 2007.

The result of these three optimistic assumptions would be the emergence and growth of a new market for microdisplays that would equal the magnitude of the existing business-presentation market for front projectors. Microdisplay revenues from entertainment systems would approach $1 billion in this case.

Using more conservative assumptions markedly reduces the forecast. In our conservative case,

1. Total rear-projection-TV sales stall at 5.5 million units in the face of strong price competition from flat panels.
2. Microdisplay rear-projection TVs will make a smaller penetration (35%) into the CRT-rear-projection-TV market.
3. Consumers will be slow to embrace front-projection TV, and sales reach only 1.5 million units.

The total effect of these three assumptions would be to reduce total microdisplay revenues from entertainment systems to approximately $400 million, less than half that in the optimistic forecast (Fig. 2).

Another key question is the competitiveness of the three microdisplay technologies – high-temperature poly-Si (HTPS) LCD, DLP, and LCoS. Today, there are over 20 LCoS providers, all of whom cannot survive the coming turmoil. Texas Instruments' position appears secure as the only DLP supplier, but the competitiveness of HTPS remains uncertain, considering Sony's recent withdrawal from supplying HTPS microdisplays to external customers. The company has chosen to use the technology only for Sony-branded products, citing low yields and declining prices for its decision. Does this mean Epson will take all of Sony's business, or will suppliers look to DLP and LCoS technology for alternative solutions? Is this a harbinger of the end of HTPS projection?

The situation is being complicated by other factors, such as the desire of some companies to use microdisplay panels as a loss leader to gain market share, a fairly common practice in other industries. Predicting who will play this game – and who will win or lose – is difficult. The results can have a major impact on the success of microdisplay projection.

We believe LCoS remains a key wild card in this market, particularly for rear-projection TV. With a large number of Taiwanese and Chinese companies developing LCoS panels, engines, and rear-projection TVs, there is a good chance that one or two of them will break out with a winning combination of performance and price that could produce substantial sales. If this happens, it could easily pull the entire microdisplay segment forward, and it is a key part of our optimistic forecast scenario. The recent announcement that Intel will supply LCoS panels for rear-projection TVs will be a major boost for this technology, too. But unless LCoS rear-projection TVs come to market soon and gain some foothold, the prospects for this wild-card scenario will diminish.

Table 1: Market Forecast Data Used in Figs. 1 and 2 (in thousands of units)

Optimistic Case	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
CRT ≥ 30 in.	8200	8900	12000	11500	11500	10500	9500	8500
Front projection	53.6	79.6	180	350	600	1000	1800	3100
Rear projection	2280	2700	3800	4600	5500	6300	7100	8000
Plasma	40	140	400	700	1300	2100	3100	4500
>30-in. AMLCD TV		140	40	400	1100	3000	7500	16000
Total	**10573.6**	**11959.6**	**16420**	**17550**	**20000**	**22900**	**29000**	**40100**
Conservative Case	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
CRT ≥ 30 in.	8200	8900	12000	11500	11500	10500	9500	8500
Front projection	53.6	79.6	180	350	600	900	1200	1500
Rear projection	2280	2700	3800	4600	5500	6000	5700	5500
Plasma	40	140	400	700	1300	2100	3100	4500
>30-in. AMLCD TV		140	40	400	1100	3000	7500	16000
Total	**10573.6**	**11959.6**	**16420**	**17550**	**20000**	**22500**	**27000**	**36000**

The near-term prospects for microdisplays clearly hang on their success in the TV market. While incremental projection-TV sales of 3.5 million represent a sizeable new market for microdisplays, the conservative forecast sees the technology as a bit player among the flat-panel stars, sold mostly on the basis of its low price. Meanwhile, flat-panel big screens will dominate in the high-priced segments. To make reality conform to the optimistic forecast, the microdisplay industry will have to educate consumers about the unique balance of performance and price offered by microdisplay-projection-TV solutions. ■

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Circle no. 12

show report

SMAU 2003: A Virtual World?

More end users, fewer exhibitors, and LCD-panel shortages that delayed the introduction of many LCD-monitor products made for a very different SMAU in 2003.

by Michelle Barnes and Bryan Norris

AT 12,000, the number of exhibitors at SMAU 2003, held October 1–6, 2003, in Milan, Italy, was half that of the previous year's event. And since monitor suppliers in Italy had suffered another disappointing year for sales – figures compiled after the third quarter were down another 1% compared with 2002 – it was not surprising that many monitor companies chose not to exhibit at this year's show. Nonetheless, interesting arrays of monitors were presented by well-known local suppliers such as ***Hantarex***, ***Olidata***, and ***Olivetti Technost***; by international players such as ***neovo***, ***Philips***, ***Samsung***, and ***Sharp***; and by distributors showcasing brands such as ***ProView*** and ***Relisys***. And some oddball names always appear out of the blue in Italy.

However, in many booths where IT suppliers had formerly promoted hardware, companies were now selling anything from office fixtures and fittings to video games. (The full-length recliner chairs on one stand were being well tested, especially during siesta times.) And this year, an enormous 6000 m^2 of exhibition space, half a hall, was dedicated to the video-game and multimedia world. Here Olidata had provided over 1000 PC game stations so that players could fight it out in numerous tournaments and competitions.

With more focus on the IT end consumer, the "SMAU Shop" covered an area of more than 800 m^2. This shop was managed by ***Computer Discount***, the largest and one of the best-known computer-store chains in Italy, with 240 outlets. So, not surprisingly, most of the 380,000 visitors to the fair were dedicated amateurs or end users and not the "business professionals" who have been the prime focus of IT shows in the past.

But monitor companies have one advantage over suppliers of other kinds of hardware: their product is a necessary tool for showcasing all kinds of technology. So, the software booths in one hall were dominated by ***Berlinea***'s 17-in. TFT-LCDs, supplied by its relatively new Italian distributor, Amico-e/Everex, while the stands of telecom compa-

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Byran Norris

Fig. 1: *Olidata's basic 17-in. LCD, the L17AX, was labeled "Made in Thailand."*

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nies in another hall were filled with ***Olidata***'s 17-in. LCD monitors.

