Official Monthly Publication of the Society for Information Display

INFORMATION DISPLAY

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DISPLAY MANUFACTURING ISSUE

Markets and manufacturing
Masks for flat panels
Lasers and flat panels

Cover: The drive for lower-cost flat-panel displays has resulted in the development of manufacturing equipment that can handle very large glass panels, and therefore yield more FPD screens per panel. This panel was produced on Semiconductor Systems' APEX FPD-500, a cluster-style photoresist processing system that can handle flat-panel substrates up to 500 mm².

Semiconductor Systems, Inc.

Next Month in Information Display

Technology Roundup Issue
- LCDs
- CRTs
- Emissive Displays
- Display Standards

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editorial

Display Manufacturing is Global

Information Display has become the premier magazine covering display technology, applications, and markets. We will continue to build on that strength.

In addition, with this issue we are staking out display manufacturing as part of our turf. We are planning to add 10 feature articles a year to our editorial coverage, the majority of which will be devoted to manufacturing issues, and we will also add to our "New Products" and "Industry News" coverage.

Part of our motivation for this decision certainly stems from the resurgence of display manufacturing in North America: the intensive interest in the Display Manufacturing Technology Conference and Exhibition (January 31 – February 2, 1995); the rapidly growing participation of manufacturing-equipment companies at the annual SID International Symposium, Seminar, and Exhibition; the activities of the USDC, ARPA, DoD, and SEMI; the ramping up of production initiatives at OIS, Motif, Xerox, AT&T, Standish, Sony America, Clinton, Kopin, FED, and many others; and the intensive activities of companies making display-manufacturing and test equipment, a few of which are mentioned in the pages of this issue.

But even more important is the inescapable truth that we live in a global technological economy. And nowhere is that more true than in the display community. The sale of color laptop computers in Dubuque in 1996 will probably depend more on the successes of manufacturing engineers in Osaka and Mie than on the efforts of system designers in Boca Raton and Sioux City. A recent decision made in Paris sent the share prices of a small company on Long Island reeling. The monitor you buy from Philips may have been made in Taipei. The Society for Information Display, which owns this magazine, has chapters from Beijing to Darmstadt.

The renaissance of display manufacturing in North America is important. Sharp and Sony will be contributing to that renaissance as much – and perhaps more in terms of sales dollars – than Motif and Xerox. And OEMs, no matter where they are located, will find that their display shopping trips are likely to cover New Delhi and Beijing as well as Seoul, Tokyo, Taipei, North America, and The Netherlands.

"No man is an island," John Donne wrote three-and-half centuries ago. That has never been more true than today. The manufacture of displays is a global activity, and *Information Display* is an international magazine. We will be covering display manufacturing extensively – from New Delhi to Darmstadt.

– Ken Werner

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INFORMATION DISPLAY

the display continuum

Crossing the Thin Line ...

by Aris Silzars

Dan and Charlie sat glumly staring at each other. Their slightly dingy motel room had not yet been made up from last night and check-out time was fast approaching. No matter. They needed to get packed for the drive to the airport anyway.

A few minutes ago, they had returned from making their twentieth-plus-something business-plan presentation to yet another venture fund. The answer kept coming up the same. However, this time the venture fund's senior partner had been a bit more direct. Their business plan just didn't have enough "sizzle," he told them. Now, just what did that mean?

By now, they already knew that something was wrong. Following their earlier presentations, they had typically received words of encouragement, followed by weeks of "due diligence," followed by weeks of silence, followed by polite words to the effect that, although their business concept had great merit and they should pursue it with vigor, this particular investment fund was choosing to "pass." What they were now hearing was that the business growth shown in their plan wasn't fast enough, that the size of the business would not be sufficiently large after the first 5 years, and that it was going to take too long, according to their carefully constructed time-line, to get products to market.

They knew that it would take at least a year to complete the design of their new product. The required new processes had yet to be tried and proven, and that would take at least 18 months. And most important, a new manufacturing facility had to be built, new equipment installed and tested, and then brought on-line with the new process. That would take at least two to two-and-a-half years. How could they announce a product, get orders, and build up sales in less than 3 or 4 years?

Nevertheless, they knew they had to do something. Their personal funds were running low, and their wives were beginning to ask when they would get real jobs like other respectable people. A few weeks earlier, they had been introduced to a highly energetic gentleman by the name of J. B. Blackman. Now, J.B. was a real promoter. He had started in sales and had worked his way up to managing sales and marketing for several smaller companies. He didn't seem to stay very long in any one job, but he had ***personality***. He had ***charisma***. He had ***optimism***. Dan and Charlie weren't too sure that they could work with him but ... maybe, if he could help them get the company financed, it would be worth a try.

After listening to their business plan, J.B. said he would be more than happy to help. He would do it for his normal salary, plus bonus, and for an amount of stock equal to what Dan and Charlie each expected to keep. This seemed like an awfully steep price, but as each day passed their situation was getting more desperate.

And help he did. With J.B.'s promotional skills, and his major revision of their business plan, the company was finally funded and the real work could begin. Dan and Charlie were on top of the world, and spent most of their days deeply engrossed in developing their new product. This was life in the "start-up lane" – the way it was meant to be! All their hard work was soon going to lead to success, just as they had planned.

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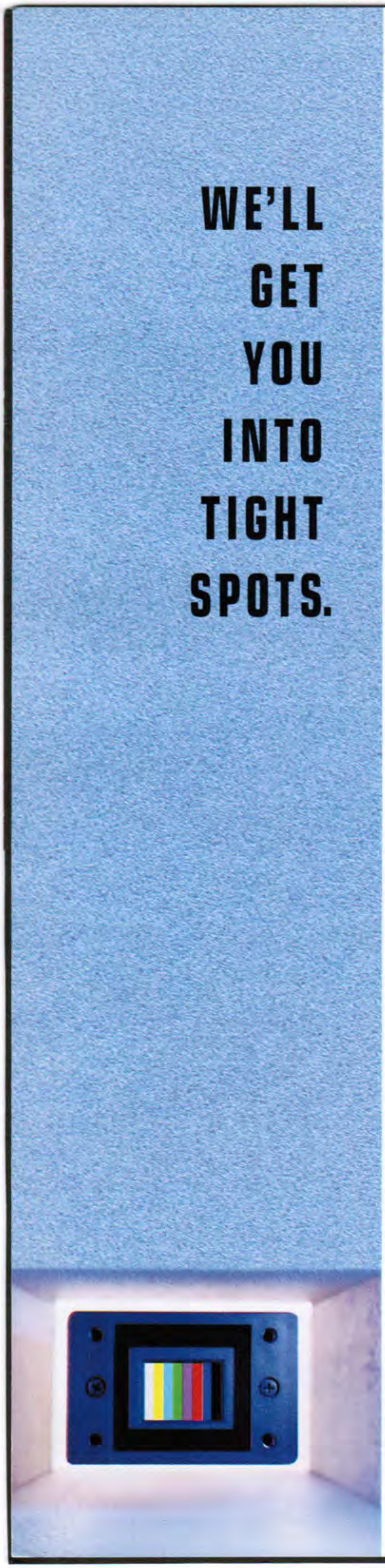

Edited by Joan Gorman

USDC membership grows

The roster of USDC members continues to grow in all segments of the industry, thereby enhancing the ability to help in establishing a significant flat-panel display (FPD) industry in the U.S. The display manufacturers and developers supporting the infrastructure-development mission of the USDC include:

- AT&T
- Coloray Display Corp.
- Electro-Plasma
- Kent Display Systems
- Kopin
- Motif
- Norden Systems, Westinghouse
- OIS Optical Imaging Systems
- Photonics Imaging
- Planar Systems
- Plasmaco
- SI Diamond
- Silicon Video Corp.
- Standish Industries
- Three-Five Systems
- Xerox

All major FPD technologies are represented among this set of companies, including ac plasma, electroluminescent, active and passive LCD, and field-emission displays. This greatly facilitates USDC's ability to address flexible manufacturing capability to meet the similar process, equipment, and materials needs of each technology as well as the specialized needs. The USDC-affiliated membership in the SEMI–North American Flat Panel Display Division has surpassed the century mark. This broad cross section of the U.S. industry is focused on developing the next generation of equipment, materials, and components required by display manufacturers to establish a significant U.S.-based volume manufacturing capability. This 100+ company roster includes many well-known and well-established global corporations as well as many modest sized, yet innovative, U.S. companies that intend to grow with the industry. To provide focus and market-pull for the USDC development activities, two USDC Users Groups have been established. One represents the commercial sector and the other represents the military and avionics sectors. These groups of companies who are system-level integrators of displays have undertaken the task to define a market and product feature roadmap for the U.S. display industry. Based on this market-pull set of requirements, the USDC plans to coordinate an industry initiative to define the technology roadmap for displays vis-a-vis the SIA roadmap for IC technology. Current membership in these users groups include:

Commercial
Apple Computer
AT&T
Chrysler
Compaq Computer
IBM
Sun Microsystems

and contributing while evaluating full membership;

Delco
Digital Equipment Corp.
Hewlett-Packard
Motorola

Military/Avionics
Allied Signal
Honeywell
Hughes Aircraft
Kaiser Electronics
Litton Systems
Rockwell
SAIC
Smiths Industries

supported by the DoD Wright Laboratory Cockpit Avionics Office.

Strategic forum on creating a U.S. FPD industry

The Center for Display Technology and Manufacturing, The University of Michigan, Ann Arbor, Michigan, will host the Flat Panel Display Strategic Forum: "Creating a U.S. Industry" to be held November 15–16, 1994 at the Radisson on the Lake in Ypsilanti, Michigan. The primary objective is to provide an opportunity for decision and policy makers to discuss the strategic development of this emerging domestic industry, and to consider policy questions as well as practical applications.

The forum will include panel discussions with leaders from many segments of the industry. Registration fee, $390.

Information: Kathi Compton, Center for Display Technology and Manufacturing, The University of Michigan/Office of Technology Transfer, 2901 Hubbard Road, Ann Arbor, MI 48109-2016. 313/747-0042, fax -0036, e-mail: kathi_compton@um.cc.umich.edu.

Industry/government flat-panel microelectronics projects

The National Center for Advanced Information Components Manufacturing (NCAICM), Albuquerque, New Mexico, has taken a major step toward the challenge of bringing U.S. manufacturers into a competitive position in the information age. Twenty-five projects are now under way in support of U.S. flat-panel displays and other advanced information components, Center officials announced. The Center is a $60-million program funded by the Advanced Research Projects Agency (ARPA) of the Department of Defense. NCAICM is charged with integrating Federal Government, university, and private sector research and development to speed the time to market for U.S.-developed advanced information components. NCAICM (pronounced n-cake-um) is a collaboration between ARPA, an agency committed to technologies beneficial to both the military and industry, and the Department of Energy (DOE), with its state-of-the-art defense program laboratories. U.S. Senator Pete Domenici, New Mexico, was instrumental in initiating the center in early 1993. NCAICM now has eight university and 39 industrial partners reaching into 16 different states and the District of Columbia. The Center, located at Sandia National Laboratories, is supported by staff from Sandia, Los Alamos, and Lawrence Livermore National Laboratories. "The NCAICM partnership between government and industry is providing U.S. microelectronics manufacturers and the emerging flat-panel display industry an opportunity to increase their competitiveness in the world marketplace," said Jim Jorgensen, the Center's director. "An important feature of the Center is that all current projects were selected based on industry views of research and development needs in the technologies."

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Flat-Panel Display Manufacturing

Before finalizing new product plans, manufacturers are looking at the markets, new applications, and their competitors for signs of which direction to take.

by Renée Mello-Robinett, Rudy Mui, and Terrence Thompson

LIQUID-CRYSTAL DISPLAY manufacturers face some perplexing production conundrums. Existing customers and OEMs who want display samples for prototyping new products for what could be substantial new applications either cannot get enough or cannot afford them. Despite substantial ramp-up efforts by the major display manufacturers, current demand exceeds supplies. However, based on current flat-panel display (FPD) usage, if all of the announced FPD production increases from existing and new sources materialize, the display shortage may change to a glut as early as next year, and prices for displays could plummet. Therefore, before finalizing new production plans, manufacturers should take a cautious look at the markets, at new FPD applications, and at the status of emerging competitors.

LCDs Solidly in First Place – for Now

Established liquid-crystal display (LCD) producers in Japan are maintaining their commanding FPD market shares. Quality driven, they continuously refine manufacturing techniques, explore innovative procedures, expand production by adding fab lines, and use larger substrate sizes to reduce panel costs and gain incremental improvements. They do all this to maintain market share with more affordable, better-performing displays. Industry analysts expect LCDs to remain the mainstream FPD for the foreseeable future in 12-in. or smaller screen applications, but all display technologies are now attracting widespread global attention as market opportunities expand.

Several FPD competitors are now gambling on alternative display or manufacturing approaches to establish footholds in advanced displays, which observers regard as a crucial technology for information-age products. Mainstream LCD prices are simply too expensive for many potential mass-market applications. And as interest intensifies in manufacturing FPDs of all types as a way of protecting the vital national electronics industry, competitiveness is becoming a focal point. OEM FPD users, as well as many of the equipment and materials suppliers that support the FPD industry, are raising serious questions concerning which display technologies will win out in both existing and emerging applications.

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Display Production Challenges

Can the Japanese lead in the production of active-matrix LCDs (AMLCDs) and passive-matrix LCDs (PMLCDs) be overcome by display producers in the U.S., Korea, Taiwan, Europe, or elsewhere? The answer may depend on whether newer producers can satisfy the needs of OEMs for higher-resolution larger-viewing-area displays that are thinner, lighter, less power-hungry, and – perhaps most challenging – lower in cost.

For new applications to be successful, OEMs may have to be assisted to better differentiate their products by using unique displays. This will require more flexible and more predictable manufacturing systems, which are capable of producing a variety of product-differentiating displays (perhaps on the same substrate). Different processing technologies are needed to control contamination and minimize panel defects on larger screens. Furthermore, inspection, test, and repair systems will be challenged to cope simultaneously with smaller circuit-feature sizes at higher manufacturing throughput rates.

