

Displaytech, Inc.

Mass-Producing Display Chips that Will Improve Image Quality, Extend Product Lifetime, and Reduce Costs

A news article in 2000 asserted that, "For many years, the Holy Grail of the display community has been the enabling of both very large-screen and very small-screen high-resolution displays with optimal clarity, field of view, and performance."⁽¹⁾ Excessive size and the cost of existing liquid crystal displays (LCDs) prevented having convergent devices such as personal organizers, laptop computers, and portable phones in one unit. In the search for faster, smaller, cheaper, and better displays, scientists turned to a new type of liquid crystal—the ferroelectric liquid crystal (FLC). Displaytech of Longmont, CO, could produce FLC chips, but it only could produce them one at a time. With funding from the Advanced Technology Program (ATP), however, Displaytech successfully developed technology to mass-produce FLC display chips. This achievement increased image quality by 600 percent, expanded product lifetime by 100 percent, and cut per-unit costs from \$6,000 to \$160. The technology is now integrated into Samsung projection TVs and JVC camcorder displays and will be commercialized in several other products shortly. Displaytech's success has encouraged more than two dozen U.S. firms to enter the Japanese-dominated display market.

COMPOSITE PERFORMANCE SCORE

(based on a four star rating)

Research and data for Status Report 94-01-0402 were collected during January – March 2001.

Existing LCDs Were Costly and Limited in Range

In 1994, LCD technology used in televisions and computer monitors was not keeping pace with the needs of emerging applications, such as high-definition televisions (HDTVs), head-mounted virtual displays, and videophone wristwatches. At that time, the manufacturing process was too expensive, and the LCDs were incapable of handling extremely small or large displays. These chips, manufactured one at a time, took an engineer several hours to build and carried massive overhead costs that priced the equipment well out of the range of the average consumer.

The process involved implanting liquid crystals onto individual silicon chips, inserting circuitry to control the "on-and-off" states of the liquid crystal, and then coating the chip with glass for durability. Moreover, as screens became larger, traditional LCDs could not pack enough pixels into displays to meet the detail requirements of extremely large displays. Overcoming the magnification problem was prohibitively expensive, as each increase in screen size cost manufacturers approximately \$1 billion in development costs. Those costs could not be passed on to the average consumer because of price sensitivity.⁽²⁾ And, for converged personal digital assistant/laptop/cell phones, the displays needed to be small, lightweight, detailed, and inexpensive. Smaller

1. Ajluni, Cheryl. "Stamp-Sized Ferroelectric LCD Can Power 50-in. TV Screens." ASAP. March 20, 2000.

2. Lieberman, David. "Displaytech Makes Big Waves in Miniature Displays." Electrical Engineering Times. May 18, 1998.

screens needed small, plentiful pixels that are viewable at any angle from the compressed display, a task that was impossible with traditional LCDs because of the pixel requirement and the need to bounce light off a triad of red, green, and blue light generators in order to show colors.

Ferroelectric Liquid Crystals Held Potential to Solve Problems

A new generation of LCDs, displays using FLCs, had the potential to be manufactured in mass quantities at affordable prices by placing the FLCs on an entire silicon wafer and then cutting the wafer into individual chips at the end of the process. This process could reduce costs by spreading direct labor costs over hundreds of units rather than just one. Before Displaytech's ATP-funded project began, projections suggested that using FLCs could reduce the price of an LCD chip from thousands of dollars to a much more affordable \$100.

These chips consist of a fast light-modulating layer of FLCs that sits directly atop a silicon very-large-scale integrated (VLSI) circuit active matrix device. FLC/VLSI devices are smaller, faster, use less power, and can be magnified to extremely large sizes without image degradation. FLC images begin with electric current sent through the silicon circuitry. Silicon circuitry routes the energy to the appropriate aluminum pixel pads

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sitting atop the silicon. The pixel pad fires individual pixels made of FLC. Whereas traditional LCDs could only enable a matrix of large pixels separated by relatively large distances of circuitry, FLC displays operate with smaller pixels situated much closer to one another. Therefore, the FLC display can produce detailed images as small as the silicon chip (about the size of a postage stamp) more quickly than do existing LCDs. Moreover, when magnified, the images are still sharp at sizes needed by HDTV technology.