Panels at a Premium

Sixty display exhibitors of CRT, LCD, and plasma monitors were listed in the SMAU catalog, promoting over 150 monitor models, half of them new in the last 6 months. And practically all of these were LCD or plasma monitors. So, apart from the sea of CRT monitors in the video-game area, there was scarcely another CRT to be seen, let alone any new models being promoted. In fact, the only CRT monitor spotted on a display supplier's stand was a 17-in. ProView unit, the EF772NS, in the booth of ***ProView***'s new exclusive Italian distributor ***Brevi***. Only four other monitor exhibitors included CRT products in their show literature: ***IBM***, ***LaCie***, ***Philips***, and ***Samsung***.

It was not only CRTs that were hard to find; suppliers with stocks of 15-in. LCD monitors were also a rarity. Indeed, this was the talk of the show. After a good September, many suppliers had suddenly cut back because of a severe shortage of 15-in. product in the selling run-up to Christmas. This problem was driving up prices and threatening the success of the fourth quarter, the most important quarter of the calendar year.

Philips, ***Samsung***, ***Sharp***, and ***neovo*** all reported exhausted stocks of 15-in. LCD monitors, with no signs of replenishment until at least the New Year. In addition, ***Brevi*** reported that both the ***ProView*** 14-in. PZ-456 and 15-in. CY-566 LCD monitors exhibited on its stand were actually in short supply. Companies such as ***Acer***, ***BenQ***, ***DHI*** for ***Hyundai***, ***iiyama***, ***LG***, and ***NEC/Mitsubishi*** – all absent from the show – were also believed to be facing 15-in.-LCD shortages. So anyone shopping for these products before Christmas would probably have been disappointed.

Square Eyes

But the show must go on, and suppliers were making the most of the consumer crowds by bringing their most stylish displays and feature-rich products to the forefront. Far and away the most popular feature was TV capability. Companies seem to think that after a hard day's work in front of a screen, or after a tough session fighting evildoers in video games, the public will crave the chance to wind down by viewing a favorite film or video. And why should one decamp to the sitting room when the film can be viewed on the same PC that has been in use for the past 8 hours?

Byran Norris

Fig. 2: *Two of Olivetti's new monitor/TVs.*

So, about one-third of the new LCD monitors being promoted at SMAU offered built-in TV tuners or inputs for video and TV signals. Suppliers of these products included ***neovo***, ***Olidata***, ***Olivetti Tecnost***, ***Philips***, ***Princeton***, ***ProView***, ***Samsung***, and ***Hantarex*** – the brand of the local Milanese manufacturer ***Sambers***. In line with its long tradition of making information- and public-display products, virtually all of the ***Hantarex*** monitors have a video input. The new "Color Planos" models – in 15-, wide-17-, 18-, 20-, and 22-in. sizes – boast built-in tuners and speakers. Interestingly, these models are being marketed as "televisions which can be used in monitor mode."

Olidata, Italy's largest local PC assembler, has always catered to the consumer market, and its 15- and 17-in. LCDs, including the new wide-17-in. model, have S-video inputs (Fig. 1). ***Olivetti***, another famous Italian brand name, appeared on an attractive range of monitor/TVs from ***Olivetti Tecnost***, which included the 17-in. LTV 170 and LTV 17p, the 21-in. LTV 210T, and the WXGA 30-in. LTV 300WS (Fig. 2). These models all feature TV tuners, speakers, and picture-in-picture (PIP). Incidentally, Olivetti Tecnost is once again able to use the Olivetti brand name on its desktop-PC and monitor products for the Italian market after a number of years when spin-off company ***ICS Olivetti*** had exclusive rights to the Olivetti brand name.

Philips previewed its new 20-in. UXGA 200P4 with S-video and CVBS inputs, which was due for launch in December with an end-user price of €1141 (US$1339). This model features 176° horizontal and vertical viewing angles, PIP, front-firing speakers, and headphone jack. It was expected in three versions, the silver VS and gray VG models with TCO '03 and the black VB with TCO '99. ***ProView***'s forthcoming 20-in. LCD monitor/TV, the HD-202AT, has a built-in tuner; the unit took pride of place on the Brevi stand. And ***neovo***'s new 20-in., the X-20AV, was the largest of this company's updated X-Series monitors featuring "distinctive aluminum alloy housing for added strength," S-video inputs, and Kensington lock ports.

The ***Princeton*** brand name is back in Europe, now being sold by the German-based ***Neodis GmbH***. And its Italian distributor ***N.C.N. Italia*** was showing two of the five new Princeton LCD monitors, the 17-in. T-17MS and 19-in. T-19MSD, both featuring USB hubs and the option of an external tuner and speakers. These models also come with the latest "high-quality" promise, a "white zero-pixel guarantee."

The ***Relisys*** range from ***Teco***, displayed by its new Italian distributor ***Erredue***, should have included the recently launched 17-in.

LCD monitor with built-in TV tuner, the RLT1720, but the unit did not make it to Milan. However, the ***Relisys*** RP4205 42-in. plasma monitor with tuner, which had already been selling well in the U.K., was on show.

As usual, ***Samsung*** was displaying the largest LCD monitor at SMAU, the new 40-in. SM403T, which started selling in Italy during September. The 403T has consumer-friendly features, including PIP and inputs for S-video, PAL, SECAM, and NTSC. And Samsung was also exhibiting its latest 24-in. SM241MP with built-in tuner and a 21-in. SM211MP with external tuner.

More Consumer-Friendly Offerings

There were also some consumer-oriented monitors at the show that did not rely on TV functionality to sell themselves. ***H-P*** had introduced three new consumer Pavilion LCD monitors, including the 15-in. Pavilion f1523 with integral speakers and the 17-in. Pavilion f1703 with detachable speakers and a microphone.