Picking Winners

At a recent Stanford University conference on economic growth and development, economist Nathan Rosenberg cautioned "experts" thought to have a clear view of tomorrow's information-superhighway technologies. He pointed out that few inventors fully comprehend a technology's impact on society or its commercial possibilities. The transistor's invention, for example, was virtually overlooked at first except as a possible hearing-aid improvement. In 1949, IBM thought that the total market for computers would be less than 20. And Bell's patent described the telephone as a mere improvement of telegraphy.

Are today's FPD producers and OEM users accurately estimating tomorrow's demands and opportunities? It's unlikely. Significant future applications will undoubtedly surprise everyone, and making our way down the road to the future is sure to be an exciting and challenging drive. As with ICs, FPD production must now move from black art to manufacturing science. Some high-stakes regional efforts now under way are intended to do just that.

Global Manufacturing Strategies

Regional FPD manufacturing strategies differ because no country has a complete manufacturing infrastructure – although Japan comes closest to this ideal. As display substrates become larger, production problems in general (and area costs in particular) increase almost exponentially. Therefore, many believe that the readily affordable large-screen – greater than 30 in. on the diagonal – solution for this decade is front or rear projection, where the small high-resolution projection light valves minimize fabrication problems. For the moment, cost-effectiveness is the factor that takes precedence, despite the inherent problems with user logistics presented by projection systems.

For direct-view options, the race is still wide open. Officially sanctioned national programs for developing such displays are complicated by a growing number of pragmatic international partnerships and independent corporate programs.

Asia. Japan is adding LCD manufacturing capacity as fast as possible to preclude serious foreign competition. New production processing techniques and less expensive color filters could cut costs more than 30% by early 1995. Current 9.5-in. color AMLCD prices are typically over $1000, with color passive-matrix versions priced from $300 to $600. Several leading AMLCD producers may offer 9.4-in. versions for as low as $500 by early 1995 – perhaps at a loss to gain footholds in new applications.

Koreans are quickly pursuing high-volume AMLCD commodity panel production – a repeat of their come-from-behind win with DRAM. Samsung and Corning have a joint venture to produce color filters. The first Korean 9.5-in. color AMLCDs, from Samsung Electronics, are in production – 10,000 annually now, 100,000 next year – and Goldstar Electronics International should begin production in late 1994. Hyundai Electronics and Orion Corp. are also expected to enter the business soon. The South Korean Government is actively trying to establish a national LCD infrastructure. For the moment, they must rely on the Japanese for critical materials, but they also may depend on innovative U.S. equipment suppliers in the immediate future.

Taiwan also needs FPD capacity to support its electronics and computer-manufacturing efforts. Firms there already have some interesting international technology alliances that might speed their efforts.

Industry analyst Norihiko Naono of the Nomura Research Institute, Yokohama, Japan, believes it will take at least 5 years for the U.S. to become competitive and profitable in AMLCD manufacturing. He says that the Koreans have cash and the ability to make quick decisions, which together will allow them to become successful at large-scale AMLCD manufacturing in just a few years. Naono also notes that the U.S. is not a technology follower, and he does not believe that the Japanese or Koreans are concerned about U.S. AMLCD catch-up efforts.

"LCDs are cost-sensitive commodities but demand is strong now. Large laptop manufacturers like Apple or Compaq can buy color displays for $900, but smaller companies must pay anywhere from $1200 to $1500. Remember also that there is a $500 materials cost in each display (Fig. 1). Right now, the top priority for Japanese FPD manufacturers is producing more color FPDs quickly and using new fabs with larger substrate sizes to get more panels and higher throughputs," said Naono. He adds that large-size LCD production is now possible, but that a 25-in. FPD would cost thousands of dollars, which was the case for the large display from Sharp Electronics announced at SID '94 in June. However, saving space on cramped Japanese desks in tiny offices could justify display expenses. After laptops, Naono sees strong demands in subnotebooks, automotive navigation, personal digital assistants (PDAs), and desktop PCs. With each application, low cost per unit of screen area will be vital for success.

North America. The United States' complex strategy involves diverse, intertwined efforts from the public and private sectors. The goal is to expand existing AMLCD production first, and then to use other innovative technologies to capture emerging niche applications. U.S. high-volume applications – which are expected later in this decade – may focus more on application-specific FPDs

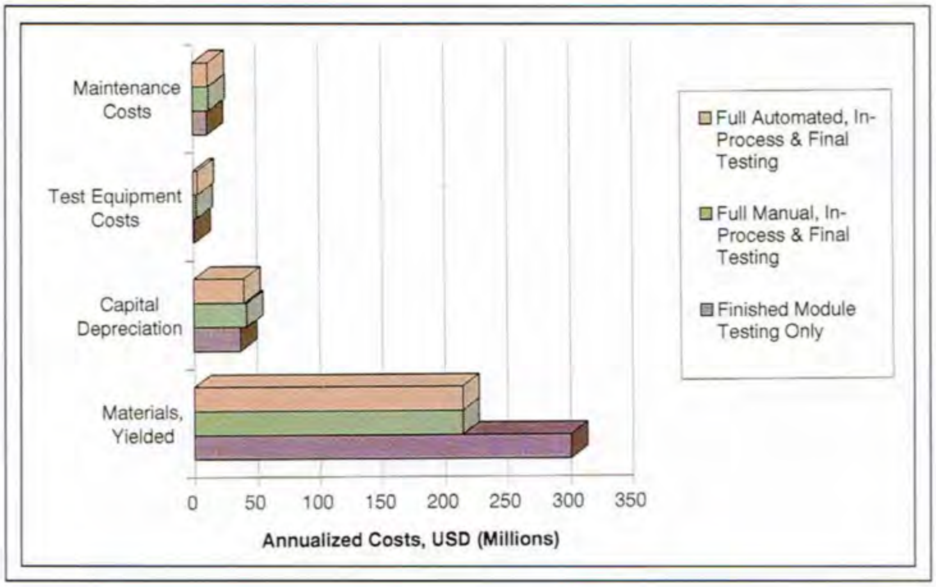


Fig. 1: *The four most significant annual costs for today's AMLCD manufacturing facilities, assuming a hypothetical factory production of 420,000 good 10-in. panels per year. Materials yielded – the total consumed for all purposes – is the largest cost, exceeding the cost of the factory itself. Savings in materials alone more than offsets the investment needed for full in-process and final test (either full automated or full manual) compared to final module testing only. (Source: Stanford Resources, Inc., April 1994.)*

(ASFPDs), gambling on a repeat of past successes with microprocessors and ASICs. The U.S., having seen what works well in existing AMLCD plants, will minimize risks with new display technologies and manufacturing capabilities.

To pull this off, the U.S. Display Consortium (USDC) was formed in July 1993. The Department of Defense (DoD) has confirmed an initial USDC thrust: domestic AMLCD production. Officially, DoD's major thrust is manufacturing-process development to realize an eventual high-volume production line – for millions of displays annually. A new $100-million shared-cost project being undertaken with Xerox PARC, AT&T, and Standish Industries is the largest DoD National Flat-Panel Display Initiative funded to date.

In another North American FPD effort, Toronto-based Litton Canada is producing AMLCDs now. With its parent, Litton Systems, active in the USDC, Litton Canada will probably broaden its marketing efforts in North America. Other U.S. FPD developers are concentrating on alternative technologies.

Europe. Two major efforts are under way. In Eindhoven, The Netherlands, a Philips Electronics-led consortium (with Thomson of France) is well on its way to producing LCDs. Also, a consortium for producing flat microtip field-emission displays (FEDs) led by Pixel International of France is close to pilot production. Pixel's partners are Raytheon and Texas Instruments in the U.S. and Futaba in Japan.

Flatter, Lighter, Brighter, Cheaper

Perceptions have broad implications, both for today's and tomorrow's FPD manufacturers and users. In some high-tech markets, less-than-optimum technologies can win with superior marketing, timing, or just very attractive prices. In display manufacturing, the realities of high production costs and analysts' predictions of emerging multibillion-dollar markets are making companies and countries scramble for market share.

Telecommunications, computers, and information products. High graphical information content is inherent in the various concepts of the information superhighway. With distinctions blurring between computers, television, and communications – and between the previously distinct ways in which people acquire and use information – applications driven by low-cost consumer market forces will almost certainly merge with high-end business and industrial applications.

Portable electronics. PDAs are just the first of many hand-held and mobile products. PDAs could merge with cellular phones and allow us to interface with computers anywhere. Heads-up displays for games, avionics, and virtual-reality applications are touted as likely growth areas.

Automotive displays. Nearly everyone agrees that this is a huge potential market. Weight, cost, the required wide viewing angles, the need to operate over a broad temperature range, and challenging ambient-light conditions are limiting factors.

Large-screen TV and HDTV. Sixty-inch or larger video systems are typically projection-based. With yields making direct-view AMLCDs cost-prohibitive at sizes much greater than 20 in., AMLCD technology is an unlikely candidate for large direct-view screens. Although LCD light-valve projection systems are still expensive (as are competing CRT projection displays), the market is expected to show significant growth. There are other projection possibilities – such as Texas Instruments' digital micromirror device (DMD) system, which is under development. For high-definition TV (HDTV), all projection technologies are candidates.[1] Japan will begin regular HDTV broadcasting in 1997 to showcase technologies during the 1998 Olympics.

Direct-view HDTV is much more challenging. The plasma display panel (PDP) is promising, with 60-in. monochrome versions demonstrated. Color dc PDPs are under development in Japan by NHK, Oki, and Texas Instruments. Photonics in Ohio is developing an ac PDP with ARPA funding. Another proven direct-view technique is electroluminescence (EL), with displays from Planar Systems and Sharp. Tektronix introduced a plasma-addressed LCD (PALCD), which is undergoing further development by Technical Visions of Beaverton, Oregon.

An intriguing flat-panel matrix-addressed CRT technology called Flat Vision is available from Matsushita Electric Industrial Co. It uses an array of nearly 10,000 miniature CRTs to produce a 3.9-in.-thick 14-in. display. The company says it expects Flat Vision to capture 10% of the world market for flat displays by the year 2000.

Producing What the OEM Market Needs

Accurate market anticipation is essential for manufacturers because of the massive investment costs. Japan's display producers – including FPD market leaders Sharp Electronics, NEC, Display Technology, Inc. (DTI, the Toshiba-IBM joint venture), Hitachi, and Hosiden – invested heavily in bringing LCD technologies through R&D and into production. This is a significant departure from Japan's past industrial successes, which came about through optimizing existing manufacturing technologies developed elsewhere. Other players, with far smaller financial commitments to existing technologies, are betting on leapfrog technologies to overcome LCD's cost-per-area limitations.

USDC: Building a Manufacturing Infrastructure

The USDC is building a U.S. manufacturing infrastructure for producing high-definition displays for emerging applications. The consortium identified 30 critical technology improvements needed to successfully meet the requests of display users. Peter Mills, CEO of USDC, says, "We are doing precompetitive R&D work, and despite reports of targeting AMLCDs, USDC is technology-neutral on display concepts. The technologies of our 119 members include LCDs, FEDs, ELs, PDPs, and other displays. Members manufacture or develop FPDs, supply equipment and materials, or are OEM users of displays."

Working with the USDC is the American Display Consortium (ADC), comprised of U.S. companies engaged in FPD manufacturing and development. ADC-funded R&D results in processes and tools for producing displays and includes cooperative efforts with the Department of Commerce (DOC), NIST's Advanced Technology Program, and the Phosphor Technology Center of Excellence.

On April 28th, the DoD committed $587 million to display efforts, and is leveraging USDC's R&D work on second-generation LCD manufacturing equipment and materials. DoD's first investment was in Motif's Active Addressing™ for passive-matrix displays. (Motif is a Motorola and In Focus Systems joint venture.)

The first USDC contracts went to Donnelly Applied Films for treated and coated substrates; Photon Dynamics for pre-assembly test, inspection, and repair systems; and Accudyne for FPD spacer application equipment. Lam Research was selected to extend the capability of advanced plasma dry etching equipment from today's 200-mm^2 FPD substrates to 600 mm^2. Additional USDC contracts are expected shortly for substrate glass and lithography equipment.

Malcolm Thompson, chief technologist for Xerox PARC and chairman of the USDC board, is excited about USDC's efforts. He says, "In year one, USDC brought together the U.S. companies needed for a domestic FPD infrastructure. Previously, there had been very independent and fragmented efforts. USDC's technical committee members jointly discuss what needs to be done, then establish goals and priorities. It's going incredibly well. We have a viable model and plan for U.S. manufacturers to become significant, and perhaps dominant, in displays and other related technologies that will be essential in coming decades.

"The key to future U.S.-produced display success will be how well FPD producers help OEMs differentiate products," said Thompson (Fig. 2).

Xerox PARC: The U.S. Manufacturing Testbed

The Xerox Palo Alto Research Center (PARC) has produced the highest-pixel-count AMLCD to date: a full-page monochrome display with 6.3 million pixels (Fig. 3). In a recently awarded \$100-million cost-shared program, PARC's existing a-Si TFT-array and color-filter expertise will be combined with Standish Industries' innovative liquid-crystal materials expertise and AT&T's chip-on-glass and TAB packaging expertise. The combined efforts of the companies' Advanced Display Manufacturing Partnership could be formidable.