ATP Funds New Production Method for FLCs

In 1994, Displaytech invented and first demonstrated FLC displays that were compatible with large and small screens and were also faster than traditional LCDs. Displaytech's FLCs displayed color without bouncing light off the traditional red, green, and blue triads and turned pixels on and off faster than did traditional liquid crystal pixels. This development resulted in even higher image quality and even faster image change speed. Although the FLC images were fast, the one-at-a-time manufacturing process was still too slow. Displaytech devised a technically sound strategy for a new manufacturing process that could reduce the net cost per unit by 99 percent and increase the daily yield from 4 to 500 units per operator. The company approached both private investors and the United States Army for funding. The Army recognized the potential of Displaytech's manufacturing process, but made no funds available for the project. Private sources of capital were reluctant to fund the project because of the risks involved with investing in a proposed method without a demonstrated manufacturing process in place.

Personal View Microdisplays



An FLC display chip, sitting atop a silicon wafer, is smaller, faster, uses less power, and can be magnified to extremely large sizes without image degradation.

To get past the technical hurdles that discouraged potential private investors, Displaytech submitted a single-company proposal to ATP's 1994 general competition to develop its new manufacturing process technology. In ATP's peer review, potential economic benefits appeared solid and the engineering plan was

judged sound. In 1995, ATP awarded Displaytech \$1.748 million for a two-year project. The award attracted \$1.503 million in matching funds from Century Partners, an established venture capital firm that focused on new technologies, and a private investor affiliated with Century.

Displaytech Solves Technical Problems

The first major technical barrier that Displaytech overcame was developing the FLC array on a "dummy" silicon wafer to test the manufacturing process. Silicon substrates are fairly expensive. Consequently, development costs would have been prohibitive if Displaytech had used real silicon wafers as it sought to develop a new manufacturing process. The company was unable to find a source for FLC materials to be mounted on "dummy" silicon, so it developed its own FLC materials.

Final image quality increased 600 percent, product lifetime increased 100 percent, and costs declined from \$6,000 per unit before ATP funding to \$160 per unit after funding.

These materials resulted in higher conductivity and higher speeds than FLCs produced from commercially available materials. Displaytech overcame a second major technical barrier by developing an affordable mass-manufacturing process for the FLC display chips. The company developed a process that yielded 35 percent usable FLC chips from the dummy silicon wafer and then incrementally increased the yield from there. Ultimately, the process was improved to the point where final image quality increased 600 percent, product lifetime increased 100 percent, and costs declined from \$6,000 per unit before ATP funding to \$160 per unit after funding.

The best-case scenario without ATP funding had been projected at \$1,200 per unit. Although the \$160 per-unit cost ultimately achieved in the project did not meet the pre-project estimate of \$100 per chip, costs are projected to decline further as plant capacity increases. The company's third task was to develop approaches for ramping-up the manufacturing process to produce

high volumes of FLC displays. As of early 2000, implementation of manufacturing improvements had increased Displaytech's production capabilities to 100,000 displays per month.

Displaytech's FLCs Are Changing Entire Industries

The postage-stamp-sized FLC chip, together with projection lens technology also developed by Displaytech, is capable of displaying images as small as the chip itself and as large as the industry demands, without image degradation. In short, Displaytech appears to have found "the Holy Grail of the display community."

The trade press lauded FLC displays as technology that will completely replace cathode ray tubes and change the way the world uses visual images.⁽³⁾ According to the press, the lighter, faster, better, and cheaper technology may completely change the market price for flat-panel HDTVs, enable full convergence of smaller machines, and spawn a new line of eyeglass-frame-mounted personal displays. The FLC technology also has shown promise in the development of optical memory systems that are faster, use less power, and are smaller than current computer-based memory systems.

Alliances with Hewlett Packard and Miyota Result in Diversified Products

The manufacturing process for FLCs appeared so promising that in 1995 Hewlett Packard (HP) approached Displaytech about forming a joint venture. The result was the birth of LightCaster, a product series of Video Graphics Array, eXtended Graphics Array, and Super-eXtended Graphics Array postage-stamp-sized panels for the personal, projector, and high-resolution markets.

Displaytech manufactures the FLC, HP manufactures the silicon chip, and Miyota mass-produces the actual displays. These displays are then shipped to original equipment manufacturers such as JVC, Samsung, and Minolta. Samsung installs LightCaster into its Tantus line of projection HDTVs. These HDTVs include both 43-inch and 50-inch screens and are one-third the weight of other HDTVs.

Each HDTV fits onto an 18-inch-deep shelf and features 2.76 million pixels with 16.77 million color shades.

The success of this ATP-funded project encouraged a major manufacturer of displays to develop FLC technology, helped U.S.-owned technology find its way into display equipment shipped by a number of companies worldwide, and encouraged more than 24 U.S. firms to enter the display market.