Philips exhibited its stylish new consumer range of 15- and 17-in. LCDs – the entry-level 150C (€316/US$369) and 170C (€449/US$527), and the multimedia 170N (€458/US$539), 150X (€341/$399), and forthcoming 170X (which was due in December). These last two "X" models feature Philips's "LightFrame™" chip, which allows brightness and sharpness to be enhanced in multiple user-selected areas or windows.

For Apple lovers everywhere, either with business or pleasure in mind, ***LaCie*** showed off its new 20-in. Proton 20vision. This monitor features USB and portrait-to-pivot function.

19-in. Monitors Mean Business

Despite all this catering to consumers, the 15 or so new 19-in. monitors at the show – from suppliers such as ***neovo***, ***Philips***, ***Princeton***, ***ProView***, ***Samsung***, and ***Sharp*** – showed that the business market is still in business.

neovo promoted four new 19-in. models, all featuring DVI-D inputs and Kensington lock ports. ***Philips*** exhibited its new 190B4 in two versions, the gray CG and silver CS, both with TCO '03 and built-in power supplies. The ***Relisys*** 19-in. TL970D, with DVI input, was displayed on the ***Erredue*** stand. And ***Samsung*** displayed two new silver-cased 19-in. models: the SM192B with optional speakers and the multimedia narrow-bezel SM193T MM featuring speakers, DVI-D input, pivot-to-portrait mode, and built-in power supply. Meanwhile, ***Sharp*** previewed its first 19-in. model, the LL-T19D1-H/B with DVI-I input, built-in power supply, and Kensington lock port. But sufficient stocks of this model were not expected in Italy until well into 2004, so for this particular unit it was a case of drumming up business for the future.

Byran Norris

Fig. 3: Stylish Hanns-G monitors, made by Taiwanese panel maker HannStar, were exhibited by Exair Computers, which is based in The Netherlands.

New Brands in Italy

The Milan show always seems to throw up a few new brands and this year was no exception. ***Atlantis Land***, headquartered in Milan (www.atlantis-land.com), was using its 19-in. I-SEE Pro 19BX as a flagship product alongside an impressive display of other LCD monitors, including the 15-in. I-SEE Pro 15BV with S-VHS input and optional tuner. All the Atlantis Land monitors come with a minimum of TCO '99 compliance and a 3-year on-site warranty.

Sherwood Computers and ***Neso*** appear to have joined forces in offering Neso's uniquely styled monitors, including the i-mii MI-500, in orange, green, or purple casing, but this time with a WhatsUp brand name. These monitors had been selling for a few months in Italy but, as everywhere, panel shortages were causing major supply problems.

Exair Computers, based in The Netherlands, displayed some stylish Hanns-G monitors (Fig. 3). Hanns-G is a brand name for units made by Taiwanese panel maker HannStar. European sales of the brand had been limited prior to SMAU. Exair also previewed its own Exair 15-in. LCD monitor, but the launch of this product had been delayed because of panel shortages. Nearby, the Korean supplier Kanam Electronics was showing its Accent brand of 17- and 19-in. LCDs, although these will start selling properly only when Hydis panels become available.

Another newish name in Italy is QDI, being offered by ***Zeus Technology***. One of the two new QDI models, the LM-520, features a screen that rotates in three dimensions. Zeus was also thinking about having its own monitor brand called Le neovo – "the new." Judging by the models displayed on the stand of ***ECC Elettronica***, this distributor has abandoned the unique brands it showed last year to concentrate on selling Vibrant models from Tatung and, new to Italy, NFREN LCD monitors from Korean BTC.

And so we bid farewell to another SMAU show, where, this time, the organizers focused more of their attention on the general public who attended what has previously been a business event. It seems that IT shows now function not only as a forum for meetings with business partners, but also for marketing to that elusive animal, the end user – and testing the consumer appeal of products.

SMAU reverts to its traditional late October time slot next year. The show will be held in Milan, October 21–26, 2004. ■

The 2003 IDRC and OLED Business Conference

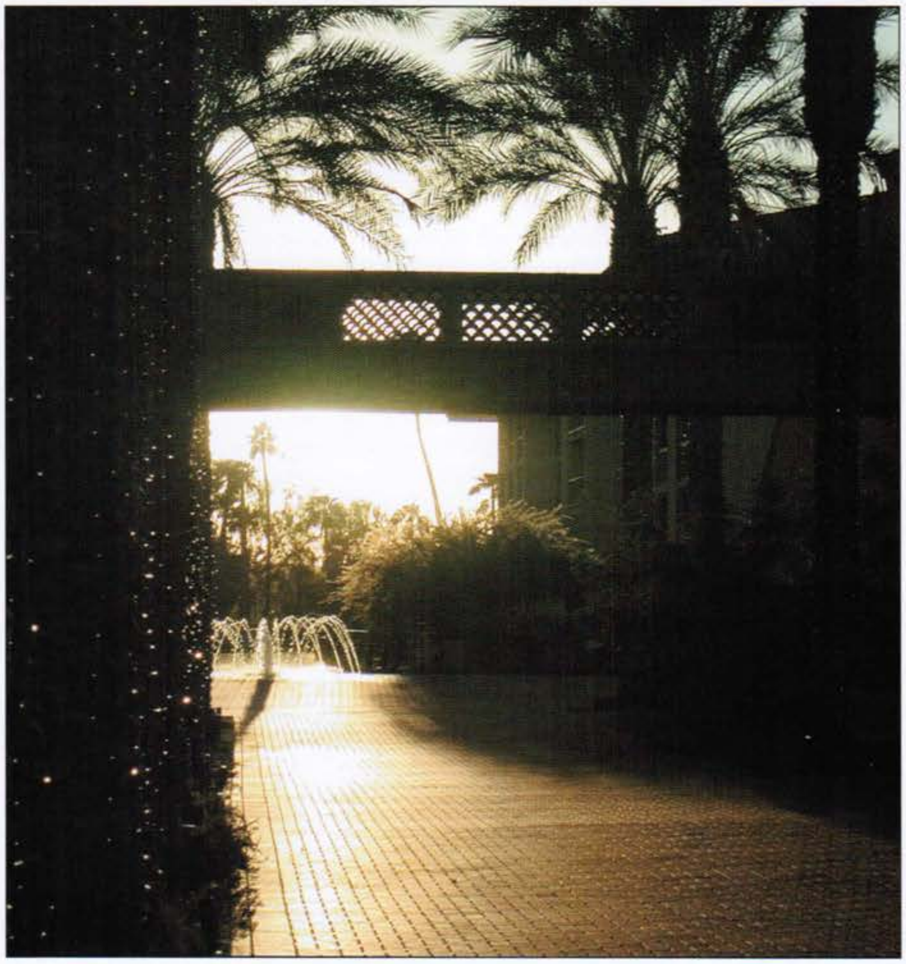
Significant display innovations and a lively Business Conference debate provided as much September sizzle as Phoenix's 100°+ temperatures.