Optimistic USDC Feedback

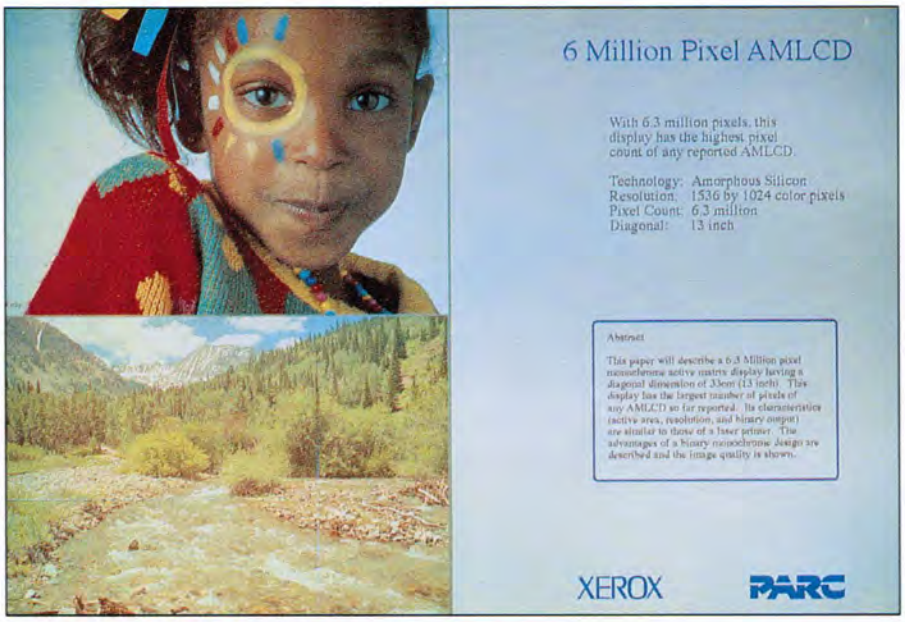
Rex Tapp, president and CEO of OIS, is also excited. "Having the USDC get display customers involved through their users' group was terrific. Now we jointly create positive solutions for customer needs. We assess display-technology tradeoffs, manufacturing options, and the economic risks involved because we are all businesses and must be profitable.

"No single display solution will work for all applications in our information-rich age. HDTV, portable telecommunications devices beyond our first-generation PDAs, and automotive requirements will be very cost-sensitive. Manufacturing obstacles will only be overcome with earlier product-conceptualization discussions and cooperation between equipment and materials vendors, display producers, and their customers," said Tapp.

John Laney, display process technology manager for Planar Systems, said, "When we started our EL display program 11 years ago, there was little available equipment or processing to achieve manufacturing success. Today, the USDC is on track by generating interest in display manufacturing and helping

OIS Optical Imaging Systems

Fig. 2: *OIS is helping OEMs differentiate products by designing and building displays to their specifications. This cleanroom manufacturing facility is where OIS is developing and building new high-performance AMLCDs to meet Apple's next-generation Powerbook requirements.*



Xerox PARC

Fig. 3: *Xerox PARC's 13-in.-diagonal monochrome AMLCD has 6.3 million pixels – 284 dots per inch (dpi) – which virtually matches laser-printer detail. This color version has the same number of pixels, each containing four subpixels: red-green-blue-green.*

So What Else Is New?

New ideas and improved concepts dominate recent display-manufacturing news. Here are some selected highlights.

FPD capacity increases

- Matsushita Electric Industrial Co. is boosting TFT-LCD production from 30,000/month now to 100,000/month next year. Fujitsu, Hitachi, and Mitsubishi also have announced plans to build new plants with 100,000-FPD/month capacities.

FED production

- Canon will begin FED volume production this year.
- Micron Display Technology, Inc., has by-passed LCDs to produce FEDs on 150-mm wafers, an effort partially funded by ARPA.
- Raytheon Co. plans volume production of ferroelectric devices by 1996.
- FED Corp., a spinoff of the Microelectronics Center of North Carolina (MCNC), has deliveries scheduled for December 1994.
- Texas Instruments is delaying FED production announcements but its partner Pixel will begin production late this year. TI is waiting for the results from Pixel's initial pilot production this fall before making further commitments.

DMD production

- Texas Instruments is expected to bring its digital micromirror device (DMD) to market this fall for projection displays.

Vacuum fluorescent displays

- Futaba is mass-producing vacuum-fluorescent displays.

Plasma displays

- Plasmaco, Inc., and other makers of plasma displays (PDPs) believe that 55-in.-diagonal color products are possible and can challenge AMLCDs soon.

Pixel addressing

- Motif's Active-Addressing™ scheme permits near-AMLCD performance with passive-matrix displays.
- Optrex has another active-addressing technique.

Filters

- Dimension Technologies, Inc., is developing a field-sequential color approach that avoids filters. The work is sponsored by a National Science Foundation Phase I small-business innovative-research grant and ARPA.
- In Focus Systems has a holographic color-filter manufacturing technique said to be better than dye filters and easier to produce.

Backlighting

- Landmark Technology has a new high-intensity backlighting approach, as does Sensing Technology Corp.
- Tektronix, Inc., and Avionics Engineering have announced a scheme for improving brightness and contrast in TN displays by strobing miniature backlights synchronously with the vertical address scan of the LCD.
- BrightView Technology has a flat collimating microprismic light-pipe device capable of improving LCD brightness.

Inspection systems

- Photon Dynamics has won *Test & Measurement World Magazine*'s award for "Best in Test" in 1994 for its FIS-100 Flat-Panel Inspection System.

CVD deposition

- Applied Materials has an advanced high-uptime CVD system for AMLCD panels that improves overall throughput by incorporating a built-in cleaning cycle between panels. The company also manufactures FPD sputtering and etching systems.

Lithography

- MRS Technology is producing stitching aligner steppers.

develop the infrastructure needed to pull it off. One exciting area that needs a lot of effort is the substrate glass. Glass-generation distinctions should be made between improved glass versus simply larger glass with old problems. Going larger will not solve any fundamental yield problems for you." Planar, a developer and producer of EL displays, is also working with Kopin Corp., Allied Signal, and Sarnoff on active-matrix EL projects.

Kopin Corp., a materials-oriented company with roots in MIT's Lincoln Labs, has a go-smaller approach for building AMLCDs. They fabricate AMLCD single-crystal-silicon (x-Si) active circuits on silicon wafers with IC processing, and then lift the high-resolution display circuits off the wafers and attach them to glass substrates for LCD assembly.

Kopin's vice president Jack Salerno describes their SmartSlide™ AMLCDs as the highest-resolution displays being manufactured anywhere for projection and head-mounted applications (Fig. 4). He said, "Small, high-pixel-density panels make sense because the manufacture of any active-matrix-addressed LCD panel becomes increasingly problematic as the area increases.

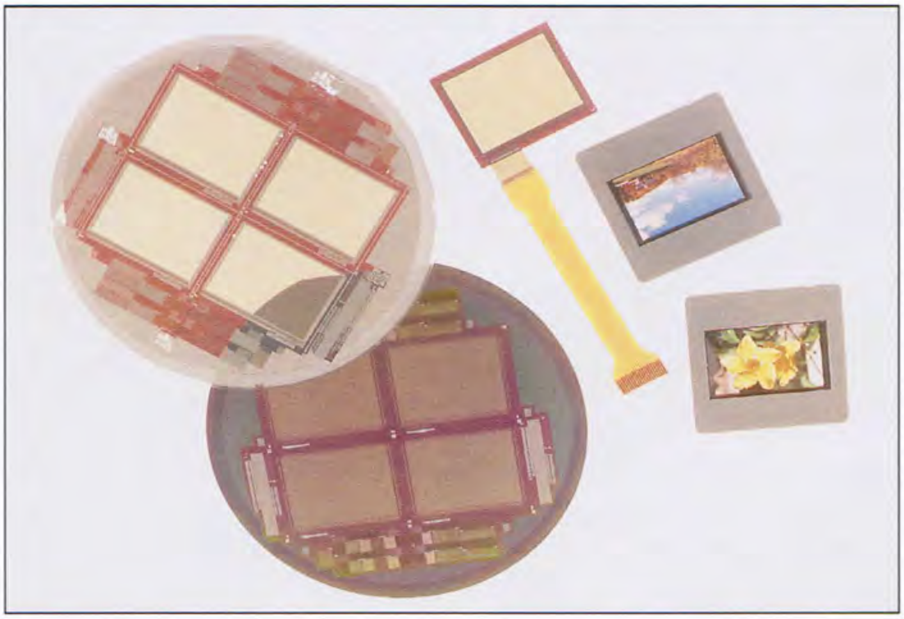
Kopin, with the Microelectronics and Computer Corp. (MCC) and numerous other partners, also has a grant from the DOC to apply this technology to AMLCD circuits complete with on-board display drivers and logic circuits for laptop-computer applications.

Kopin is using proven infrastructure to produce displays by leveraging IC and LCD knowledge to avoid risks. The U.S. is strong in most R&D but lags in manufacturing now. The USDC efforts will help correct that situation.

"I feel that the U.S. can be very successful with alternative technologies that complement existing displays. With the x-Si approach, I suspect that the eventual market will be huge, maybe bigger than today's AMLCD laptop market.

Winning by Tweaking, Innovating, or Establishing Alliances?

With major long-term markets uncertain, and the investments needed for developing and manufacturing new displays substantial, one certainty is increased global alliances between display producers and users. Partnering efforts between companies help share costs and develop markets. Many partnered pro-



Kopin Corp.

Fig. 4: Kopin's AMLCD single-crystal-silicon SmartSlide™ is fabricated on wafers with conventional IC processing, then lifted off for mounting. Kopin describes it as the highest-resolution display available for projection and head-mounted display applications.

jects involve firms from many countries, and some larger firms are currently so global that they avoid national labels. Teamwork – using the strengths of partners – is creating a very fluid new manufacturing environment that changes to meet market demands.

CRTs still dominate virtually all but laptop, camcorder, PDA, and other mobile display applications. However, neither current-generation CRT nor LCD technologies are likely to dominate by the turn of the century. LCDs have application drawbacks, including limited screen size and high cost.

The bottom line: it is still a wide-open race for the display of choice for the year 2000. It is indeed premature to pick a display winner today when one or more emerging – or presently unthought of – display technologies could be the new winners.

Manufacturers must rely upon predictable manufacturing for success as competition stiffens. The only clear winners will be the consumers because fierce competition usually results in better products at lower cost.

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Large 1X Masks for Flat Panels

Today's state-of-the-art very large precision masks can meet the needs of FPD manufacturers through 1995.

by Martin Boothman and Graciela Guel

IN 1986 AT XEROX, Malcolm Thompson was projecting masks with critical dimensions (CDs) of 2.0 μm over a 400 × 400-mm active area. Today, the best commercial mask makers can produce very large precision masks (VLPMs) with 2.0-μm lines over a 450 × 500-mm active area on a 20 × 24 × 0.190-in. chrome-on-glass plate.

This article looks at the changes in 1X (the mask image patterned without magnification) VLPMs over the last 6 years and at some equipment currently utilizing VLPMs; it then makes projections of the changes that will be needed over the next few years.

Very Large Precision Masks

A 1X VLPM is any mask that is 200 mm^2 or larger, with lines or spaces smaller than 25.0 μm, and/or registration requirements between any two levels of 10.0 μm or less.

There are now three basic exposure systems for the use of a 1X VLPM: contact, proximity, and projection. A projection system is the most desirable because it does not introduce the defects inherent in contact printing, but such systems were not available until recently.

All three lithographic techniques are less expensive than stepping lithography, and have the added advantage of requiring only one exposure step per layer. Therefore, one way for manufacturers to reduce FPD manufacturing costs is to reduce the cost of their lithographic steps by using 1X VLPMs with contact, projection, or proximity lithography.

Even though 1X masks applicable to the manufacture of active-matrix LCDs (AMLCDs) have been available since 1988,[1] most display manufacturers continue to use stepping lithography for all of the FPD layers. Two major reasons for this have been the perceived lack of large-area masks that meet FPD manufacturing needs and the absence of large-area precision printers with the resolution and registration required for an FPD's critical layers. These two obstacles have been overcome. VLPMs are being manufactured today, and new printers with adequate resolution and registration for large-area applications are on the market. Alternative lithographic techniques are now available for manufacturing FPDs at substantially reduced costs.

In the Beginning

The first large-area masks were made similarly to those used for graphic arts, starting with emulsion on film to make a master and then copying to chrome plates. The specifications, dimensions, and tolerances have undergone substantial changes since then.

The CDs for displays have shrunk dramatically from 1.6 mils (40 μm) in 1984 to their present value of 0.1 mils (2.5 μm) (Fig. 1). Projected CD requirements for 1995 are 0.08 mils (2.0 μm) for some display technologies.[2] The figure indicates this goal will be reached if the CD trend line continues into 1995 with its present slope.

Tolerances have also become more rigid for VLPMs. In 1988, the layer-to-layer registration tolerance for VLPMs was ±1.0 mil (±25.0 μm). The projected tolerance is now to ±0.04 mils (±1.0 μm) on 12 × 12-in. plates and ±0.08 mils (±2.0 μm) for larger plates with active areas of up to 20 × 18 in. using low-expansion glass.

As display manufacturing matures, display sizes are growing – along with the active area of VLPMs (Fig. 1). Growth was practically linear, from 35 $in.^2$ (7-in. plate) in 1984 to 166 $in.^2$ (11 × 17-in. plate) in 1992, with a sudden increase to 360 $in.^2$ (24-in. plate) in 1994.

Today and Tomorrow

Display sizes continue to grow – especially in TV and HDTV applications. For these applications, the expectation is to soon have wall-hanging displays that are a few centimeters thick and 40–55 in. on the diagonal. Each display technique faces the challenge of accommodating these increasing display sizes. The largest flat-panel color display reported to date is a 40-in.-diagonal device that uses plasma display technology (NHK).[3] For non-TV applications – such as laptop monitors – display sizes could be as large as 20 in. on the diagonal, but with better resolution than displays intended for TV or HDTV.

