

MicroFab Technologies, Inc.

Using Solder-Jet Technology to Attach Semiconductor Chips to Circuit Boards

High-density chips require high-density soldering methods to solder leads to circuit board contacts. Continuing advances in electronics miniaturization spurred manufacturers to seek cheaper and faster methods for packing greater functionality into less space, without using toxic chemicals during the tooling process. They sought new methods that lacked the complexity, expense, tooling-intensiveness, and time-consuming steps of the existing methods. One technology that emerged is liquid solder-jetting, a process that uses the printing industry's ink-jetting methods to "write" molten solder directly onto electronic components such as circuit boards, surface mount packages, and chips.

COMPOSITE PERFORMANCE SCORE

(based on a four star rating)

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Research and data for Status Report 93-01-0183 were collected during October - December 2001.

Ink-Jet Printing Technology To Connect Microelectronic Components

MicroFab Technologies, Inc., a small company based in Plano, Texas, was founded in 1984 by an expert in ink-jet printing technology. In 1994, the company received \$1.6 million in funding from the Advanced Technology Program (ATP) to apply its ink-jetting methods in a novel way to disperse molten metal solder drops to attach semiconductor chips to circuit boards. The resulting technology can produce droplets as small as 40 microns across (about half the width of a human hair). No other technique had been able to establish sizes this small. The size of the droplets allows more information to be packed into less space, with far more control over the process. In addition, jet-based solder equipment can produce and place molten solder droplets at rates up to 2,000 droplets per second.

MicroFab's method "writes" the solder patterns on circuit boards at high temperatures using an ink-jet printer. The technique is unique in its ability to write solder lines and achieve line density four times that of traditional lithography methods.

MicroFab Explores Two Methods To Generate Solder Streams

During the ATP project, MicroFab explored continuous and drop-on-demand methods for generating solder streams. In the continuous method, the liquid solder goes through a charging electrode system that creates pressure oscillations of constant frequency that break up the solder stream into uniform droplets and can produce thousands of solder droplets per second. A disadvantage of this method is that unused drops are produced that must be recycled or discarded, which raises an environmental concern.

The drop-on-demand solder method uses a reservoir of fluid that is acted on by a force, which causes it to eject droplets in a discrete volume. It is a slower process that has the advantage of generating no excess droplets that must be discarded. MicroFab selected the drop-on-demand method for its ink-jet soldering because this method avoided the environmental concerns of the continuous method. Ink-jet solder deposition is a low-cost alternative to traditional soldering methods because no masks or screens are required.

It is flexible because images are formed and stored digitally, and it is highly repeatable at differing resolutions. It lends itself to customization and reworking. Because ink-jet soldering is driven by computer-assisted design, it provides more flexibility in the types of patterns that can be created and the variety of applications for which it can be used.

The solder-jet technology can produce droplets as small as 40 microns across (about half the width of a human hair). No other technique has been able to establish sizes this small.

Real-time process control is possible because the depositions can be inspected immediately after the process, thus reducing prototyping and development time. This represents a major improvement over other less flexible methods.

Consortium Formed to Test Prototypes

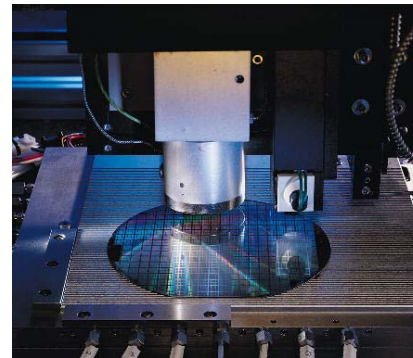
During the time that MicroFab collaborated with ATP, the company also entered into a consortium with high-end original equipment manufacturers, which represented the potential end users of this technology. These manufacturers, including Motorola, Delco, Texas Instruments, Kodak, and AMP, received prototype machines that used the solder-jet technology, tested them, and provided feedback to MicroFab as development proceeded.

The ATP award helped MicroFab to collaborate with and attract additional funding from a consortium of five major electronics manufacturers to further develop its technology.

Accordingly, the requirements of the technology were more quickly and accurately defined, and MicroFab was able to more easily and accurately configure the machines to implement the technology. These relationships also had the potential to improve the ultimate diffusion of the technology.