by Ken Werner

THE 23rd International Display Research Conference (IDRC 2003) was held at the Pointe South Mountain Resort in Phoenix, Arizona, September 15–18, 2003. Matsushita Plasmaco announced the fabrication of a full-sized PDP prototype using a high-efficacy positive-column cell design; Philips Laboratories introduced an entirely new display technology based on "electrowetting"; and Mitsubishi Electric Corp. described third-generation Feedforward Driving (Fig. 1).

The conference opened with a day of tutorials. Steven A. Van Slyke (Eastman Kodak Co.), one of the co-inventors of the OLED, presented "Review of Small-Molecule-OLED Technology" (Fig. 2). Within this broad review of OLED structures and materials, Van Slyke commented that Kodak has been "looking into white emission," *i.e.*, a white OLED structure containing a blue-emitting layer and a yellow-emitting hole-transport layer. He also observed that the techniques being used to obtain wide-angle viewing in LCDs for television usually are accomplished at the expense of power efficiency. As a result, LCDs for portable applications still generally have limited viewing angles, which is an advantage for OLEDs, Van Slyke said.

While Kodak is famous for its development of small-molecule OLEDs, Cambridge Display Technology (CDT) develops large-molecule OLED materials, also known as



Ken Werner

Fig. 1: As the sun set at the Pointe South Mountain Resort in Phoenix, the (relative) cool of the evening invited outdoor conversation at IDRC 2003.

Ken Werner is the editor of Information Display *magazine.*

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light-emitting polymers (LEPs). In the second tutorial, "Progress in Light-Emitting-Polymer Technology," Jeremy Burroughes, CDT's CTO, started with a discussion of the structure of conjugated polymers, the nature of excitons, and the molecular engineering of LEPs. Later, he discussed the properties of the various materials used in polymer OLEDs in some detail, moved through device-decay mechanisms and ways of dealing with them, and concluded with a survey of current applications. In summary, Burroughes said that the first LEP products are now in the marketplace and being produced in high volume, and that printing is the route to low-cost manufacturing while maximizing display efficiency and lifetime.

In the Q&A session, Larry F. Weber (Matsushita Plasmaco) asked about the state of the competition between small-molecule and polymer technologies for OLEDs. Burroughes answered that if the lifetimes are equal, then solution processing (which is associated with polymers) will come out ahead because of the efficiency, but the high purity of monomers is a benefit. He went on to say that one group made otherwise identical devices with monomers and polymers, and it was impossible for viewers to tell the difference between them.

Paul Drzaic (Alien Technology), General Chair for IDRC 2003, asked about the outlook for barrier films, which are one way of protecting OLEDs from water and oxygen. Burroughes answered that Barix™ is coming along but is overly complicated, and TACT time could be an issue. Also, films for top-view displays are coming soon. "But if you are talking about barrier films for roll-up displays, *that* will take a long time."

In the final tutorial, "Organic Electronics for Flat-Panel Displays," Michael G. Kane (Sarnoff Corp.) focused on TFTs rather than OLEDs, although OLEDs are also "organic electronics." The concept of organic electronics, Kane said, is to replace traditional electronics based on inorganic semiconductors (such as silicon) with organic electronics that can be deposited onto large areas using low-cost substrates such as plastic and coated paper.

Work done by a team from Sarnoff, Penn State University, Kent State University, and Rensselaer Polytechnic Institute on organic TFTs (OTFTs) using pentacene as the organic semiconductor on a polyester substrate "pushed OTFTs forward into the worlds of cicuitry and displays and defined a workable process. It is the baseline for the work that has come since."

In discussing the future, Kane postulated "Kane's rule," which says, "The market is not interested in molecules," *i.e.*, "Organic electronics can succeed only where it demonstrates a clear advantage over current inorganic-semiconductor approaches." Because a batch OTFT process will not be lower in cost than a conventional TFT process, its only advantage lies in the plastic substrate, and this may not be enough to displace the entrenched silicon technology. However, "Everything changes if OTFTs can be processed in a continuous line." Ink-jet printing is one possible process that would be compatible with continuous (roll-to-roll) processing, but it is not the only one – gravure printing is another. Kane showed a photograph of a gravure-printed OLED prototype.

When asked if there were any good alternatives to pentacene for OTFTs, Kane said that pentacene has the highest field-effect mobility of available organic semiconductors.