Present geometry requirements for most display technologies are ≥5.0 μm. Manufac-

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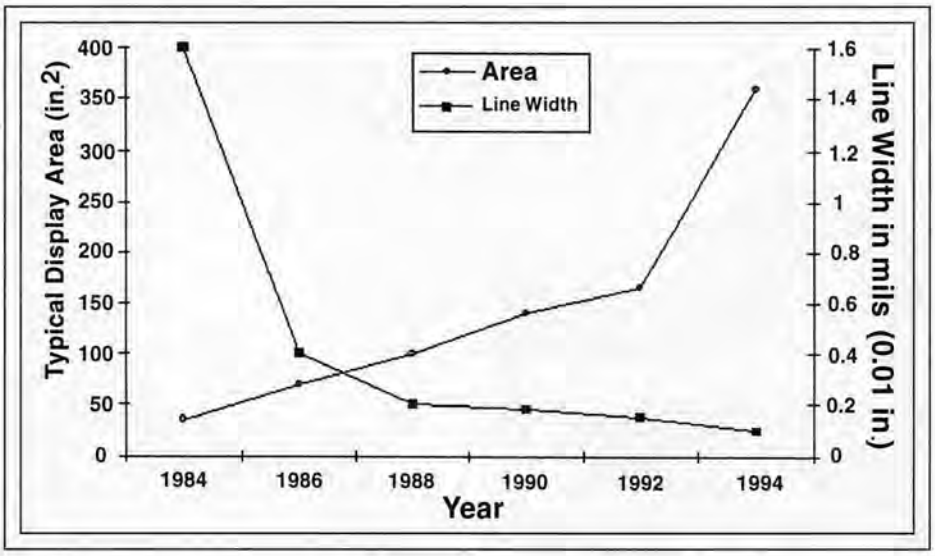

Fig. 1: *Display areas have grown dramatically since 1984 and critical dimensions have shrunk. (Data based on Microphase's VLPMs.)*

turers expect that AMLCDs will require smaller geometries for 1995 (~2.0 µm). Display pixel sizes for FPDs in general range from 15.0 µm to a few millimeters, depending on the technology. Displays using thin-film-transistor (TFT) technology require the smaller geometries (2.0–5.0 µm),[4] but they are presently being produced only for small-area applications.

Layer-to-layer registration tolerances (overlay) are between 1.0 µm for critical features and 5.0 µm for non-critical features. Some technologies have smaller critical features and require tighter overlay registration, but most display layers will align well with the 5.0-µm overlay tolerance.

VLPM Manufacturing Materials

There are several available materials for manufacturing VLPMs: emulsion plates, chrome plates, and iron oxide plates. Each material has advantages and disadvantages, and the choice of material depends mainly on the mask application.

The first material used to produce LPMs was emulsion on glass or film. Emulsion plates are inexpensive, and large emulsion plates with good emulsion uniformity were developed several years ago, mainly for graphic-art applications. Resolution and tolerances that can be achieved on emulsion material are 0.4 mils (10.0 µm) for both plates or film as large as 24 × 24 in. These tolerances are adequate for circuit boards and for non-critical layers on FPDs. However, such tolerances make emulsion plates unsuitable for the tight-tolerance lithography needed for most FPD manufacturing. (A secondary disadvantage is that emulsion plates and films are easily scratched.)

Chrome masks with submicron resolution have been used for years in the semiconductor industry. Chrome masks are long-lasting, and systems exist to repair clear and dark defects on plates as large as 7 × 7 in. However, there are several drawbacks to chrome VLPMs, including stringent demands on glass planarization quality, lack of defect-free substrates, and the current lack of equipment to properly manufacture, inspect, and repair chrome VLPMs. Even though chrome-mask technology is mature for small plates, it still needs further development for large-area mask blanks.

Before chrome, iron oxide was the material of choice for large-area applications. It was easier to coat large plates with iron oxide using chemical vapor deposition (CVD) than to coat them with chrome using sputtering. Another advantage to iron oxide masks is that you can see through the mask when the field is dark, but the use of iron oxide coatings entails two disadvantages: (1) iron oxide is not as resistant to scratches as chrome coatings, and (2) iron oxide is more difficult to etch uniformly than chrome.

One challenge to producing VLPMs is the substrate itself. To produce precision masks, the substrate material must have good planarization, a low thermal-expansion coefficient, and a very low defect density – defect-free is desirable. To keep up with registration tolerances, substrates with low coefficients of thermal expansion – such as quartz, borosilicate glass, or non-alkali glass – are required (Table 1). Soda-lime glass has been an excellent and economical substrate material for many mask applications and continues to meet the requirements of VLPMs with overlay precisions no more demanding than 5.0 µm. With the use of borosilicate glass or quartz as a substrate, the VLPM overlay precision could be ≥1 µm. Regardless of the substrate material, temperature and humidity must be controlled during the manufacture of VLPMs and during the lithographic application.

Exposure Systems

There are currently several ways to generate masks. Each method pursues the continuing need to improve resolution, tighten registration, and provide more uniform CDs.

Laser pattern generator. "LPGs" – or laser photo plotters – are high-throughput systems that are already on the market. LPG systems expose masks by scanning a laser onto photographic emulsion, which is coated on either glass or film. The emulsion's resolution and the laser beam's positioning provide most photo plotters with a resolution and registration of about 25.0 µm (~1.0 mil). Micronics, Inc. has an LPG that can provide CDs as small as 3.0 µm and an overlay of 0.5 µm over 200 mm on chrome plates, but the drawbacks are that the plotter is very expensive and Micron-

Table 1: Thermal Expansion Coefficients for Some Mask Substrate Materials

Material	Borosilicate	Non-alkali	Quartz	Soda-lime
Thermal expansion coefficient ($x10^{-7}$ @ 50-200°C)	37	43	5	94

Microphase Laboratories

Fig. 2: Microphase Laboratories took a purpose-built approach to a system for inspecting and repairing VLPMs. This is the company's ML-LAIR.

ics is just now developing a U.S. service center. Other LPGs are being developed.

Optical pattern generator. The OPG, like the LPG, has the advantage of writing the mask directly from the data – such as GDSII files. OPGs have better resolution and registration than standard LPGs. They have been producing photo plates with CDs as small as 2.5 μm for years. OPGs have not had the high throughput of LPGs, but designers have enhanced the throughput of recent systems by increasing the flashes per hour by as much as three times – to about 40,000 flashes/hour. New OPGs now under development may include a fixed-aperture reticle capable of stepping small repetitive patterns – less than 150 mils. These new systems are expected to be on the market shortly.

Step-and-repeat systems using reticle stitching. Steppers have been very convenient devices for manufacturing large-area plates. One of their advantages is their throughput. A disadvantage is the need to generate many reticles when one is producing a complicated final VLPM. This increases the VLPM's cost and required lead time. Optical reduction factors of 1X, 2X, or 5X are used in MRS, Canon, Nikon, and Electromask steppers, as well as in Microphase Laboratories' own ML-LAS-508 stepper. These systems permit critical dimensions smaller than 3.0 μm.

Combination of systems plus multi-contact printing on large plates. Another technique uses a combination of systems plus multi-contact printing to produce large plates. In 1987, Microphase used this technique to produce plates with active areas as large as 13 × 15 in. The plates were produced by building a 6.5 × 15-in. active area on the mask and then exposing two masks together to make the full array. This method will not work for present AMLCDs, which require much tighter specifications.

Lagging Metrology

Metrology poses a big challenge to mask manufacturing. Systems like the KLA or Nikon – which find defects and measure CDs, registration, and overlay precision – are not available on the market for plates larger than 7 in. Systems that can handle larger plates do not have data-to-die capabilities or do not detect defects smaller than 5.0 μm. To certify VLPM quality, it is necessary to have an inspection system that can find defects as small as 2.0 μm with reasonable speed. This situation is complicated because the system must inspect such a large area.

Microphase's Contribution

Unable to buy the equipment needed to make our next product generation, we at Microphase Laboratories undertook the construction of our own machinery for the manufacture, inspection, and repair of VLPMs. One result of this effort is the ML-LAS-508 large-area stepper, which can write chrome photo plates with active areas of 508 × 457 mm (≥25-in. on the diagonal). This system was designed and constructed under a project with Planar Systems, and was partially funded by ARPA. After VLPMs are manufactured, they are inspected with the ML-LAIR inspection and repair system, which was designed and assembled at Microphase through a contract with Tektronix and was partially funded by NIST (Fig. 2).

The ML-LAS 508 is an optical stepper designed specifically to expose VLPMs. It uses two independent X and Y stages with 20 in. of stage travel in each direction. Its laser-interferometer positioning system has an accuracy of ±0.05 μm. The stepper operates at 436 nm and has an optical reduction ratio of 5X. The system has an automatic air-gauge focusing system that is accurate to 0.1 μm of focus and an automatic air-gauge plate-leveling system. The focusing capability helps control the stitch positioning three-dimensionally through the software. The stitching overlay for line continuity is 0.25 μm. The inspection and repair – when required – of VLPMs are just as important as the actual generation. There are no inspection systems currently on the market for VLPMs. Microphase's ML-LAIR system has a confocal microscope that shares the optical path with a YAG laser to repair dark defects and an Ar^+ laser to repair clear defects. The ML-LAIR measures CDs from 2.0 to 100 μm, and has repair resolutions of 5.0 μm for dark defects and 10.0 μm for clear defects.

The ML-LAS-508 and ML-LAIR permit the production of 24 × 20-in. VLPMs with 25-in.-diagonal active area and specifications that fulfill the requirements for present AMLCDs, as well as the anticipated requirements for 1995 (Fig. 3, Table 2).

1X Printers Available

1X masks for flat panels can be used with printers for proximity, projection, or contact lithography. A printer for large-area applications must meet or even surpass the litho-

Table 2: State-of-the-Art VLPM Specifications*

	Metric	English
Plate size up to	508 × 609 × 6.35 mm	20 × 24 × 0.250 in.
Active area up to	457 × 508 mm	18 × 20 in.
Minimum geometry/space	2 μm	0.08 mils
Tolerance	±0.5 μm	±0.02 mils
Stepping precision	±0.25 μm	±0.01 mils
Total registration**	±1 μm, over 305 × 305 mm	±0.04 mils over 12 × 12 in.
	±2 μm, over 457 × 508 mm	±0.08 mils over 18 × 20 in.

* The specifications are for the Microphase VLPM shown in Fig. 3.
**The total registration is specified for borosilicate or quartz substrates.

Microphase Laboratories

Fig. 3: *This 20 × 24-in. chrome VLPM with a 25-in.-diagonal active area was manufactured at Microphase Laboratories to answer the production requirements of LCD manufacturers at least through 1995.*

graphic requirements for non-critical AMLCD layers, i.e., a 5.0-μm resolution with a uniformity variation less than or equal to 10% and a layer-to-layer overlay of less than 5.0 μm within the active area.

One of the important requirements for large-area printers is illumination uniformity. There are several approaches that can be used to improve the uniformity of illumination. For example, the Tamarack system includes scanning projection of an optical system to cover the whole VLPM area,[5] while Hugle Lithography's system has a lens array.[6] Whatever the method, there are several vendors that have printers for large-area applications, including Tamarack, Hugle, Karl Suss,[7] and Optical Radiation Corp.[8]

Most of the optical printers on the market have an optical resolution of ≤5.0 μm and an alignment accuracy of ≤5.0 μm. These printers operate in the 330–450-nm region, handle substrate plates as large as 500 × 600 mm (20 × 24 in.), and operate at 1X optical reduction ratio. All the printers – whether projection,[5,6] proximity,[7,8] or contact[9] – can handle VLPMs as reticles. The throughputs of printers are better than those of steppers, and some printers are capable of 60 plates per minute. These specifications fulfill the requirements for non-critical AMLCD layers.

The Mix-and-Match Approach to FPD Manufacturing

MRS, a U.S. stepper manufacturer, has developed an excellent FPD lithographic tool that is competitively priced. The MRS can image 400 mm^2 in less than 2 min. The stepper is capable of resolving CDs of ≤3.0 mm ± 10% with aligning accuracy (overlay) of ≤0.5 μm. This stepper could be used for the lithography of all AMLCD layers.

Where high throughput is required for display technologies that have tight tolerances, a "mix-and-match" technology incorporating stepping lithography for critical layers and an alternative lithography for non-critical layers will reduce manufacturing costs. (Mix-and-match lithographic techniques are currently used in the lithography of wafers and do reduce manufacturing costs.[9]) Manufacturers such as Image Quest are now using Tamarack and MRS systems together to increase throughput and reduce initial capital requirements. AMLCD registration requirements are constant for all layers, but for some lithography steps with less-critical resolution requirements, proximity, projection, or contact printing may be used because resolution and defect requirements are less stringent. Mix-and-match gives its practitioners a competitive edge by significantly reducing display-manufacturing costs.

Manufacturer/Vendor Relationships

The FPD manufacturer and the VLPM vendor must work together very closely, beginning at the design stage, if possible. VLPM cost savings can be as high as 75% with small design changes, especially in the fanning out of leads. Some of the new CAD software packages, such as Autocad, are not compatible with the existing conversion software. Because of the absence of metrology tools, constant feedback between customer and VLPM supplier is essential.

We at Microphase feel that joint ventures between FPD manufacturers and VLPM suppliers will also become important because of the relatively high cost of process development and new equipment. FPD manufacturers and the VLPM suppliers have many requirements in common, such as uniform resist coatings, uniform etching, packaging, and high-

masks

quality substrates. One more area that would benefit from joint ventures is the establishment of standards, which affect equipment design, materials development, process development, and manufacturing costs for both VLPMs and FPDs.

Notes

[1]*Information Display* **4**/7&8, 21 (1988).

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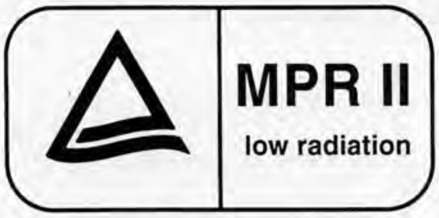
The Marks on the Back of the Box

TÜV Rheinland is Germany's leading approved monitor test house, but what do their certification marks mean?

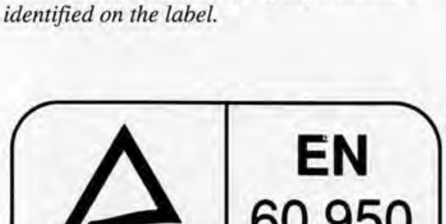
by The Staff of *Information Display*

CERTIFICATION from an approved test house that a monitor or VDT complies with applicable standards has become a requirement for participation in many segments of the European market. TÜV Rheinland is the leading approved German test house, and its marks are accepted throughout Europe. Monitors originating from manufacturers around the world carry these marks. But the variety of standards that now require certification ensures that there is also a confusing profusion of marks.

