FSI INTERNATIONAL, INC.

A Gas Method to "Dry" Clean Computer-Chip Wafers

Manufacturing processes create parts for further assembly or final use, as well as a certain amount of waste. Even if waste is severely controlled, the part that emerges from fabrication is almost always contaminated to a greater or lesser degree by unwanted particles. The level of unwanted particles varies with the process, and so does its effect on the rest of production. If the new part is a slice of silicon crystal about to be covered by microscopic integrated circuits, the presence of unwanted particles — even in minute amounts — is disastrous. Extreme cleanliness, therefore, is the rule in silicon chip-making plants, where fabrication takes place in clean rooms designed to eliminate contamination.

COMPOSITE PERFORMANCE SCORE
(based on a four star rating)
* *

New Technology to Clean Ever Smaller Chip Features

In computer-chip fabrication, a silicon-crystal wafer is thoroughly cleaned before microscopic electronic components are deposited on it. Conventional cleaning techniques use caustic wet chemicals that could be

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hazardous to workers and that must be discarded after use, generating disposal costs and the potential for environmental pollution if the chemicals are not handled properly. In addition, for chips with feature sizes below a minimum, wet chemicals may not be able to get to some features, such as trenches, because of surface tension.

Potentially Safer and Less Costly

The ATP award allowed FSI International, which provides semiconductor wafer surface conditioning equipment and support products, to develop a "dry" cleaning procedure that uses chlorine, chlorine/hydrogen, and other gases to clean dirt, trace metals, and other particles from wafer surfaces. Researchers completed the assembly and installation of an experimental module and developed required support processes. Although the gases are toxic, they are more easily controlled than wet chemicals. And even though the gases incur disposal costs, the amount of chemical waste generated by theFSI technology is expected to be much smaller than that created via traditional wet cleaning. Thus, the new technology should improve human and environmental safety and reduce cleaning costs during wafer processing.

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FSI's methodologies for gas-phase dry cleaning were developed for use in making computer chips and have potential applications in the fabrication of printed circuit boards, disk drives, and optoelectronics. If the market emerges and the FSI technology becomes widely used, substantial economic benefits would likely accrue all along the supply chain for computers and other equipment that include chips. The technology is undergoing initial testing at Texas Instruments. If the testing is successful, FSI officials say, Texas Instruments would likely buy and use systems incorporating the new technology.

ATP funding was critical to generating the gas-phase dry cleaning technology, FSI officials report. The company would not have done the research and development work at that time without it. The ATP award also enabled FSI to collaborate with Massachusetts Institute of Technology researchers during the project.

PROJECT HIGHLIGHTS

Project:
To develop a cost-effective process to remove surface contaminants from computer-chip wafers during manufacturing, using dry gases (as opposed to wet chemicals) that can clean the ever smaller features on new generations of chips.

Duration: 3/1/1993 — 2/28/1995
ATP Number: 92-01-0022

Funding (in thousands):

ATP	$2,000	36%
Company	3,482	64%
Total	$5,482	

Accomplishments:
FSI achieved its R&D goal of developing a dry gas wafer-cleaning method. Evidence of progress is that the company:

- received three patents related to the ATP project:

"UV-Enhanced Dry Stripping of Silicon Nitride Films" (No. 5,534,107: filed 8/18/1994, granted 7/9/1996), "Apparatus for Surface Conditioning"

(No. 5,580,421: filed 12/21/1994, granted 12/3/1996), and"Cleaning Method"
(No. 5,716,495: filed 3/25/1996, granted 2/10/1998);

- applied for nine additional patents, one of which has been unofficially granted (allowed but not yet published);

- presented or published nine technical papers in the area of dry cleaning, etching or stripping of surfaces;

- received a license to complementary technology that could accelerate the commercialization of an advanced dry gas-phase cleaning system;

- entered into an agreement with Texas Instruments for early-stage testing of a prototype; and

- constructed a manufacturing facility to handle all FSI International

Surface Conditioning Division manufacturing, including products incorporating the ATP-funded technology.

Citations by Others of Project's Patents: See Figure 1.

Commercialization Status:
No commercialization has occurred so far, owing to unanticipated changes in demand for the new technology. The shift in 1997 to 0.25-micron minimum feature sizes for wafer processing was expected to challenge the capabilities of conventional wet cleaning processes. Wet processing, however, continues to meet cleaning needs for 0.25-micron features and may even be viable to minimum sizes of 0.18 micron, which are expected to be introduced in the year 2000.

Outlook:
Commercialization prospects are uncertain. Much depends on how the market moves, as well as on remaining development work needed to demonstrate the robustness, manufacturability and reliability of the process and equipment in a chip-manufacturing environment. Although the ATP-funded technology has not replaced traditional wet cleaning in chip processing, as originally envisioned by the ATP-project proposal, FSI anticipates the emergence of new applications requiring the unique capabilities of its technology.

