

A Technology Boost for U.S. Manufacturers of Flat Panel Displays

Consumers are always hungry for the latest and greatest, especially in computers and televisions. Demand is high for the development of larger, higher-resolution displays. Flat-panel displays offer larger viewing areas, higher resolution, lighter weight, and require less space than traditional cathode-ray tube (CRT) technology. Applications range from laptop computer screens to high-definition television to signs. As new digital HDTV is adopted in the United States, flat-panel displays are likely to increase in economic importance. The 1998 global market for flat-panel displays totaled \$11.8 billion, and is growing approximately 9 percent per year, with 12 percent expected by 2003.¹

COMPOSITE PERFORMANCE SCORE

(Based on a four star rating.)



Common Problems Impeding U.S. Producers

A flat panel display (FPD) consists of two glass plates with an electro-optical material compressed between them that responds to an electrical signal by emitting light or modulating backlighting. On the glass plates are rows and columns of electrical conductors that form a grid pattern. It is the intersection of these rows and columns that define picture elements, called pixels. The modulation of light by each pixel creates the images on the screen. There are three broad types of commercially available FPDs: liquid crystal displays, electroluminescent (EL) displays, and plasma display panels.

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made. Because of the complexity and size of flat panel displays, flaws such as “opens” (spaces where there should be wires) or “shorts” (wires where there should be spaces) are quite common. According to some estimates, manual inspections and repairs have accounted for as much as 40 percent of the total cost of flat panel production. By finding solutions to problems causing defects, U.S. flat-panel display companies saw an opportunity to fight their way into the Japanese-dominated world market.

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An Industry-led Collaborative Research Initiative

In the early 1990s, Japanese producers emerged as market leaders in flat panel display technologies. By 1993, Japan held 92 percent of the world market share for liquid crystal displays, 68 percent for plasma displays, and 47 percent for electroluminescent (EL) displays.²

In an attempt to change this unfavorable world market

¹ SRI Consulting, Tech Monitoring, *Flat-Panel Displays*, 1999.

² Kala Krishna and Marie Thursby, *Whither Flat Panel Displays?* NBER Working Paper 5415, January 1996, cited in Albert Link, *Economic Analysis of the Advanced Manufacturing Technology for Flat Panel Display Joint Venture at Project End*, Draft Report to ATP, April 1997: 23 (unpublished).

PROJECT HIGHLIGHTS

PROJECT:

To improve the ability of U.S. firms to manufacture flat panel displays efficiently, by developing equipment to inspect and repair displays automatically, and by developing improved methods of mounting integrated circuits to increase resolution.

Duration: 8/15/1991 – 8/14/1996

ATP Number: 90-01-0060

FUNDING (in thousands):

ATP	\$7,306	49%
Company	<u>7,604</u>	51%
Total	\$14,910	

ACCOMPLISHMENTS:

A group of U.S. producers of flat panel displays cooperated to address common problems that were plaguing the industry. They made a number of advances that should improve their ability to compete in world markets, currently dominated by foreign producers. Specifically, they:

- developed a process of tape automated bonding (TAB), a technique for mounting integrated circuits on a display surface, for which a patent was received by Planar;
- introduced the TAB process into commercial production;
- developed prototype equipment for automatically inspecting flat panel displays for flaws and automatically repairing these flaws;
- explored other approaches for the fabrication of driver circuitry for displays, including flip-chip-on-glass and Silicon-on-Glass technologies;
- presented papers at industry meetings; and
- filed a patent application which was granted:
“Die Bonding Connector and Method”
(No. 5,426,266; filed 11/8/1993, granted 6/20/1995).

CITATIONS BY OTHERS OF PROJECT'S PATENTS: See Figure 4.2.

COMMERCIALIZATION STATUS:

The tape automated bonding process developed by Planar has been introduced into commercial production.