Ken Werner

Fig. 2: *Steven A. Van Slyke (Kodak) presented his tutorial on small-molecule OLED technology.*

The Technical Program

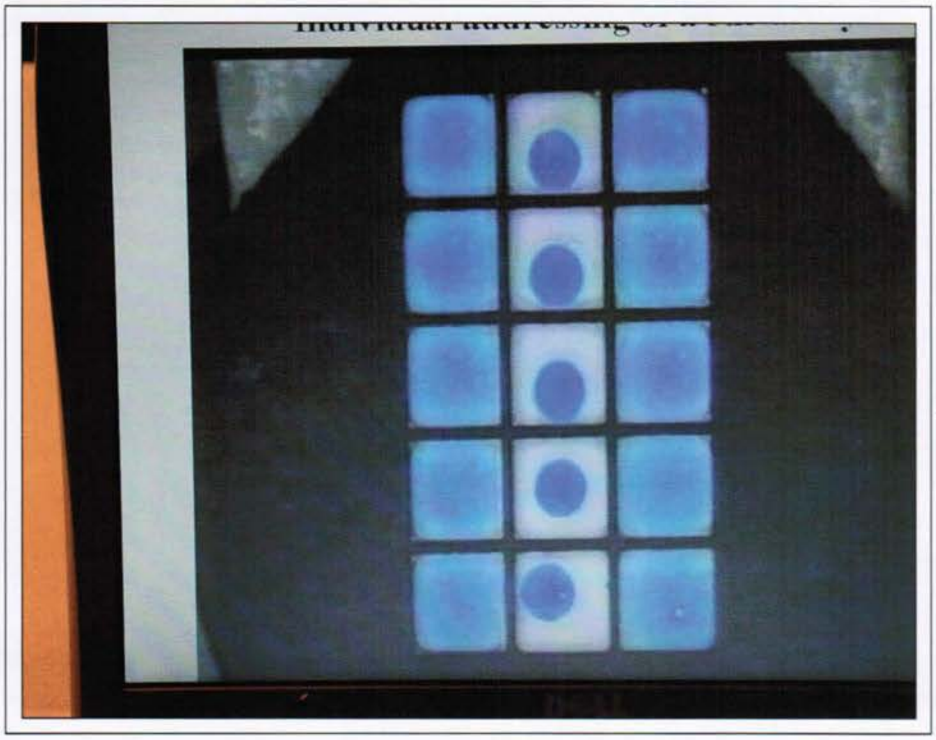
The technical program was organized with the emphasis on OLEDs. P. K. Raychaudhuri and his colleagues from Eastman Kodak Co. described microcavity OLED structures with high-reflectivity silver anodes in conjunction with an ultrathin hole-injection layer made of CF_x or a metal oxide. Such structures can produce an on-axis efficiency twice that of conventional structures.

Julie Brown (Universal Display Corp.) and her colleagues discussed the recent progress in high-efficiency phosphorescent-OLED (PHOLED) technology. The current generation of phosphorescent materials includes a red material with a current efficiency of 14 cd/A, a green material with 27 cd/A, and a blue material with 10 cd/A. The red material has a lifetime of 15,000 hours at a luminance of 300 cd/m^2, and the green material has a lifetime of greater than 20,000 hours at 600 cd/m^2. "We are still lifetime-challenged in the blue," said Brown, "but we are working toward that magical 10,000-hour lifetime." She also made the point that the high efficiency of PHOLEDs makes it possible for them to be driven with existing a-Si TFT technology.

On behalf of his colleagues at MicroEmissive Displays (MED), Ian Underwood described his company's full-color emissive microdisplay that uses a light-emitting polymer. The structure is simple, consisting of a thin LEP layer placed directly on top of a pixelated CMOS substrate. A full-color 160×120 microdisplay has been designed, and "a number of" pieces have been produced.

In a lively Q&A session, Paul Drzaic asked why MED decided to use polymer instead of small-molecule-OLED material. Underwood replied that solution processing is attractive at wafer scale, and that the company was also "able to establish a better relationship with polymer suppliers."

One of the often-cited benefits of using LEP materials in OLEDs is that devices can be fabricated by solution processing, and photolithography is not necessary. It was therefore interesting that Tomoyuki Tachikawa and his colleagues from Dai Nippon Printing Co. described a photolithographic method for fabricating full-color polymer light-emitting devices. In the Q&A session, Ernst Lueder said, "I do not yet understand why this process is superior to one that applies and patterns OLED material at the same time." Unfortunately, it seemed that language differences made it impossible for the presenter to understand the question. The time came for the proceedings to move on, and the question remained unanswered.



Ken Werner

Fig. 3: Johan Feenstra and his colleagues from Philips Research Laboratories showed this demonstrator for a new display technology called "electrowetting."

Paul Burrows (Pacific Northwest National Laboratory) examined OLEDs from another perspective in his presentation, "The Organic Light-Emitting Ceiling: Is It Possible?" He noted that incandescent bulbs produce about 15 lm/W, cost \$0.50 apiece, and have a lifetime of about 1000 hours. Compact fluorescent lamps produce 60 lm/W, cost \$5–10 each, and have a lifetime of 10,000 hours. He noted that the less-expensive ones often do not deliver their advertised output.

By contrast, LEDs are still very expensive. Burrows devoted the rest of his presentation to exploring approaches to obtaining white OLEDs that are cost-competitive. Small-molecule phosphors have the required quantum efficiency, he said, and polymers have a low drive voltage. But university research indicates that doping can reduce small-molecule drive voltage.

He concluded that the cost per square meter and weight are too high unless plastic substrates are used. He suggested that this is a case where government investment is appropriate because the economic pay-off is very high, but the development cost is too great for any one company. The results of this development, including cheap substrates and higher efficacy, would immediately feed back to displays, he said.

James Broderick (Buildings Technologies Program, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy) may not have been offering the kind of money Burrows had in mind, but he did outline a variety of Department of Energy funding opportunities in his presentation, "R&D Opportunities in Solid-State Lighting" (see www.netl.doe.gov/business).

Not Only OLEDs

Although OLEDs were emphasized at IDRC, some of the most interesting papers were not OLED related. Larry Weber (Matsushita Plasmaco) announced the fabrication of a 42-in. PDP prototype using a high-efficacy positive-column cell design.