Here are illustrations of TÜV Rheinland's marks and their meanings.



Certifies compliance with the the Swedish MPR-II electromagnetic emissions recommendations. This mark is one of many "T-Marks," which confirm compliance with the requirements of the single specific standard identified on the label.

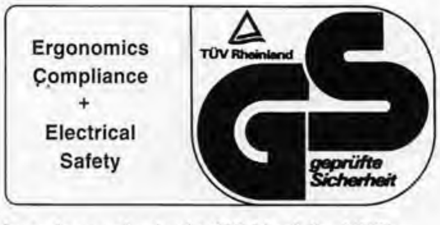


This T-Mark certifies compliance with EN 60 950, the European standard for electrical safety. T-Marks are modular. Manufacturers can combine as many marks as they feel are required by their target markets -- after paying for the additional certification testing, of course.

A T-Mark certifying compliance with Part 3 of the ISO 9241 international ergonomics standard.

These two equivalent marks – which TÜV Rheinland calls the "GS-Mark" – certify compliance with safety and ergonomics standards required by the German Equipment Safety Law ZH 1/618, 10.80, and ergonomics standards required by European Community Directive 90/270/EEC. (ZH 1/618, 10.80, "Safety Regulations for Display Work Places in the Office Sector" is available in English.)

Testing for this "Ergonomics Mark" incorporates all tests needed to obtain the GS mark, and adds the detail contrast specification from ISO 9241/3 and the electrostatic, electric, and magnetic-field recommendations from MPR-II. The Ergonomics Mark is therefore much broader than any individual T-Mark.



In order to obtain the GS-Mark for VDTs, compliance with ergonomics standards is required by the German Equipment Safety Law and in part by European Community Laws (EC Directive 90/270/EEC). Ergonomics applies to Video Display Units for professional application with standards listed in ZH 1/618, 10.80, "Safety Regulations for Display Work Places in the Office Sector." ■

Lasers and Flat-Panel Displays

Lasers often provide the best (or sole) way to perform an FPD processing step, but which laser is best for each task?

by Floyd Pothoven and Lee Branst

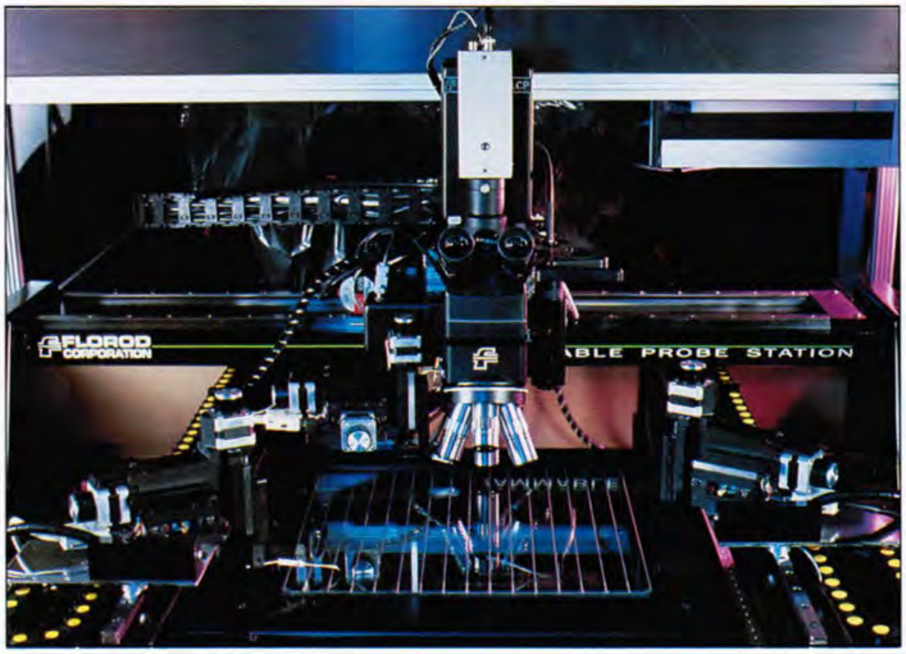
THE USE OF LASERS in the manufacture of flat-panel displays (FPDs) has become widespread. This is especially true for active-matrix liquid-crystal displays (AMLCDs). An observer would be hard-pressed to find a manufacturer of AMLCDs that does not use lasers, especially in the repair process (Fig. 1).

In microelectronics manufacturing – a field that is closely allied to FPD manufacturing – lasers are used for a wide range of functions. Among these are measurement, positioning, and inspection tasks performed by reflecting laser light off the surface of a wafer or other device. In photolithography, lasers emitting at ultraviolet (UV) wavelengths are used to make mask patterns by selectively breaking the bonds of the organic molecules that comprise the photoresist. The photoresist is thus "exposed" in much the same way that ambient visible light exposes the chemicals in photographic film. Such applications are also found in the FPD world.

But most manufacturing applications using lasers rely on the laser's ability to ablate, or remove, material. This process usually harnesses the laser's pyrolitic, or heat-generating, capabilities. The intense beam of photons generated by the laser produces extreme heat at the target site, thus melting, vaporizing, and removing material at that site. A laser's ablative ability can be used to cut, drill, scribe, mark, and interactively trim resistors. These processes can be accomplished with laser light over a wide range of wavelengths.

To understand the applications of lasers in the FPD arena, we should first review some basics. There are five laser characteristics that are important to successful laser ablation: energy, wavelength, mode, pulsewidth, and pulse repetition rate.

Energy. Enough laser energy must be delivered to elevate the temperature of the target material well above the vaporization point. Insufficient energy will merely melt the target, and the resulting shiny surface may reflect subsequent laser pulses. (But melting



Florod Corp.

Fig. 1: *A modern probe station can combine laser-repair capabilities with visual inspection and electrical testing – all under programmable control. This is Florod's PPS Programmable Probe Station.*

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is desirable in the case of laser welding.) Too much energy causes overpenetration, which damages underlying layers. It also may cause material to splatter over a relatively wide area, which can create short circuits at the minuscule dimensions typical of microelectronics and FPD fabrication.

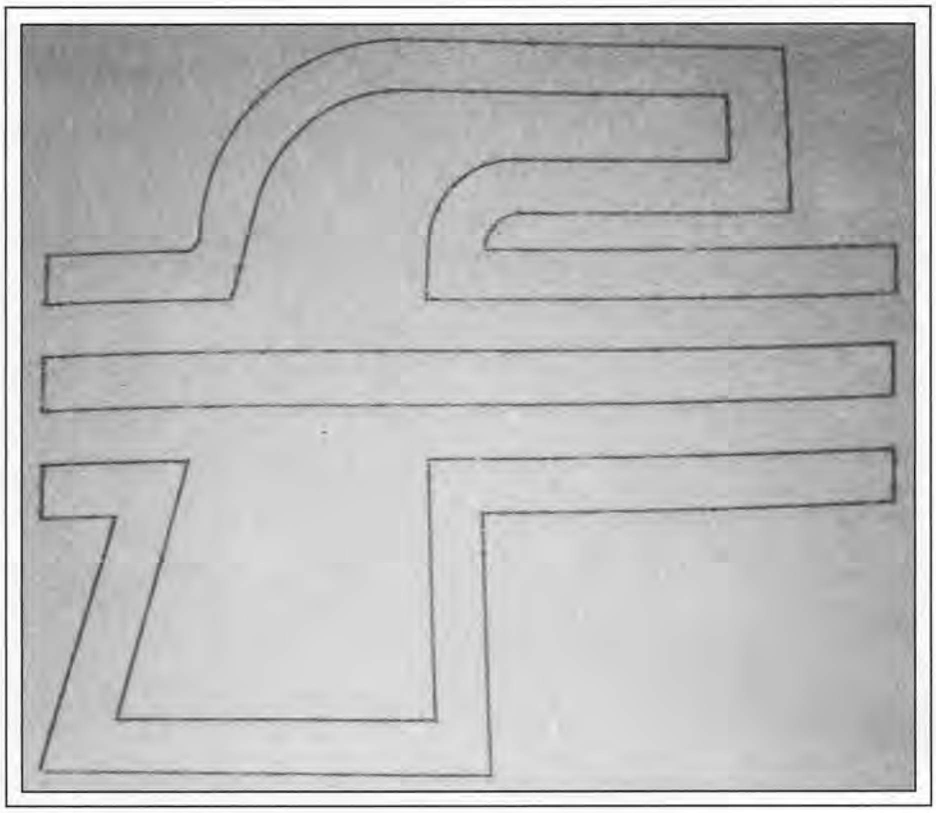
Several hundred microjoules of energy are usually sufficient for miniature cutting jobs. Metals, especially aluminum, are the hardest materials to cut because of their high conductance and reflectivity. Organic materials are much easier. Glass represents a special problem, as we shall see.

Wavelength. Each laser emits light at a characteristic wavelength (or wavelengths), which must be matched to the absorption wavelength of the target material. In addition, shorter wavelengths mean that smaller device structures can be accessed without affecting nearby features. Depth of focus is directly proportional to wavelength.

Mode. Some lasers emit light continuously and are consequently called continuous-wave (CW) lasers. Others are pulsed, emitting bursts of light energy. Some lasers of both types can be outfitted with a device called a Q-switch, which can generally deliver higher peak power over a shorter timespan than the original laser alone. This is a desirable combination for many applications.

Pulsewidth. Laser pulsewidth – the time duration of the laser pulse – is important because the longer the pulsewidth, the more heat is created at the work site. Too much heat can cause substrate damage; too little can result in incomplete material removal.

Pulse repetition rate. A high laser rep rate generally results in quicker controlled material removal over a larger area. But this is not always necessary – or even desirable – when the highest accuracy is required.



Florod Corp.

Fig. 2: *The quadrupled YAG laser can provide fast, high-quality glass marking without generating cracks.*

Lasers for FPD Manufacturing

The crystal ruby laser, developed in 1960 by Ted Maiman at Hughes Research Laboratories in Malibu, California, was the first working laser. Since then, dozens – perhaps even hundreds – of other laser types have been invented. (When researchers began to realize that lasing materials were not rare, one wag suggested, "You could make a telephone pole lase if you put enough energy into it.")

Different lasers have different properties, so the search continues to find lasing media with higher peak powers, better optical characteristics, transmission at specific wavelengths, improved electrical conversion efficiency, and combinations of these properties (as well as others we haven't mentioned).

The following list of laser types used in the manufacture of FPDs thus constitutes a snapshot in time. This relatively short list includes lasers that have been used for some time and others that have only recently entered the arena.

The Nd:YAG, more popularly known simply as the YAG laser, is probably the most widely used laser in FPD manufacturing – and is one of the most popular types for many industrial processes. Its name derives from its lasing medium: a crystal of yttrium aluminum garnet (YAG) that has been doped with neodymium. The YAG has a basic output wavelength of 1064 nm.

This laser is popular because, when Q-switched, it can generate very high peak powers (into the megawatt range) with a very short pulsewidth (as short as a few nanoseconds). This means that the laser can ablate material of very small dimensions (about 2-µm minimum laser spot size) while keeping the surrounding heat-affected zone to a minimum. In addition, Q-switched YAGs provide extremely high laser pulse repetition rates (over 10 kHz). This permits rapid removal of relatively large amounts of material.

By placing specific crystals in the path of the YAG's output beam, the emitted light can be frequency-doubled, tripled, or quadrupled. The resulting output wavelength is thus divided by two, three, or four to 532, 355, or 266 nm. Bringing the output wavelength down into the UV range means that even smaller device geometries can be ablated.

Two other lasers used in FPD manufacturing come from a family known as noble-gas lasers. Of these, the xenon and argon lasers have found a place in FPD manufacturing. The xenon laser emits at a number of frequencies from about 480 to 540 nm, providing the laser beam with a unique, brilliant green color. The pulsewidth is about 1 µs.

The argon laser emits blue light at 514 nm. Unlike the other lasers discussed here, it is valued for its CW – not pulsed – characteristics. This laser has low peak power. We'll cover its CW-based advantages later.

The excimer laser is a hybrid type in which noble and halogen gases combine in a high-temperature plasma to produce pulsed light at UV frequencies. The primary excimer laser types are xenon chloride (emitting at 308 nm), krypton fluoride (248 nm), and argon fluoride (193 nm). The combination of wavelength, peak power, and repetition rate effectively suit these lasers for certain applications.

The carbon dioxide (CO_2) and helium-neon (He-Ne) lasers are two widely used lasers that have limited application in FPD manufacturing. The CO_2 laser is used in many macro-scale materials-processing applications because it can develop tremendous power. Russian scientists claim to have developed a version with an output power of 30 kW! However, its long wavelength (>10 μm) and large heat-affected zone have made it less suitable for microelectronic applications.

The ubiquitous He-Ne laser is widely recognized for its signature red beam (633 nm) and its use in point-of-purchase bar-code scanners. Its CW beam is useful in various inspection, metrology, and positioning applications, but its low power (a few milliwatts) makes it unsuitable for most materials-processing tasks.

Florod Corp.

Fig. 3: In FPD substrate processing, bigger is better. Modern laser processing stations can accommodate displays as large as 1 × 1 m.

FPD Manufacturing Applications

Probably the largest number of laser-based devices employed in the manufacture of FPDs are used for device repair. This is especially true in the production of AMLCDs. (The early history and development of this area is an interesting subject in itself and was covered earlier in *Information Display*.[1]) In this application, the laser is used to destroy redundant driver elements for display rows or columns, or may be used to destroy transistor elements for individual pixels. Almost any laser type can be used to destroy a device structure – an application that does not demand much delicacy. The YAG laser was the initial laser used for this purpose and it still has many adherents, especially within large integrated Japanese companies. But Florod's xenon laser came to dominate this application, especially in the U.S. Xenon's added attraction is that its longer pulsewidth allows it to remove defective device structures even after the liquid-crystal sandwich is completed – and without leaving a permanent gas bubble in the liquid.