Composite Performance Score: * *

Number of employees: 540 at project start, 1,295 at the end of 1997

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Unofficial collaborator: Massachusetts Institute of Technology, Department of Chemical Engineering

Commercialization Delayed but Still Expected

Since initiation of the ATP project, manufacturers of wafer-surface conditioning equipment have found ways to squeeze more improvements out of wet-chemical cleaning methods. Consequently, chip fabricators have less need for a dry cleaning technique than was initially anticipated. The company expected that the shift in 1997 to smaller (0.25 micron) minimum feature sizes for wafer processing would challenge the capabilities of conventional wet cleaning processes. Wet processing, however, continues to meet cleaning needs at this level and may even be viable to minimum feature sizes of 0.18 micron, which are expected to be introduced in2000. Furthermore, progress has been made in reducing the amount of chemicals needed for wet cleaning processes.

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Commercialization of the ATP-funded technology, therefore, depends on how much more the wet method can be extended, as well as on the remaining development work needed to demonstrate the robustness, manufacturability, and reliability of the process and equipment in a chip-manufacturing environment. Although the new technology has not become a broad replacement for traditional wet cleaning in wafer processing, as originally envisioned by the ATP-project proposal, FSI anticipates the emergence of new applications requiring the unique capabilities of its technology. If the dry cleaning

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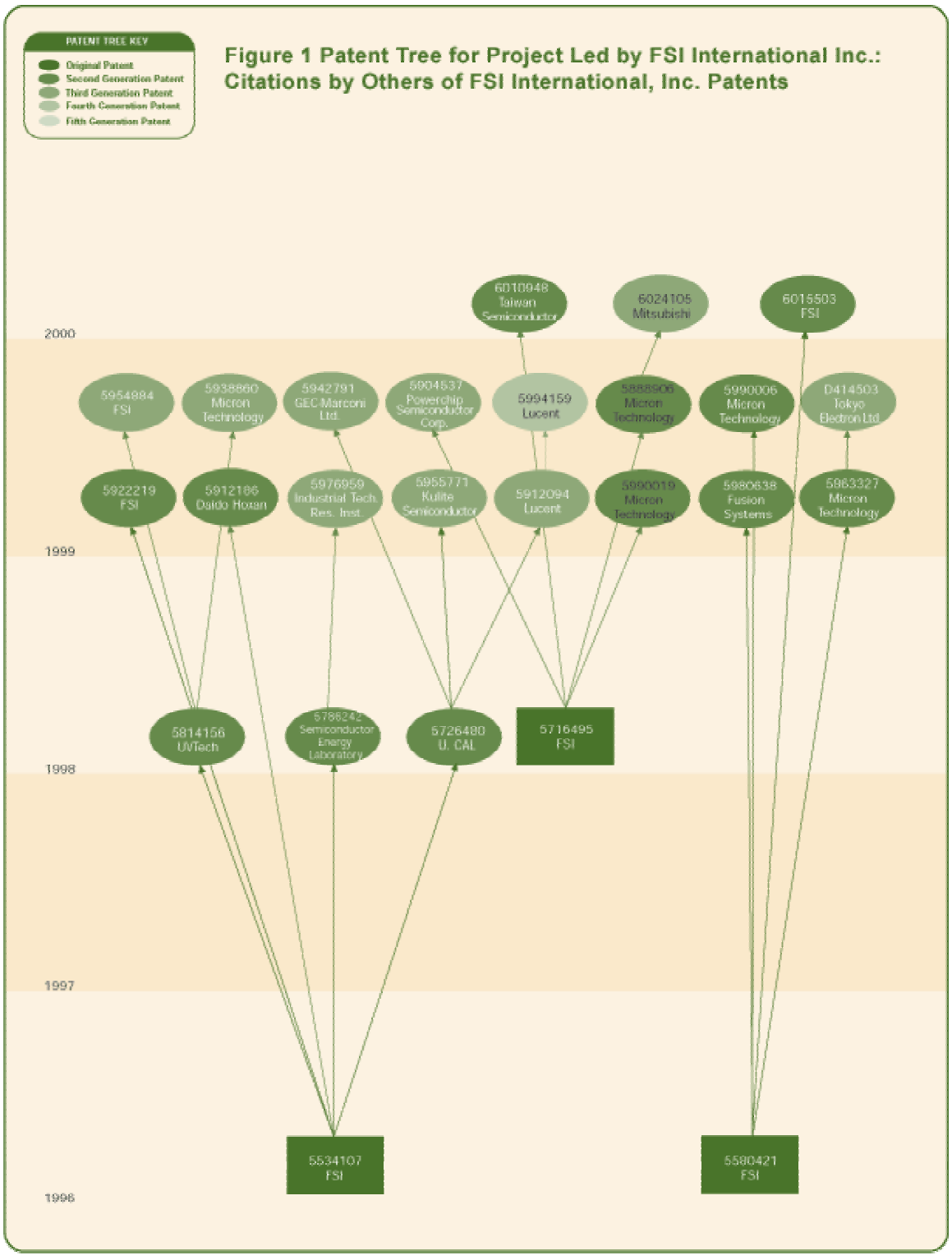
technology is commercialized, chip fabricators that use the new technology might achieve process improvements worth up to five times their costs for the technology, company officials say. FSI has continued to develop this technology while delaying commercialization until demand increases sufficiently. If that happens soon, the company could have a product on the market in 1999.



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