The relatively low efficiency and high power consumption of PDPs stem from the basic physics of gas-discharge cells. In a gas-discharge cell such as a PDP pixel or a conventional 4-ft.-long fluorescent lamp, the luminous regions are the negative-glow and positive-column regions. The positive-column region is by far the more efficient, and in a large fluorescent lamp most of the lamp's glowing area consists of the positive column. As a result, fluorescent lamps have an impressive luminous efficacy of approximately 80 lm/W.

But as the cell size gets smaller so does the positive column, and more and more of the cell's luminous output comes from the inefficient negative-glow region. In a 2001 patent, Weber described a practical technique for drawing the discharge from one cell to another, thus lengthening the positive column and making the pixel – which is now composed of two cells, the "trigger cell" and the "state cell" – more efficient, without resorting to a closed-cell structure. Indeed, said Weber, the structure of this panel is even simpler than that of a traditional column-type barrier-rib panel because one electrode is eliminated and the remaining electrodes can be opaque.

At IDRC, Weber announced that the ideas described in the patent have now been incorporated into an operating 42-in. prototype that produces an image similar to that of an equivalent conventional PDP, except that it is brighter.

In the past, the motivation for staying with open cells rather than going to the closed cells developed by Pioneer was that the simpler open-channel substrate was substantially cheaper and its use avoided a two-dimensional precision alignment. With time, these benefits have become far less significant, Weber said, but the simpler structure can be made from soda-lime glass, which is about one-third the cost of the high-strain-point glass used for closed-cell designs.

Johan Feenstra and his colleagues from Philips Research Laboratories in Eindhoven, The Netherlands, and Redhill, U.K., presented a paper on a completely novel display technology based on "electrowetting." The motivation for the new technology was to create a reflective display with higher reflectivity than that of conventional reflective LCDs or electrophoretic displays. The new technology uses a transparent electrode on top of a white substrate. On top of the electrode is a hydrophobic insulator, and on top of that is a drop of colored oil. Finally, there is water over the oil, and electrical connections are made to the water and the electrode. Without an applied voltage, the oil spreads over the entire pixel surface and reflects light according to its coloration. When an appropriate bias is applied, the oil droplet is moved to one side and approximately 75% of the white reflector is exposed (Fig. 3). The pixels can be switched at video speed.

Ken Werner

Fig. 4: Les Polgar (gesturing toward Tom Miller): "I remember when some very serious observers thought that amorphous silicon was a joke – a very bad joke indeed. We need to be patient."

Jun Someya and his co-workers from Mitsubishi Electric Corp. presented an evolution on their third-generation Feedforward Driving (FFD) technique, which is used to obtain true video speed in LCD-TV displays. FFD is highly effective but requires frame stores that get expensive as resolution climbs toward the HDTV range. The new development, motion-adaptive compression, makes improved quality possible along with reduced memory requirements and cost (see the detailed article by Mr. Someya, "Third-Generation Feedforward Driving," in this issue).

OLED Business Conference

The OLED Business Conference organized by the Southwest Chapter of SID immediately followed IDRC. Intellectual property emerged as the central topic. The central debate was whether or not Eastman Kodak is stifling the OLED industry by overly restrictive licensing practices, and if not whether Kodak's position is reasonable and would-be competitors who are less well endowed than Kodak (as far as OLED IP is concerned) are just whining.

In the formal presentations, DuPont's Tom Miller noted that OLEDs were only a $200 million business in 2003 but will be a multi-billion dollar business by the end of the decade. DuPont's plans call for the production of full-color OLEDs in the 2004–2005 time frame and flexible-substrate displays in 2006–2007.

Miller noted that Pioneer is still the leading supplier of OLEDs, but DuPont's manufacturing partner RITdisplay may become as large in 2004. At the moment, he said, everybody is losing money, including Pioneer, but companies have to invest heavily to build a market.

One of the challenges facing OLEDs, he said, is the continuing rapid progress of LCDs. LCD technology is "progressing like a supertrain and prices keep dropping and dropping." Nonetheless, volume shipments are increasing, and they could increase faster with more industry collaboration. Various standards would speed infrastructure development and technology adoption, Miller said.

In the Q&A period, Malcolm Thompson asked, "So, what is your solution to the IP problem?" Miller said, "Shift from companies founded solely to sell IP to companies based more on a model of collaboration and development. It is challenging. We need to pay inventors, but there needs to be enough money to go around. Among other things, we should have a standard industry licensing agreement; continually negotiating these is a waste of time."

Les Polgar, the founding President of Eastman Kodak's Display Products Business, and now Principal of Talpra Consultants, said in his presentation that the OLED industry needs to focus on going to market. This requires building OLED credibility with real products and also requires a lot of unglamourous process, design, and manufacturing work. And, he said, part of this pragmatic market-building should be an industry commitment to leave claims of "disruptive technologies" and "paradigm shifts" behind.

Barry Young of DisplaySearch noted that 21 OLED fabs were operating in 2002. He presented three recent events as milestones: (1) Samsung/Pioneer's showing of a transparent active-matrix OLED (AMOLED), (2) IDTech/Chi Mei Optoelectronics's showing of a 20-in. AMOLED with an amorphous-silicon backplane at SID 2003, and (3) CDT's demonstration of a blue phosphor with a lifetime of 11,000 hours.

Sidney Rosenblat (Universal Display Corp.) presented guidelines for negotiating IP licenses. He observed that although technology licensing models can have significant financial rewards, they require significant R&D expenditures. Companies must be able to get their technology onto the market while maintaining its proprietary position. "It is not easy," he said, "and for each success there are numerous failures."

In the Thursday afternoon roundtable that concluded the Business Conference, Les Polgar said, "I remember when some very serious observers thought that amorphous silicon was a joke – a very bad joke indeed. We need to be patient (Fig. 4)." He then expanded on a point made during his formal presentation: "Let us leave here forgetting about killer applications because, if we create the expectation that only the killer app is a success, we are doomed to failure.... Let us roll up our sleeves and leave the talk of killer apps to the speculators."