Removal of redundant structures is not the only kind of AMLCD repair. Manufacturers can also perform additive repairs, in which metal missing after the original deposition process is added with the use of an argon laser. Here, a metal-bearing compound – which can be a gas, liquid, or solid – is deposited over the bare area, and the argon laser's CW beam dissociates the metal from the precursor material while simultaneously bonding the metal to the substrate. Thus, an electronic open can be closed to form a complete circuit.

The laser's ablative properties also make it valuable for other material-removal operations. Manufacturers can use a YAG or xenon laser to cut shorting bars on an FPD. One maker uses a Q-switched YAG laser for high-rep-rate scribing of indium tin oxide (ITO) patterns on touch-screen panels used with displays. The unscribed area forms a conductive pattern in the ITO. Lasers are also used to add and remove metal from the masks used to pattern the electronic devices on FPDs. This eliminates opens and shorts in the finished product.

Laser operations on glass are a particular challenge. In some of the repair scenarios above, the beam must pass through a glass substrate. This is not a problem for most common laser types. The situation is different, however, when the laser must affect the glass itself. In this case, equipment designers must select a laser wavelength to which the glass is opaque.

A recent application of this type is marking glass panels with identifying symbols for quality-control purposes. CO_2, excimer, and UV YAG lasers all have wavelengths suitable for this task. However, the Q-switched quadrupled YAG laser is generally superior to the others because its high rep rate and high peak power provide fast processing and high-quality marking without generating cracks in the glass (Fig. 2). These same positive characteristics have made the UV YAG laser a leading candidate for glass-scribing operations. And the YAG may also find application in an operation called fritting, in which two layers of glass are vacuum sealed around the edges by a laser.

Laser microwelding has also found a place in FPD manufacture. A YAG laser pulse is "stretched" in time so that it will melt, rather than vaporize, small amounts of metal. The high rep rate of a Q-switched YAG thus permits the welding of fine wires and other delicate pieces.

The xenon laser already has a long pulsewidth, which is accompanied by a low rep rate. This makes the laser suitable for spot-welding applications. One longstanding technique allows for the repair of electrical opens in address lines via spare lines that cross over the originals. "The welding process consists of simply zapping a small spot in the repair line crossover. This removes both metal layers from the center of the spot and redeposits the gate metal on the walls of the hole. This technique produces very reliable and low-resistance connections."[2] One variant provides for deliberate deposition of excess metal at points where a weld would be required. Zapping this spot makes the metal flow to complete the connection.

Metal annealing is an operation that can be accomplished via the properties of modern excimer lasers. These excimers combine a large spot size with sufficient power and rep rate to make raster-scanned annealing relatively efficient.

This is a very quick description of some main laser types and their applications to FPD manufacturing. Manufacturing engineers are continually developing new laser applications to meet manufacturing requirements, and equipment makers have to keep up with these new applications and the need to work on ever-larger substrates (Fig. 3).

Notes

[1]L. Branst and F. Pothoven, "Laser Repair of LCDs," *Information Display* (Sept. 1988).
[2]D. E. Castleberry and G. E. Possin, "A 1 Mega-Pixel Color a-Si TFT Liquid-Crystal Display," *SID Intl Symp Digest Tech Papers*, 232-234 (1988). ■

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Then one day a friend asked them if they had seen the article in the *Wall Street Journal* about how their company was going to revolutionize the electronics business. WHAT? Where did that come from? A quick reading, and they could see that the article made claims way beyond what they were planning to do. But J.B. said not to worry. It was just normal promotional talk, he reassured them. And not only that, the excitement that their future technology and products were creating was so great that they could now raise even more money. He would show them how to do it through a public stock offering.

Dan and Charlie were very concerned since they had no idea how they could speed up product development and manufacturing implementation to match what was now being promised by J.B. However, when they tried to discuss this with J.B., he told them that no one would ever expect them to meet these promises anyway.

Having now achieved the status of a publicly traded company, the attention from investors, analysts, and the financial press increased dramatically. These people weren't content to hear only from J.B. They wanted to hear from Dan and Charlie as well. Soon it became harder and harder to reconcile the discrepancies between the earlier promises and their actual progress. Not only that, neither Dan nor Charlie was any good at this. They hated the public exposure and scrutiny. These unpleasant encounters were alleviated, at least temporarily, by the periodic new technical results they could announce and by the sales numbers they could show from the development contracts they were bringing in.

Financially, they were doing fine. The public offering and previous venture investments, plus the development contracts, were making their company look very attractive. In fact, they had so much cash in the bank that the next several years were assured, even at the ever-increasing loss rate.

Nevertheless, more storm clouds were gathering. Even though they could demonstrate their product in the laboratory, they could only get one or two full-spec ones for every 10 or 20 that they built. It seemed that occasionally the process worked, but most of the time something was going wrong – they just didn't know exactly what. Also, their manufacturing manager, whom they had brought in to build the factory and install the processes, had just tendered his resignation because he said that the process they had invented was not compatible with high-yield high-throughput manufacturing. He put it rather bluntly – their product was going to cost 10 times what the mainstream users were willing to pay.

Meantime, J.B. put the public-relations machine into even higher gear. Announcements of impending product deliveries were made almost weekly. Most analysts continued their rosy assessment of the company. The stock price continued to climb with only an occasional minor "correction." Then, one day, J.B. was gone. He sold his stock, made a bundle, and he was GONE. Within weeks, Dan and Charlie had to announce that the products would not be available as promised, and that the technology required additional development before cost-effective manufacturing could be achieved. In fact, they would have to do a major re-design of the process, but they were sure they had found an answer that would get them back on track in about 9 months.

Unfortunately, Dan and Charlie never got to try out their ideas because they spent the next several years in various courtrooms fighting the numerous stockholder lawsuits that resulted from the promises J.B. had made on their behalf. In the eyes of at least some of these investors, they had crossed the thin line between overly optimistic promises and what the legal profession calls fraud. And J.B. – except for a few depositions in which he denied any wrongdoing and/or understanding of the technology – spent those same years working yet other deals and other promotions.

Therefore, consider and heed the following: Until you see a way to manufacture your product for a reasonable cost, you don't have a business. You must establish a product base and market value quickly, then put major effort into developing a cost-effective manufacturing process. To go from R&D to manufacturing is to make the transition from ***recipes*** to ***manufacturing processes***. Recipes tell you how to do it – manufacturing processes tell you how to do it each and every time with predictable results. And finally, as long as you have (and can continue to get) Other Peoples' Money to fund your operation, you can live on promises and the claimed successes from each new technology demonstration. Most of the time, your investors will be thrilled to hear them. They won't find out what you really can or can't do until you have to survive as a real business, i.e., sell a product and make a profit. But, keep in mind that making a promise is like taking out a loan – eventually you have to pay it back – with interest. If you over-promise, sooner or later it will catch up with you. And as Dan and Charlie would tell you, the results are likely to be highly unpleasant.

If you have stayed with me this far, then perhaps you have also noted that this is the inaugural issue of *Information Display* dedicated to manufacturing technology. That we should choose this emphasis is a reflection of the increasing importance that cost-effective manufacturing plays in the market success of all types of display technologies. The "Information Society" has and will continue to have an almost insatiable appetite for a wide variety of displays. However, when all the posturing and PR is over, it will have accepted only those that demonstrate a combination of new levels of performance, high reliability, and competitive cost relative to existing mature technologies. Feasibility demonstrations and promises of things to come will quickly lose their luster if they are not soon followed by manufacturable products providing competitive value to mainstream volume users.

The second annual **Display Manufacturing Technology Conference**, to be held at the Santa Clara Convention Center this coming January 31 to February 2, will provide a major opportunity for all of us to interact and exchange thoughts on manufacturing methods for all classes of display devices and technologies. Conference Chair **Sal Lalama** and Technical Program Chair **Jim Atherton** have worked diligently, along with their entire program committee, to provide an interesting 3-day meeting. This year there will also be an exhibition with participation by companies providing equipment, materials, and services for display manufacturing. This conference is well on its way to becoming a major event for the entire display community.

In other industry news, **Kopin Corp.** of Taunton, Massachusetts, has announced agreements with two divisions of **Philips Electronics North America Corp.**, specifically, **Philips Consumer Electronics Co.** of Knoxville, Tennessee, and **Philips Laboratories** of Briarcliff Manor, New York. Under a joint agreement with Philips Consumer Electronics, the two companies plan to develop and manufacture full-color active-matrix liquid-crystal-display (AMLCD) systems using Kopin's SmartSlide™ imaging devices for projection color televisions, monitors, and compact projector products. The agreement with Philips Laboratories is for developing advanced AMLCD products based on Philips' falling-raster single-panel technology, designed to produce full-color video images with one monochrome AMLCD.

Motif, Inc. of Wilsonville, Oregon, has promoted **Kevin C. Cornelius** to the position of Vice President of Marketing and Sales. Kevin, formerly director of marketing and sales, has been with Motif since its early beginnings. Prior to joining Motif, he was at Tektronix, where he served in a number of marketing, strategic-planning, and sales positions. He will be responsible for worldwide marketing and sales of Motif's Active Addressing™ LCD technology.

C. Robert Kline, Jr. has joined **SI Diamond Technology, Inc.** of Houston, Texas, as Vice President of Business Development. Previously, Dr. Kline was President and CEO of Horizon Battery Technologies, Inc., a joint venture of BDM International and Electrosource, formed to build an advanced high-power lead-acid battery. At SI Diamond, he is expected to be a key contributor in the planned transition from development to production. Another new addition to the SI Diamond staff is **Dr. Lisa Schioler**. She has been appointed as the Director of Sponsored Programs and will be managing the Washington, D.C. office for SI Diamond.

Steve Lieberman, VP Marketing and Sales for **Projection Imaging** of San Juan Capistrano, California, has announced the appointment of Shafer & Shafer, an advertising and PR firm specializing in high-technology products, to help develop the introduction strategy for their 21-in. multimedia-enabled portable presentation monitor. To date, Projection Imaging has raised approximately $1 million in equity financing and is looking for additional funding to complete the transfer of its product from R&D to manufacturing.

Meadowlark Optics of Longmont, Colorado, has added **Anthony Artigliere** as their new Sales and Marketing Manager. Most recently, Mr. Artigliere worked as Product Manager for the optical-component line at the Melles Griot Catalog Division in Irvine, California. Meadowlark Optics designs and manufactures precision optical components and systems, specializing in the area of polarization control.

Vernon Beck informs me that his consulting firm, **Vernon Beck Consulting, Inc.** specializes in the analysis of theoretical and practical limitations of electron optical systems. His corporate background was with IBM in Fishkill, New York, where he worked to extend the limits of electron-beam lithography. He is familiar with such topics as self-calibration and reduction of eddy currents, hysteresis, and thermomechanical effects. Earlier, he worked on electron optics for CRTs. Dr. Beck can be reached at 203/431-0697 in Ridgefield, Connecticut.

Displaytech Inc. of Boulder, Colorado, has introduced an RGB FastFilter for use in field-sequential color display systems. The filter combines with small high-resolution black-and-white CRT tubes to create full-color displays. The FastFilter can be used in such applications as simulation systems, 3D visualization, telepresence, medical systems, and personal digital assistants.

Crystallume, Inc. has moved to new and larger facilities designed to accommodate their planned growth. Their new address is 3506 Bassett Street, Santa Clara, California. Crystallume specializes in the manufacture of diamond coatings for electronic applications, including displays.

I look forward to seeing many of you at the Display Manufacturing Technology Conference. If you would like to reach me before then, the phone number is 609/734-2949 and the fax is 609/734-2127. If you are a dedicated e-mail user, I can be found at: aris_silzars@maca.sarnoff.com and if you prefer old-style mail, send your information to Jay Morreale at Palisades Institute for Research Services, Inc., 201 Varick Street, Suite 1006, New York, NY 10014. ■

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NCAICM Joint Industry/Laboratory Projects

Flat Panel Display Projects

- *Precision Thick Film Technology for 100% Yield of Large Area High Resolution Color AC-Plasma Display Panels*
  Photonics Imaging, Northwood, OH with Sandia National Laboratories and Los Alamos National Laboratory
- *Improved Emissive Coatings for Super High Efficiency Color AC-Plasma Display Panels*
  Photonics Imaging, Northwood, OH with Los Alamos National Laboratory and Sandia National Laboratories
- *Low Cost Electrode Fabrication Process for HDS Color Flat Panel Displays*
  Photonics Imaging, Northwood, OH with Sandia National Laboratories and Los Alamos National Laboratory
- *Advanced Development of Large Area Full Color Electroluminescent Flat Panel Displays*
  Planar Systems, Beaverton, OR with Los Alamos National Laboratory and Sandia National Laboratories
- *Low Cost, Large Area, Field Emission Display Development Program*
  Silicon Video Corporation, Cupertino, CA with Science Applications International Corporation, Johns Hopkins University, and Lawrence Livermore National Laboratory
- *Novel, Blue Light-Emitting Polymer Diodes for Color Flat Panel Displays*
  UNIAX Corporation, Santa Barbara, CA with Hewlett-Packard Company, University of California at Santa Barbara and Los Alamos Laboratory
- *Advanced Lithography Tool for Large Area Flat Panel Device Manufacturing*
  Polyscan Corporation, Fountain Valley, CA with Sandia National Laboratories
- *High Performance Manufacturing Technology for Field Emission Device Flat Panel Displays*
  Micron Display Technologies, Inc., Boise, ID with EG&G, Photon Dynamics, Microprobe, Superior Vacuum Technology and Lawrence Livermore National Laboratory
- *Diamond Cold Cathode Technology for Field Emissions Display Manufacturing*
  SI Diamond Technologies, Inc., Houston, TX with Sandia National Laboratories
- *Glass Panel Alignment and Sealing for Flat Panel Displays*
  FED Corporation, Hopewell Junction, NY with Coloray Display Corporation, Micron Display Technologies, Inc., Plasmaco Corporation and Sandia National Laboratories
- *Field Emitter Array Patterning for Large Flat-Panel Displays*
  FED Corporation, Hopewell Junction, NY with Zenith Corporation, Shipley Company, Inc., MCNC Center for Microelectronic System Technologies, North Carolina State University and Lawrence Livermore National Laboratory