Other companies also are applying Displaytech's FLC technology:

- JVC installs Displaytech LightView monochrome FLC video display modules into its digital camcorders. These microdisplays are much better than traditional display options.
- Concord and Minolta will each begin using LightView viewfinders in their high-quality digital still cameras in the near future.
- Densitron Technologies, a global supplier of industrial electronics and computers in Denmark, France, Germany, Sweden, and the United Kingdom, signed an exclusive distribution agreement with Displaytech. This gives Displaytech a sound footing in Europe that solidifies its global presence. ⁽⁴⁾

Conclusion

Before Displaytech's ATP-funded project, the Japanese maintained 90 percent of the global market share for LCDs. ⁽⁵⁾ Today, although the Japanese still have a strong presence in the LCD market, Displaytech's success has shown that U.S. competition can succeed in this market. ⁽⁶⁾ More than 24 U.S.-based firms are now in the display market.

In addition to licensing partnerships, Displaytech is actively marketing its FLC display's potential for multiple uses. The company is in discussions with suppliers and potential partners to develop the following in-house and licensed products: wearable computers, technical document viewers, fax pagers, cellular phone fax receivers, fingerprint recognition mechanisms, machine vision equipment, image search and retrieval devices, and optical memory capabilities.

4. "Displaytech's First-Half of 2001 Very Bright." PR Newswire. June 5, 2001.

5. DeJule, Ruth. "Flat Panel Technologies." Semiconductor International. January 1997.

6. Ibid.

PROJECT HIGHLIGHTS

Displaytech, Inc.

Project Title: Mass-Producing Display Chips That Will Improve Image Quality, Extend Product Lifetime, and Reduce Costs (FLC/VLSI High-Definition Image Generators Produce Affordable, Improved Displays)

Project: To develop a new FLC-based image-generation technology and mass-manufacturing process for advanced display, printing, and computing applications that uses a silicon chip with circuitry densely patterned into a miniaturized, high-resolution pixel array with individually controllable pixels and high reliability.

Duration: 2/15/95-2/15/97

ATP Number: 94-01-0402

Funding (in thousands):

ATP Final Cost	\$1,748	54%
Participant Final Cost	<u>\$1,503</u>	46%
Total	\$3,251	

Accomplishments: ATP funding allowed the development of a manufacturing process for the mass production of FLCs for displays. Without this funding, the best-case scenario was a cost reduction of 80 percent. The new process resulted in the following achievements for projection displays:

- o 600-percent quality improvement
- o 100-percent product lifetime improvement
- o 97.4-percent reduction in cost, bringing the displays within the appropriate cost range for commercialization.

The success of this ATP-funded project encouraged a major manufacturer of displays to develop FLC technology, helped U.S. owned technology find its way into display equipment shipped by a number of companies worldwide, and encouraged more than 24 U.S. firms to enter the display market. ⁽⁷⁾

Displaytech received three core patents stemming from the ATP-funded project:

- o "Optics arrangement including a compensator cell and static wave plate for use in continuously viewable, reflection mode, ferroelectric liquid crystal spatial light modulating system"
(No. 6,016,173: filed February 18, 1998, granted January 18, 2000)

- o "Continuously viewable, DC-field balanced, reflective, ferroelectric liquid crystal image generator"
(No. 6,075,577: filed September 4, 1999, granted June 13, 2000)

- o "Continuously viewable, DC-field balanced, reflective ferroelectric liquid crystal image generator"
(No. 6,144,421: filed February 19, 2000, granted November 7, 2000)

Commercialization Status: Starting in 1995, Displaytech announced several joint ventures and partnerships with Hewlett Packard, Miyota, Motorola, Samsung, JVC, Concord, and Densitron Technology to pursue commercialization of its technology. There now is a network of worldwide licensees of Displaytech's core FLC technology, and more are planned. The technology is integrated into Samsung projection TVs and JVC camcorder displays and will be commercialized in several other products shortly.

Outlook: The FLC manufacturing process has the potential for extremely broad application across the electronics industry. Inexpensive FLCs have the potential to improve displays in most electronic equipment. Moreover, the technology could potentially spawn entirely new products through convergence of old products and the development of eyeglass-mounted computers and personal video displays. The outlook is excellent for continued market success of existing products and commercialization of entirely new products.

Composite Performance Score: * * *

Number of Employees: Twenty employees at project start, 150 upon completion of status report

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7. Lieberman. "Displaytech Makes Big Waves."