MicroFab Leverages Solder Jet Technology

The development of solder jet technology enabled MicroFab to create other viable technologies as well. In



Liquid solder-jetting uses the printing industry's ink-jetting methods to "write" molten solder directly onto electronic components such as circuit boards, surface mount packages, and chips.

its own production, it applies the drop-on-demand process it developed during the project. MicroFab uses the solder jet technology in its Jetlab[®] platform, which has a selling price of approximately \$200,000. The Jetlab[®] platform is a tool for a variety of industries—including microelectronics, photonics, medical diagnostics, and drug delivery—to identify jetting processes and fluids that best meet their specific needs. In addition, MicroFab sells fluids designed for micro-optic and microelectronic applications. It also supplies printhead subsystems using the ATP funded technology.

Conclusion

Many were skeptical of MicroFab's proposed process. In fact, major players in the industry said that it could not be done. Such skepticism reflected the highly risky nature of the venture. Private capital was unavailable to the company in order to pursue development of the technology. Without ATP's help, MicroFab would have had great difficulty in proceeding with its concept. In the words of MicroFab's research director David Wallace, "We'd done some preliminary technical work and feasibility studies to show our concept's viability, but it was at a stage where it was far too risky to get venture capital or investments from large end-user companies that would be beneficiaries of the technology."

ATP's backing also gave other major players in the industry the confidence to test the new process. The ATP award helped MicroFab to collaborate with and attract additional funding from a consortium of five major electronics manufacturers to further develop its technology. MicroFab continues to work with these manufacturers and other end users to develop and refine the technology.

PROJECT HIGHLIGHTS

MicroFab Technologies, Inc.

Project Title: Using Solder-Jet Technology to Attach Semiconductor Chips to Circuit Boards

Project: To develop a fast, accurate, and flexible process for "writing" solder droplets onto electronic circuit boards by applying the concepts of ink-jet printing.

Duration: 1/1/1994-12/31/1996

ATP Number: 93-01-0183

Funding (in thousands):

ATP Final Cost	\$1,639	70%
Participant Final Cost	<u>695</u>	30%
Total	\$2,334	

Accomplishments: MicroFab, with ATP funding, developed a prototype process to demonstrate the dispensing of 40-micron to 120-micron spheres of molten solders onto high-density electronic components at temperatures up to 220 °C, on demand, and at rates up to 2,000 per second.

MicroFab received the following five patents for technologies resulting from its ATP-funded project:

- "Method of making solder interconnection arrays" (No. 5,377,902: filed January 14, 1994; granted January 3, 1995)
- "Solder compositions and methods of making same" (No. 5,411,602: filed February 17, 1994; granted May 2, 1995)
- "Process for manufacturing metal ball electrodes for a semiconductor device" (No. 5,861,323: filed June 6, 1994; granted January 19, 1999)
- "Methods and apparatus for forming microdroplets of liquids at elevated temperatures" (No. 5,415,679: filed June 20, 1994; granted May 16, 1995)
- "Printhead for liquid metals and method of use" (No. 5,772,106: filed December 29, 1995; granted June 30, 1998)

MicroFab published several papers and gave several presentations regarding the ATP-funded technology. Toward the end of the project, the company attracted funding from the Defense Advanced Research Projects Agency (DARPA) to test the dispensing of high-lead solders at even higher temperatures (325 °C), with partial success.

Commercialization Status: MicroFab has progressed to the point of commercializing its ATP-funded technology. At the time the information for this report was being collected, the company was in the process of launching an outsourcing business to provide its soldering techniques to customers. In the fall of 2001, MicroFab also licensed its technologies for use in solder balls. MPM, a division of the Cookson Group, PLC, invested more than \$5 million in the development of this technology.

Outlook: MicroFab continues to test the solder-jet technology pioneered under the ATP-funded project for additional applications in microelectronics and other industries. One technical issue that still remains is achieving reliability in the yield of the solder droplets that are produced. MicroFab is continuing research and development efforts to explore ways of improving reliability.

Composite Performance Score: * * *

Number of Employees: 18 employees at project start, 30 employees as of December 2001. A new micro-optics division consisting of five employees was created as a result of the project.

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Collaborating Consortium Members:

Motorola, Delco, Texas Instruments, AMP, and Kodak