OUTLOOK:

Project accomplishments, particularly the work on TAB which enabled substantial improvements in the resolution level of flat panel displays, have increased the competitiveness of U.S. FPD producers. Yet the challenges faced by U.S. producers are large, and the results of the project alone appear insufficient to meet those challenges. The general outlook for the U.S. industry remains uncertain at this time.³

Composite Performance Score: ★ ★

COMPANIES:

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Joint Venture Members at Project End: Photonics Imaging, Inc., Electro-Plasma, Inc., Kent Display, Inc., Westinghouse Norden Systems, Inc., and Planar Systems, Inc.

Subcontractors: Florod and Micron Corporation

Collaborator: University of Michigan

Spin-off Company: Ward Synthesis.

situation, a group of U.S. flat panel display manufacturers, organized as the Advanced Display Manufacturers of America Research Consortium (ADMARC), applied to the Advanced Technology Program for research funding. In 1991, ADMARC companies received an ATP joint-venture award of \$7.3 million for a five-year project to develop technology that would improve the ability of U.S. firms to manufacture flat panel displays efficiently and with improved performance and quality. Consortium companies matched the ATP award with \$7.6 million, for total project funding of \$14.9 million. After receiving funding from ATP, the consortium changed its name to the American Display Consortium (ADC).⁴

Initially, the American Display Consortium was made up of three members: Photonics, Planar Systems, and

Optical Imaging Systems (OIS). OIS was later bought by another firm and left the consortium. Following the departure of OIS, several additional companies joined the consortium, including Electro-Plasma, Inc., Northrop Grumman, Norden Systems, Plasmaco, Inc., and Kent Display Systems. By the end of the project, the ADC had grown to include 14 member companies, but Photonics and Planar remained the leaders of the ATP project.

Approximately half of the participating companies shared the costs of the tasks that were undertaken. All of the companies had access to periodic reviews of technical progress as well as the intellectual property created by the project. But those companies that did not participate in sharing the project's costs were not allowed to help set the research agenda for the project.

³ Substantial additional technical assistance to the industry has been provided by DARPA and that assistance may further improve the outlook for U.S. producers.

⁴ This is not the same organization as the U.S. Display Consortium, which later formed and received money from the Defense Advanced Research Projects Agency (DARPA) to research flat panel displays. ADC later became a member of the U.S. Display Consortium.

A Shared Motivation for Improvement Among Head-to-Head Competitors

At the outset of the project, all three of the participating companies were struggling financially, and were preoccupied with their individual business and production problems. Although the participating companies' businesses were based on different technologies (i.e., liquid crystal, electroluminescent, and plasma displays), the companies shared common problems and goals. They all wanted to be able to increase the density of driver circuitry and interconnections in order to improve display resolution, and they wanted automated testing to decrease production costs. By improving quality and lowering costs, they could better compete with foreign manufacturers and regain market share. At the same time, they were among the community of U.S. flat-panel display producers who were also competing among themselves for market share.

The resulting project structure was a horizontal joint venture of competitors who were all operating in a difficult market situation. Maintaining a climate of openness, with a high degree of sharing of information appeared to be much more challenging to achieve in this joint venture project than in many of the others that ATP has funded. It is perhaps not surprising that each member tended to have its own area of focus and major issues of concern, and that the project tasks were primarily divided along individual company lines. This division of research is in contrast to the cross-company research teams, used, for example, in the Printed Wiring Board Joint Venture led by NCMS described in this chapter.

Technology for Automatic Inspection and Repair

The consortium took several major approaches and areas of focus: Photonics sought to automate systems for inspection and repair on the manufacturing line in order to decrease the costs associated with quality assurance. The company sought to develop an automated system that could inspect displays quickly and reliably, allowing engineers to modify the production equipment before more flawed displays were produced. An additional goal was to develop an automatic repair system that could add or remove conductive material on a display to repair opens or shorts. Both steps toward automatic repair could decrease production costs, allowing U.S. companies to compete more effectively with their foreign competitors.

Photonics worked with Florod, a subcontractor, to develop prototype automatic inspection equipment. The first resulting prototype, AIM-1, had substantial per-

formance problems. To fix these problems, Photonics worked with consultants from the University of Michigan to design the second prototype, AIM-2. Photonics then issued a contract to a spin-off company, Ward Synthesis, to construct the new device. The AIM-2 can successfully detect a number of different defects on various types of flat panel displays.