In 2004, IDRC will be held in Asia, where it is also called Asia Display. Asia Display will be combined with the Korean Information Display Society's IMID conference and will be held August 24–27, 2004, in Daegu, Korea. The combined event is expected to be the largest display conference and exhibition ever held in Korea. ■

SOCIETY FOR INFORMATION DISPLAY NEWS

Larry Hornbeck Honored

by Richard Fink
Chair, SID Texas Chapter

Dr. Larry Hornbeck of Texas Instruments, the inventor of the digital micromirror device (DMD) chip, was presented with the Texas Chapter Technical Achievement Award on Monday, November 17, 2003, in Austin, Texas, at a special Chapter event held in cooperation with the Nanoparticles Applications Center of Texas State University in San Marcos, Texas. This event, which included a talk presented by Dr. Hornbeck, was video linked to Dallas, Houston, and San Antonio using facilities provided by the law firm of Winstead Sechrest and Minick, P.C. In total, about 100 persons attended this event in all four cities.

At the beginning of the 21st century, cinema and television continue to rely upon fundamentally distinct exhibition technologies having their origins in 19th century inventions. Now, cinema and television exhibition technologies are beginning to converge to the same digital solution – Digital Light Processing™ (DLP)™ projection-display technology pioneered and commercialized at Texas Instruments. DLP™ projection systems are becoming increasingly popular for home entertainment; in fact, big-screen tabletop TVs based on DLP™ technology are now sold in more than 2000 U.S. retail stores.

DLP Cinema™ technology is emerging as the choice for digital cinema worldwide, with more than 100,000 shows of major first-run movies to an audience of more than 10 million. At the heart of these projection systems is the DMD chip, a MEMS-based technology integrated with CMOS circuitry. ■

Zvi Yaniv (right), Director of the SID Texas Chapter, and Dr. M. Anandan (center), V.P. of the Americas Region of SID, present the Texas Chapter Technical Achievement Award to Dr. Larry Hornbeck (left).

letters

Letter to the Editor

This letter is in reference to the interesting article by Donald Davis entitled "The Future Is Plastics!" published in *Information Display* **19**, No. 10, 4 (2003).

In the interest of liquid-crystal-display (LCD) history, I would like to point out that the use of plastic substrates in LCDs was first proposed by P. Andrew Penz and co-authors from Texas Instruments in 1981. They published their findings in the *SID Intl. Symp. Digest of Tech. Papers*, 116-117 (1981). These authors also demonstrated the viability of the concept.

Werner E. Haas
Fellow, SID ■

backlight

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improve in performance," he predicted, "and they will expand to fill electronics market growth demands while they get cheaper. This will further increase barriers for both OLEDs at the small-display end and plasma at the large-display end," he said. "The fastest-growth market will be LCD TVs."

Exactly how the FPD story in TVs will play out over the next year – and, indeed, the next 5 years – is perhaps the issue that has the most people searching for a crystal ball. But the interplay among technologies cuts across a number of different application spaces as well. "I keep on being surprised that plasma panels in very low-tech stores are being used for advertising purposes," said Alan Sobel. "This will grow, but it is possible that electronic paper and big LCDs will make some inroads here."

Electronic paper in its various forms also has more than a few seers scrambling. Ernst Lueder hailed the anticipated arrival of "reflective displays with an 80% reflection coefficient providing real paper-white panels," as well as "flexible color displays, 0.5 mm thick, as portable receivers for text and images. With an attached memory IC," said Lueder, "they start competing with printed books."

"Electronic paper will begin to make some real appearances in the form of advertising signage and electronic books," Sobel said, "but the books need a lot of infrastructure that is not there yet."

Analyst and consultant Chuck McLaughlin foresees "a major crossroads for microdisplays generally and LCoS specifically" in 2004, with many questions in play. "Where goes the presentation market?" he asked. "Are we approaching a chicken in every pot? Big corporate conference rooms all have projectors. Is the market approaching saturation or will the less-than-$1000 projector give the market new life in education?"

McLaughlin answered his own question. "While some of my brothers see saturation, I am on the side of sustained unit growth based on lower prices," he said, "but revenue growth will stall. The game will come down to Epson *vs.* TI on the microdisplay front, with the latter winning. Look for further consolidation of projector integrators, with the Chinese taking over."

Elsewhere, Sobel expects that FEDs "will finally give up the ghost. "I do not believe that there will be a breakthrough that solves their lifetime problems," he said. Pollack noted that new technology for integrated display speakers "may find displays that can speak for themselves by the end of 2004." And as for OLEDs, the new kid on the block, sources expressed an incredible diversity of opinions, and the coming year in OLEDs appears to be extremely murky.

All in all, as Stewart Hough sees it, the coming year will be another troubled year for the FPD industry. As of January 2005, he predicted, "We will have spent yet another year undervaluing the strategic nature and importance of displays and will have further pushed the commodity model, wasting an opportunity for higher revenue and profit by allowing displays to continue to be relegated to the same class as DRAMs, connectors, and batteries."

And what else might the year bring? "Acquisitions, mergers, and sales," said Hough. "And if IP issues remain unresolved, increasing fragmentation, positioning, and growth suppression." ■

***David Lieberman** is a veteran display journalist living in Massachusetts; e-mail: davidlieberm@earthlink.net.*

editorial

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Tiling Rear-Projection Cubes

AR Technology, Ltd., founded in June of 1991 (under a different name), was one of the first private companies in Russia. It is the only company in Russia specializing in original projection devices and systems, said General Director Alexander V. Sadchikhin.

The company has two major specialties. The first is two types of projection systems comprising video walls based on Texas Instruments' DMD technology and LCD spatial light modulators. Current production consists of tiled DMD-based rear-projection cubes that use a patented method for connecting modules in such a way that they have less than a 0.5-mm optical (not mechanical) gap between the screens. The company can make tiled displays up to 3 m.