Advanced Microelectronics and Optoelectronics Projects

- *Advanced Single Wafer Metalization*
  CVC Products, Inc., Rochester, NY with Emcore, National Semiconductor, North Carolina State University and Sandia National Laboratories
- *Chemical Vapor Cleaning for Advanced Contamination Free Manufacturing*
  Air Products and Chemicals, Inc., Allentown, PA with Schumacher Co., Lehigh University and Sandia National Laboratories
- *In-situ Particle Monitoring in Microelectronic Manufacturing Processes*
  Insitec Measurement Systems, San Ramon, CA with Sandia National Laboratories
- *Development of High Density Ferroelectric Memory*
  Micron Semiconductor, Inc., Boise, ID with Symetrix Corporation and Sandia National Laboratories
- *Manufacturing Technology for a One Megabit Ferroelectric PZT Non-Volatile Memory*
  Radiant Technologies, Inc., Albuquerque, NM with Bellcore, Raytheon Company, High Density Circuits, Inc., Virginia Polytechnic Institute and Sandia National Laboratories
- *Red Vertical-Cavity Surface-Emitting Devices for Printing and Data Communication*
  Honeywell, Inc., Bloomington, MN with Xerox and Sandia National Laboratories
- *Advanced Information Component Manufacturing for Optoelectronic Shared Memory Massively Parallel Processor*
  Martin Marietta Laboratories, Syracuse, NY with IBM, AT&T, Honeywell and Lawrence Livermore National Laboratory
- *Development of Automated Packaging Machine for Optoelectronic Components*
  United Technologies Photonics, Bloomfield, CT with Ortel, Newport, Massachusetts Institute of Technology and Lawrence Livermore National Laboratory

Advanced Lithography Projects

- *An Automatic System Identification Workbench for Active Structure Control*
  Metron, Inc., Reston, VA with Naval Research Laboratory and Los Alamos National Laboratory
- *Active Vibration and Motion Control for Advanced Lithography*
  AT&T Bell Laboratories, Arlington, VA with Sandia National Laboratories

A key to success in both international marketplaces and battlefields of the future will be information and the ability to produce the components to support it. One projection suggests that microelectronics, optoelectronics and optical displays will form an information-systems market exceeding $2 trillion by the year 2000. Japanese and other foreign manufacturers, who currently dominate the U.S. consumer electronics and small-area flat-panel display markets, also recognize the huge potential market for next-generation technologies. "Congress created the Center to provide the nation's high-technology information-component industries with the assistance of the national laboratories' broad technology base," Jorgensen said. "Many of the technologies the labs are bringing to bear were first used in our weapons work." The projects now under way are an important step "in work that is at the frontier of information technology," said Gary Denman, ARPA director. "This is one of the key technology areas where a future manufacturing base can be built in the U.S. With this center, we are building an environment for rapid progress for an entire industry," he said. Funding to date is being spread evenly between flat-panel display research and other critical microelectronics information and component research. Flat-panel displays are not just a consumer item for the future. Lightweight and portable panels of all sizes will be needed for military vehicles, ships, aircraft, and command centers of the future. Most current small-area flat-panel displays are some form of liquid crystal. It does not appear that liquid-crystal technology can easily be scaled up to large-area displays, so researchers are studying alternative technologies. These alternatives are based on plasmas, electroluminescent materials, and field-emission devices. Plasmas and electroluminescent materials glow when excited electrically. Field-emission devices emit electrons to excite a phosphorous material on a screen. In addition to flat-panel research, NCAICM researchers are concentrating on agile manufacturing technologies associated with advanced silicon integrated circuits, high-speed optoelectronic communications, and electronic systems. As microelectronics features become smaller and smaller, two areas of concern to industry are contaminants and advanced lithography mechanical limitations that may prevent the precise levels of detail needed. NCAICM projects are carried out by teams of researchers from industry, universities, and the DOE national laboratories. Of the current program's total of 25 projects, four are "precompetitive," meaning that results will be made available to all participants and others as determined by the center's advisory board. The board is made up of representatives from industry, the DOE laboratories, and ARPA. The center is also coordinating its activities with the U.S. Display Consortium, Sematech, and other industrial groups.

The four "precompetitive" projects are:

- A flat-panel display modeling effort, adapted from the Sematech consortium's economic analysis of semiconductor equipment and facilities. Researchers are using a Sematech-like approach to examine life-cycle costs for flat-panel display types, including capital and resource costs. These economic models will allow industry to analyze various approaches and determine how to better direct individual company efforts.
- Although a great deal is known about high-voltage phosphor materials used in the screens of television sets, the field-emission displays now envisioned would use low voltages (below 5 keV). Materials provided by industry partners are being studied for electron emission from the field-emitter arrays and for the phosphors on the viewing screen. Two laboratory facilities are being made available to industry to analyze these issues.
- In the area of microelectronics contamination, NCAICM researchers are developing sensors for detection of contamination and measurement of defects during the actual manufacturing process. The contamination-detection study has implications for both microelectronic devices and flat-panel displays. Researchers are using scanning electron microscopes, dispersive X-ray technology, and other ultrasensitive contamination monitoring techniques to better understand and resolve problems.
- Another vital area for microelectronics manufacturing is lithography, where small, micron-sized features are detailed for subsequent etching to create a complex multi-layered finished product. A goal of one NCAICM team is an automated system of active structural controls for advanced lithography equipment, which will reduce vibrations introduced during the manufacturing process. This automated damping system will help reduce imperfections and waste and improve productivity in the manufacturing process. About 80% of the NCAICM funding is committed to joint projects between industry and national laboratories, where intellectual property rights can be protected. The industrial partners will receive about $30 million to conduct research and development in the areas of flat-panel displays, advanced microelectronics and optoelectronics, and advanced lithography. "A national laboratory like Sandia is a good industry-neutral site for these projects," said Jorgensen. "We have materials and process expertise to contribute as well as extensive government-owned facilities and equipment." ■

NCAICM Joint Industrial/Laboratory Projects Participants

Companies

Air Products and Chemicals, Inc.
AT&T
AT&T Bell Laboratories
Bellcore
Coloray Display Corporation
CVC Products, Inc.
EG&G
Emcore
FED Corporation
Hewlett-Packard Company
High Density Circuits, Inc.
Honeywell, Inc.
IBM
Insitec Measurement Systems
Martin Marietta Laboratories
MCNC Center for Microelectronic System Technologies
Metron, Inc.
Micron Display Technologies, Inc.
Micron Semiconductor, Inc.
Microprobe
National Semiconductor
Naval Research Laboratory
Newport
Ortel
Photon Dynamics
Photonics Imaging
Planar Systems
Plasmaco Corporation
Polyscan Corporation
Radiant Technologies, Inc.
Raytheon Company
Schumacher Co.
Science Applications International Corporation
Shipley Company, Inc.
SI Diamond Technologies, Inc.
Silicon Video Corporation
Superior Vacuum Technology
Symetrix Corporation
UNIAX Corporation
United Technologies Photonics
Xerox
Zenith Corporation

Universities

University of Arizona
Johns Hopkins University
Lehigh University
University of New Mexico
Massachusetts Institute of Technology
North Carolina State University
University of California at Santa Barbara
Virginia Polytechnic Institute

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To participate as an exhibitor at DTMC '95 in Santa Clara, please call Erika Suresky, Exhibit Manager, Palisades Institute for Research Services, Inc., at 212/620-3375, fax -3379.

Edited by Joan Gorman

Monitor-interface microcontroller chip set

Display Laboratories, Inc., Boulder, Colorado, has introduced MIMiC™, a monitor-interface microcontroller chip set. The monitor interface (DLAB520A) contains circuitry to control the geometry, color, brightness, focus, and convergence of CRT monitors, projectors, and HDTVs. The microcontroller (DLAB550A) contains a firmware model of conventional analog monitors and controls the settings of the DLAB520A to generate the analog waveforms needed for a near-perfect picture at any frequency within its operating range. The chip set can run from 15 to 130 kHz horizontally and from 50 to 150 Hz vertically.

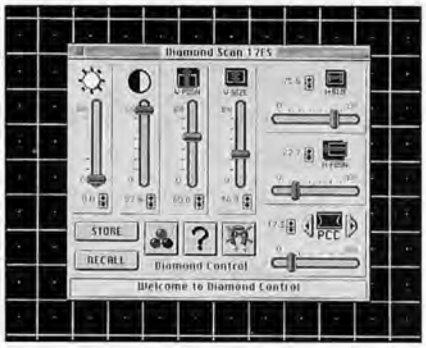
Information: James R. Webb, Display Laboratories, Inc., 2540 Frontier Ave., Suite 109, Boulder, CO 80301-2400. 303/938-9099, fax 303/938-9199.

Circle no. 1

On-screen monitor-adjustment software kit

Mitsubishi Electronics America, Inc., Cypress, California, has introduced Diamond Control™ for Macintosh®, an on-screen user-adjustable software system created for the Diamond Pro® 21T and Diamond Scan® 17FS high-performance color monitors. The software is designed for use with Macs and Power Macs operating at least System 7.1 software. The set of on-screen icon-based control panels, accessible via mouse or keypad, allows users to define display set-up, color temperature, and power-management parameters. The graphical interface is highlighted by slider and button controls with corresponding numerical values for all set-up parameters. The monitor's factory pre-calibrated and user-defined settings, a readout of the current vertical and horizontal scanning rates, and an extensive Help menu are also accessible through this panel. In addition, a color-temperature panel offers visual and numerical adjustments for three sets of white-point color parameters. The unique power-management panel offers power-down (dimmed state) and shut-down (full power off) settings that can operate either independently or in coordination with Energy Star-compliant graphics cards. Diamond Control™ works in conjunction with the front-panel controls, and adjustments made by either one can be mirrored in both systems. All information is stored in the monitor's microprocessor, and communication with the Mac is handled through a proprietary serial cable, requiring an available RS-232 serial port during the period of use. The Diamond Control™ kit, which includes a software diskette, serial interface cable, and instruction booklet, is free of charge with the purchase of the Diamond Pro 21T and is available at a suggested retail price of $19.95 with the Diamond Scan 17FS.

Information: Mitsubishi Electronics, Display Products Group, 5665 Plaza Drive, Cypress, CA 90630. 714/220-2500, fax 714/229-3854, toll free 1-800/828-6372.



Circle no. 2

Notebook privacy filter

3M Optical Systems, Roseville, Minnesota, has announced the PF50 notebook privacy filter that weighs under 1 lb. and measures less than 0.5 in. thick. The filter is ideal for business travelers as well as others who need privacy when using notebook computers in public places. On an airplane, confidential information displayed on a notebook computer cannot be viewed by the traveler in the next seat unless he is directly in front of the screen. The filter has an antiglare feature to improve contrast and reduce glare from office lights or sunlight. The lightweight, durable polycarbonate screen comes with a compact travel case for easy portability, and sells for $119.

Information: 3M Optical Systems, 2200 W. County Road C, Roseville, MN 55113. 1-800/553-9215.

Circle no. 3

Flat-panel intensity characterization system

Microvision Corp., Los Gatos, California, has introduced the Profiler 94, a complete flat-panel intensity characterization system that provides fully automatic measurements for any type of flat panel. The system yields iso-contour, 3D wire grid, panel uniformity, hemispherical, skew, and annular-type measurements. The system includes a five-axis positioner, a 486 DX2 computer with an 800 × 600 color display, and a full system software package with a mouse-controlled GUI. The photometric unit is standard, while the colorimetric unit is available as an option. A demonstration disk using actual system software and allowing full operation with simulated input signals is available.

Information: Microvision Corp., 180 Knowles Drive, Los Gatos, CA 95030. 1-800/931-3188.

Circle no. 4

Fast 35mm-slide desktop scanner

Polaroid Corp., Electronic Imaging Systems, Cambridge, Massachusetts, has introduced SprintScan 35, a 35mm-slide scanner that digitizes images at maximum resolution in 30 s (5–15 times faster than other leading desktop slide scanners on the market for under $2500). SprintScan 35 is designed for desktop publishers, graphic arts professionals, and pre-press service bureaus that convert high-quality images into digital form. It automatically corrects color and sharpens the image during the scanning process, scans high-quality images in a single pass, and outputs at resolutions of up to 2700 dpi, providing excellent clarity and crispness. The scanner captures 10 bits per color at a 3.0 density range, allowing users to reproduce a broader range of colors with exceptional shadow detail. Scanned images are output to the computer at 8 bits per color. SprintScan 35 accepts any color or black-and-white 35mm transmissive film media, including positive and negative, mounted or unmounted transparencies, and film strips. It is compatible via a standard SCSI-2 interface with any Macintosh or Windows™-based personal computer. For Macintosh users, the scanner is shipped with a plug-in for Adobe Photoshop. For the Windows™ environment, the scanner software includes a Twain driver and a Twain-compatible scanning utility. SprintScan 35 has a suggested list price of

$2495 and comes with a 1-year warranty from Polaroid.

Information: Michael J. Spataro, Polaroid Corp., Electronic Imaging Systems, 565 Technology Square, Cambridge, MA 02139. 617/577-2455.

Circle no. 5

Light-diffuser kits

Physical Optics Corp., Torrance, California, has introduced packaged samples of its newest light-diffusion technology, referred to as Light Shaping Diffusers™ (LSDs), making them available to OEM product designers in various sizes and the most useful diffusion angles. The LSD kits are intended for use in prototype development or limited production runs. Company officials predict there will be many commercial applications for its patented new technology because it has extremely efficient light-shaping and transmission characteristics. LSDs improve the quality of light by smoothing out, or homogenizing, the irregularities in a light beam. Mass-produced in a variety of low-cost substrates, they work equally well with white light from any source, including fluorescents, filament lamps, LEDs, tungsten halogen lamps, and arc lamps. Each kit has an assortment of four diffusers, either 25 or 50 mm in diameter, with a wide range of diffusion angles. Both circular- and elliptical-transmission kits are available, in costs ranging from $275 to $375. Sheet-form LSDs and a wide variety of individually sized diffusers are also offered.