Photonics also developed a prototype automatic repair station with the help of another subcontractor, Micron Corporation, who delivered the prototype to Photonics in December 1995. Demonstrations have shown that the repair equipment can successfully repair defects in active and passive liquid crystal displays.

Technology for Improved Resolution

The other goal of the project was to improve the degree of resolution, a key performance criterion for FPDs. The higher the resolution of images on the screen the better, and higher resolution requires more pixels. Pixels are controlled by integrated circuits (ICs), or driver chips, mounted on the glass. More pixels require additional driver chips, each of which must be connected with the display. More pixels and more driver chips present other manufacturing challenges that the consortium sought to address.

To increase resolution for a given screen size requires increasing the density of circuit integration and the density of connections between chips and display. To achieve a higher level of integration, Optical Imaging Systems (OIS) sought to stack and interconnect memory and/or logic elements on the driver chips that control the pixels. It did this by using polysilicon-on-glass (PSOG) transistors. These thin-film transistors serve as electrical switches on many large-area displays, and are especially important to the manufacturers of active matrix LCD.

The PSOG task was redefined after OIS was bought by another company and could not pursue its part of the research on the project. The consortium's new effort, called the silicon-on-glass (SOG) task, directed by Photonics, was intended to investigate a version of this technology that would be applicable to driver chips for all FPD technologies, not just active matrix liquid crystal displays (AMLCDs). A prototype was developed using SOG technology, but testing found that some of the chips could not handle high voltages. As a result, the SOG task was terminated in the project. Reportedly, several large semiconductor firms subsequently undertook further development of the silicon-on-glass approach to increasing integration of driver chips.⁵

⁵ Link, 1997, p. 25. Substantial additional technical assistance to the industry has been provided by DARPA and that assistance may further improve the outlook for U.S. producers. 25.

Driver circuitry for active-matrix LCDs (AMLCDs) is fabricated directly on the display area itself with the individual pixels that the drivers control, while driver chips for plasma and electro-luminescent displays, as well as some driver chips for AMLCDs, are mounted on the edge of the display area.

Planar explored another approach to fabricating driver circuitry on the edges of displays. Planar sought to develop flip-chip-on-glass (FCOG) technology, which would allow for the ICs controlling pixels to be fabricated directly onto the glass. Planar demonstrated the technical feasibility of FCOG technology. The cost of the technology, however, led company participants to conclude that the technology was “not economical at this time.” The FCOG task was therefore concluded ahead of schedule, and instead, Planar began working on a technology called tape automated bonding (TAB).

TAB was and is the primary approach to attaching driver chips to the edges of flat panel displays. This technology works by mounting integrated circuits on tape and then attaching this tape to the display glass. Planar researched and successfully developed techniques to attach adhesive to the display glass, align the tape on the glass, and then bond the tape to the glass. Planar subsequently introduced the TAB process into commercial production.

Tape Automated Bonding (TAB) Technology: a Central Achievement

In the opinion of those closely associated with the project, its central achievement was the improvement of the TAB technology, the primary approach for mounting driver circuitry on the edges of flat panel displays. Planar’s work on the TAB technology resulted in the capability to triple the resolution of flat panel displays.⁶ Not only does the manufacturer benefit, but so do the customers of improved displays. And, the ability to improve resolution will make these U.S. companies more competitive internationally.

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Project-related advancements in TAB were disclosed in a patent issued to Planar in June 1995. The advancements in technical knowledge were also disseminated in a series of presentations at professional gatherings: at the Symposium on Electronic Imaging—Science and Technology; at the annual meeting of the Society of Imaging Science and Technology; and at the Electronics Display Forum 95.

⁶ Chris King, phone interview, May 13, 1999.

Figure 4.2 Patent Tree for Project Led by American Display Consortium: Citations by Others of Planar Systems Patents