AR Technology is also developing laser CRT technology. Their latest announcement, made at FLOWERS 2003, is ring focusing of the e-beam to produce image quality equal to that of 70-mm film. The FLOWERS presentation also discussed the development of an epitaxial film for the laser target. "We believe no other technology can produce equal quality," said Sadchikhin. Further R&D is required, but it is difficult to attract investment in Russia. "Nevertheless, I am an optimist." The technology currently produces a high flux of 15,000–20,000 lm with a measured efficacy of between 2 and 2$\frac{1}{2}$ lm/W. "The laser CRT can offer high brightness and efficiency with traditional electron-beam management and optics," Sadchikhin concluded.

Incotex is a large company; AR Technology is a small one. They have different businesses, but both are Russian, both have ambitious general directors, and both are energetically making displays. It will be interesting to follow their progress.

— KIW

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

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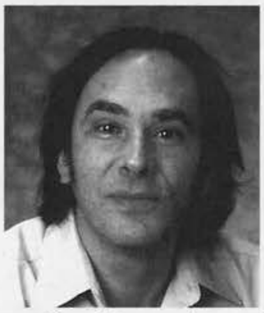

Responses Keep Ringing

by David Lieberman

Last month's "Backlight" column ("Ring in the New") consisted of a compilation of predictions from a variety of sources on how the coming year in FPDs might unfold. What I failed to predict was the strong response I received to my request for input from these display-industry participants and observers, and I continued to receive replies after that New Year's column was complete. So, if you do not mind indulging me in a multi-part column, here is what some industry folks expect to see in 2004 in various technologies and application spaces.

Al Davis of ClairVoyante Laboratories, Inc., scanned the FPD horizon in applications requiring different sized displays. "We will be seeing more cellular telephones with higher-resolution displays, more options, and more colors," he predicted. "As for monitors, it seems that higher dot-per-inch units, 140 and greater, will be coming into the market. With additional capacity, LCDs will become the televisions of choice, with lower cost and better performance than PDPs," he predicted. "And projection will be relegated to low-cost solutions."

Dick Kessler of Sterling Design, on the other hand, foresees front projectors' "growing dramatically in volume for crossover applications – home theater and PowerPoint presentations."

Consultant Alan Sobel has one of his eyepieces focused squarely on the road. He expects 2004 to bring "more electronic displays in automobiles, mostly for map functions, but also for some driving functions. In Japan," he said, "TV is available to drivers when the car is not moving, and that happens quite a bit on their traffic-clogged roads. I devoutly hope that we do not see anything of the sort here; the carnage would be dreadful!" Sobel further predicts that "head-up displays on automobile windshields will grow, but slowly."

As for Joel Pollack of Sharp Microelectronics of the Americas, his telescope is pointed at both the small and the large. "The growth of color and other factors in cellular telephones and other mobile devices, and the tremendous interest in LCD TV, are going to have a big impact on the market in 2004," he predicted. "Higher-resolution LCDs for cellular telephones will create a whole new set of expectations in the market," he said, "and the refinements in performance and response time of TV-grade LCDs will increase user acceptance."

Pollack also predicted that mobile LCDs with a wide viewing angle "could have some real impact as people start to use PDA displays for more functions. When people start using multimedia," he said, "they'll want to use the display in both portrait and landscape modes. The ability to hold a device in your hand or set it on a table and see good color in all circumstances will become important."

Ernst Lueder, a consultant for the University of Stuttgart, also sees dramatic improvements in LCDs in the near term. "Large-area LCDs will break into the domain of plasma displays," he said. "Faster LCD addressing, well beyond present overdrive, will provide brilliant large-area LCDs, including HDTVs." Moreover, Lueder predicted, "Color pixel layouts with increased resolution and even greater perceived resolution will start to replace the present boring layouts."

As consultant Stewart Hough sees things, the continuing dominance of the LCD is assured. "LCDs, in general, will still dominate and will continue to

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calendar

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March 18–24, 2004 Hannover, Germany

SID 2004 International Symposium, Seminar & Exhibition. Contact: Mark Goldfarb, PCM, 212/460-8090 x202, fax -5460, e-mail: mgoldfarb@pcm411.com.
May 23–28, 2004 Seattle, WA

INFOCOMM 2004. Contact: infocomm04.expoexchange.com.
June 5–11, 2004 Atlanta, GA

Display Taiwan 2004. Contact: +886-2-2396-7780, fax +886-2-2341-4559, e-mail: sysop@mail.pida.org.tw.
June 9–12, 2004 Taipei, Taiwan

24th International Display Research Conference (Asia Display 2004). Contact: SID HQ, 408/977-1013, fax -1531, e-mail: www.sid.org.
August 24–27, 2004 Daegu, Korea

Advanced Display Technologies Symposium (FLOWERS 2004). Contact: Prof. A. Smirov, +375-17-2398858, fax -2398486, e-mail: smirov@gw.bsuir.unibel.by.
September 7–10, 2004 Minsk, Belarus

EL2004 International Conference and Workshop. Contact: Adrian Kitai, McMaster University, e-mail: el2004@mcmaster.ca.
September 20–23, 2004 Toronto, Canada

48th Annual Human Factors & Ergonomics Society Meeting. Contact: HFES, 310/394-1811, fax -2410, e-mail: info@hfes.org.
September 20–24, 2004 New Orleans, LA

PC Expo/Techxny 2004. Contact: CMP Media LLC, 1-888-234-9476, e-mail: www.techxny.com.
October 3–7, 2004 New York, NY

The Americas First Display Engineering and Applications Conference (ADEAC 2004). Contact: Mark Goldfarb, PCM, 212/460-8090 x202, fax -5460, e-mail: mgoldfarb@pcm411.com.
October 25–27, 2004 Ft. Worth, TX

12th Color Imaging Conference 2004. Contact: IS&T, 703/642-9090, fax-9094, e-mail: info@imaging.org.
November 9–12, 2004 Scotsdale, AZ ■