Information: Jeremy Lerner, Physical Optics Corp., 20600 Gramercy Place, Bldg. 100, Torrance, CA 90501-1821. 310/320-3088, fax 310/320-8067.

Circle no. 6

Dual-LCD stereoscopic projection system

StereoGraphics Corp., San Rafael, California, has announced its new Dual-LCD Stereoscopic Video Projection System that creates crisp high-resolution full-color stereo images using live or recorded video, suitable for inexpensive flicker-free viewing by groups of up to 100 or more. The system is designed for broadcast, video, satellite, microwave, or closed-circuit communications via land lines using coaxial cables or fiber-optic networks requiring a high-quality image. Proprietary color-correction optical filters, along with a high-reflectance silver surface screen and passive polarizing CrystalEyes® eyewear, provide stereo images over a wide range of viewing angles and viewer head positions. Applications include trade-show presentations, teaching and training, teleconferencing, museum exhibits, entertainment, manufacturing, and quality control, remote manipulation and viewing, and industrial and corporate video presentations. The projector is a portable TFT active-matrix ×3 LCD color projector with a horizontal resolution of 450 lines and 110,450(×3) pixels. The diagonal image size ranges from 25 to 300 in. using a 160-W metal-halide lamp. The assembled dual projector weighs 80 lbs., measures 12 in. high by 16 in. wide by 24 in. deep, and sells for $11,000 with a 1-year warranty. The complete system includes the dual projector, remote-control units, dust covers, depixelation and polarizing filters, projection screen, projector alignment tape, operator's manual, 10 sets of CrystalEyes® deluxe passive eyewear, and a 100-pack of paper polarizer eyewear. Additional eyewear is available, with the 10-

pack of deluxe CrystalEyes® passive eyewear at $300, and the 100-pack of paper polarizer eyewear at $100.

Information: StereoGraphics Corp., 2171 East Francisco Blvd., San Rafael, California 94901. 415/459-4500, fax 415/459-3020.
Circle no. 7

Hand-held colorimeter

Graseby Optronics, Orlando, Florida, has announced the SLS 9400, an affordable hand-held colorimeter that measures the output of a CRT screen to ensure that the color characteristic being emitted corresponds to the required color coordinates. This innovative device will help OEMs and end users in the display industry calibrate and quantify color, and provide feedback for adjustment or comparison purposes. The SLS 9400 employs four detectors for improved color accuracy. The four proprietary detector/filter combinations provide an extremely close match to the standard CIE tristimulus curves, resulting in highly accurate color measurements from all types of CRT phosphor sets. The accuracy achieved by the SLS 9400 sets new standards for a portable colorimeter. It rests comfortably in one hand, has a large graphics LCD which is tipped upward for a more natural viewing angle, and operates easily from simple, menu-driven commands. The separate detector probe has a vacuum-seal suction cup for attachment to the CRT but the mechanism can be deactivated if not needed. The introductory price of the SLS 9400 colorimeter is $4995 through December, 1994.

Information: Scott Giancola, Graseby Optronics, 12151 Research Parkway, Orlando, FL 32826-3207. 407/282-1408, fax 407/273-9046.
Circle no. 8

RGB-to-NTSC/PAL encoder

Analog Devices, Norwood, Massachusetts, has introduced the highly integrated AD721 RGB-to-NTSC/PAL analog encoder that is the industry's first to integrate pin-selectable ENCODE/Bypass mode and buffer amplifiers for directly driving RGB monitors. The AD721's on-chip (gain of 2) 100-MHz triple video amplifier can easily drive 75-Ω reverse-terminated loads. Users benefit by saving design time and costs associated with expensive video amplifiers and inefficient mechanical switches. This, and the ENCODE functionality, provide video-system designers with a high-performance, fully calibrated monolithic solution – no additional low-pass filters or delay lines are required. The AD721 operates from ±5-V supplies and offers low-power operation down to 50 mW. It is housed in a 28-pin plastic-leaded chip carrier (PLCC) and is specified for operation over the commercial 0 to +70°C temperature range. Prices begin at $6.25 in quantities of 10,000.

Information: Analog Devices, Inc., 181 Ballardvale Street, Wilmington, MA 01887. 617/937-1428, fax 617/821-4273.

Circle no. 9

Diffusion-bonded target

Tosoh SMD, Inc., Grove City, Ohio, has introduced the Diffusion-Bonded Tungsten Titanium Target, which allows sputtering at 6–9 kW instead of the customary 2–3 kW without risk of debonding. Utilizing patented diffusion-bonding technology, the W-Ti target dramatically increases sputtering-process productivity. Tosoh SMD's controlled metallurgy and fabrication processes result in ultra-fine microstructure throughout the W-Ti target, ensuring consistent film performance over the target life. The 99–100% dense target offers a better deposition rate and improved particle performance. For use in large planar systems, the target is available in high-purity material for defect-free films. Since the diffusion-bonded target has a disposable backing plate, the expense of shipping and managing a backing-plate inventory is eliminated. The target assembly is light in weight and quickly installed.

Information: Steve Bardus, Product Manager, Tosoh SMD, Inc., 3600 Gantz Road, Grove City, OH 43123. 614/875-7912.

Circle no. 10

Circle no. 56

Workstation-compatible AMLCD projection panel

Proxima Corp., San Diego, California, has announced the Proxima Ovation 920, the first fully workstation-compatible active-matrix LCD (AMLCD) projection panel capable of displaying 1280 × 1024 images. Among its advanced imaging capabilities are fit-to-view and zoom modes, and a unique LightBoard™ feature that lets users draw right on the image. The Proxima Ovation 920 is also the only product in its class to offer complete remote control of software through the Cyclops® cordless mouse. The 10.4-in. LCD panel features Proxima's proprietary active color-enhancement (ACE) technology for superior image quality, and is capable of projecting more than 2 million true colors (from a palette of 16.7 million). Its 24-bit video processing provides brilliant true-color matching, while intuitive controls and a graphical user interface ensure ease of use. Compatible with all popular workstation and PC platforms, the Proxima Ovation 920 is capable of displaying video resolutions ranging from 640 × 480 to 1280 × 1024. A digital video controller projects all three international video standards, as well as S-VHS. Proxima Ovation 920 has a suggested retail price of $14,595 and is available through value-added resellers and workstation-distribution channels.

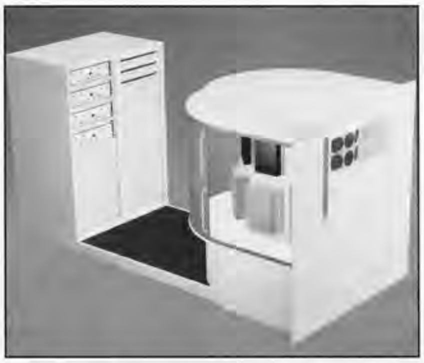
Information: George Wilson, Proxima Corp., 9440 Carroll Park Drive, San Diego, CA 92121-2298. 619/457-5500, fax 619/457-9647.

Circle no. 11

Load-lock sputter system

Balzers, Hudson, New Hampshire, has introduced the LLS 502, a load-lock sputtering system that provides total flexibility for the production of MCMs, MEMs, hybrids, semiconductors, and magnetic thin-film heads. Substrates up to 200 × 250 mm or 8 in. in diameter are degassed and etched in the load-lock chamber. Five process stations allow expansion for dc/rf magnetron sputtering, heating, and rf-bias. Cassette-to-cassette handling simplifies integration of the LLS 502 into existing production lines. The design of the high-vacuum process chambers ensures contamination-free thin-film metal coatings for interconnects, resistors, backside metallization, and dielectric films. The compact footprint and high throughput provide low investment costs and high-yield performance.

Information: Henry Gabathuler, Balzers, 8 Sagamore Park Road, Hudson, NH 03051. 603/889-6888, fax 603/889-8573.



Circle no. 12

Scanning electron microscopes

Leica, Inc., Deerfield, Illinois, has announced the Stereoscan S400σ series, a new member of the Stereoscan S400 series of scanning electron microscopes (SEMs). The Leica S430σ was introduced during the International Congress on Electron Microscopy (ICEM '94) held in Paris, July 18–24, 1994. The series is the result of a cooperative project with Fisons Kevex, resulting in full integration of the Windows™-based "Sigma" x-ray analysis system with any one of the Stereoscan S400 series SEMs. With the S400σ series, customers can choose either the Oxford ISIS or Kevex Sigma x-ray system. Like the Stereoscan S400i series, the Stereoscan S400σ series has functional as well as mechanical integration and utilizes the Stereoscan S400 PC and peripherals.

Information: Leica, Inc., 111 Deer Lake Road, Deerfield, IL 60015. 1-800/248-0123, fax 708/405-0030.

Circle no. 13

Direct AR coatings for CRTs

Viratec Thin Films, Inc., Faribault, Minnesota, has introduced CaRT™, a conductive anti-reflection tube-coating process that allows high-performance optical and conductive thin-film coatings to be directly deposited onto the CRT faceplates of computer monitors and TVs. This vacuum coating process can be used to alter the light transmission of the faceplate, thus reducing the number of faceplate-glass types that CRT manufacturers need. Light transmission varies from different levels of neutral-gray for increased contrast enhancement, to colorless for increased light (phosphor) output. The CaRT™ process allows coatings to be applied after the CRT is assembled, eliminating the need to adjust the manufacturing process. Expensive intermediate substrates and bonding are also eliminated. A wide range of coatings is available, including conductive for anti-static or ELF/VLF suppression. Sheet resistances as low as 100 $\Omega/\square$ can be applied. In addition, these coatings are environmentally tested to MIL-SPECs. Viratec's Infinity II coating machine, the first and only in-line coating machine of its kind, has the capacity to coat thousands of tubes per month.

Information: Bruce Kohlman, Sales and Marketing Manager, Viratec Thin Films, Inc., 2150 Airport Drive, Faribault, MN 55021-7798. 507/334-0051, fax 507/334-0059.

Circle no. 14 ■

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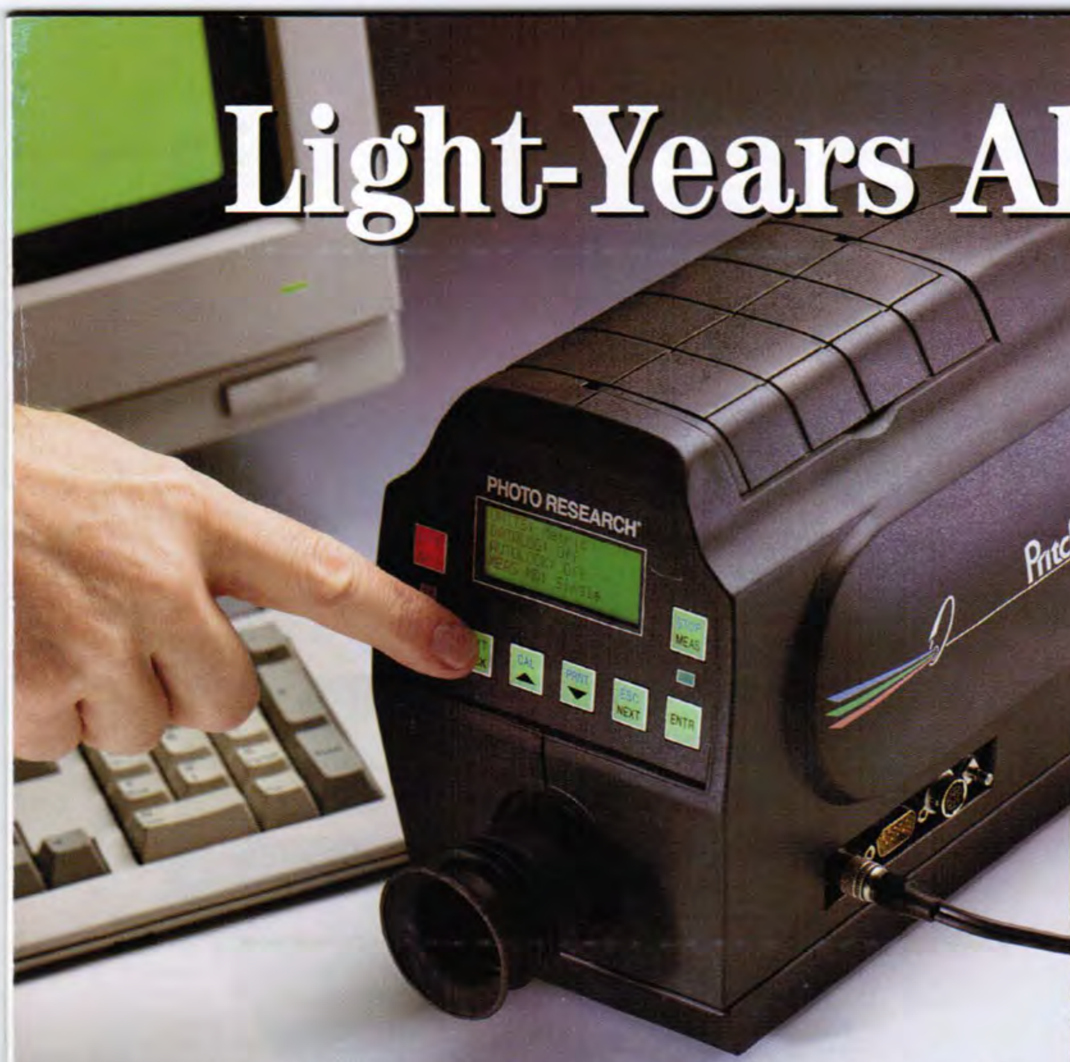

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