HAMPSHIRE INSTRUMENTS, INC.
(Joint Venture)

Large-Scale Diode-Array Laser Technology for X-Ray Lithography

Today's stamp-size computer chips are made by lithography systems that project ultraviolet (UV) or deep-UV light through stencil-like masks onto silicon wafers to produce the tiny components of integrated circuits (ICs) or chips. To make higher-performing ICs, more transistors and denser circuitry will have to be packed onto each chip.

COMPOSITE PERFORMANCE SCORE
(Based on a four star rating.)

No Stars

Ever Smaller, Denser Computer Chips

Today's densest chips have feature sizes of about 0.15 mm, which can barely be produced with deep-UV lithography. To make even smaller chips, the next generation of lithography equipment may use x-rays, which have shorter wavelengths than visible or UV light. Shorter wavelengths are needed to make tinier features.

An Inexpensive Laser Approach

X-ray lithography able to make chip features of 0.10 mm and smaller was demonstrated prior to the start of this project in 1991. But cost-effective x-ray lithography systems capable of large-scale IC manufacturing were not available. Research had shown that a relatively inexpensive device using a high-energy laser to stimulate x-ray emission could be used to produce x-rays. Suitable material (neodymium-doped gadolinium gallium garnet, or Nd:GGG) for this type of laser was available. However, the inability to precisely control the energy used to pump up the material's energy level was a key problem in making such a laser work.

This ATP joint venture project by Hampshire Instruments and McDonnell Douglas Corporation (MDC), with help from Lawrence Livermore National Laboratory, solved the control problem by developing methods for using powerful arrays of laser diodes to pump Nd:GGG in a laser-based x-ray lithography system. Hampshire, a small New York company, contributed its laser design expertise. MDC provided expertise in system design and the design of the critical high-power laser-diode pump. It also provided the world's largest laser-diode module manufacturing capacity to support post-project commercialization goals.

Prior to the ATP-funded work, MDC built a prototype laser-diode pump system with a peak power output of more than 300 kW. The system was successfully used to pump a Hampshire laser being developed for a second-generation x-ray lithography system, and its pumping was significantly more efficient than that of the flash lamps Hampshire had used in its first-generation x-ray lithography system. In addition, life testing of laser-diode pump systems showed they lasted much longer than the longest-lasting flash lamps then available.

Doubling the Peak Power Output

During the ATP project, MDC built two prototype laser-diode pump systems that each delivered more than 750 kW of peak power, by far the highest laser-diode power produced by any device then or now. Both met or exceeded all performance and reliability specifications. MDC kept one pump and delivered the other to Lawrence Livermore for testing in the second-generation x-ray lithography system being developed by the lab and Hampshire. The pump, however, was never integrated with the Hampshire laser. Flash lamps with longer life became available, leading Lawrence Livermore to shift its focus to flash-lamp pumping of the laser. The lab continues to develop x-ray lithography.

PROJECT HIGHLIGHTS

PROJECT:
To develop a laser-diode-pumped laser system for generating x-rays in a new generation of lithography equipment to enable a major advance in the miniaturization of computer chips while reducing manufacturing costs.

Duration: 7/1/1991 — 9/30/1992

ATP Number: 90-01-0126

FUNDING (in thousands):

ATP	$926	50%
Company	930	50%
Total	$1,856	

ACCOMPLISHMENTS:
Researchers demonstrated the feasibility of using a powerful laser-diode-array to pump up the energy level of Nd:GGG (neodymium-doped gadolinium gallium garnet) in a laser intended for use in producing x-rays. Such a laser could be scaled up to meet the technical, reliability and affordability requirements for third-generation x-ray lithography systems. All planned tasks were accomplished. The company presented some results at the Advanced Solid State Laser Conference in 1992.

COMMERCIALIZATION STATUS:
No attempt to commercialize the technology has occurred. Soon after the ATP project was completed, Hampshire ran into serious financial problems, declared bankruptcy and was liquidated. The company's demise halted the effort to develop this type of laser-based x-ray lithography and led to the collapse of MDC's laser-diode business.

OUTLOOK:
The New York Job Development Authority — which now owns practically all Hampshire assets, including intellectual property — shows no intention to commercialize the technology. Neither does MDC (Boeing). The semiconductor industry has shifted some of its attention from x-ray lithography to competing technologies such as deep ultraviolet (DUV) lithography utilizing excimer lasers. However, given the expectation that feature resolution limits of DUV lithography will be reached in a few years, x-ray lithography continues to arouse interest. If the industry comes to view the x-ray approach as a viable candidate for a new generation of lithography equipment, the technology developed in this ATP project could be revisited.

COMPANIES:
Hampshire Instruments, Inc. (joint venture lead)
(Since April 25, 1993, no longer in business)

Composite Performance Score: No Stars

Other joint venture participant:
McDonnell Douglas Corporation (MDC),
now merged with The Boeing Company
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Informal collaborator: Lawrence Livermore National Laboratory

High Expectations Dashed by Bankruptcy

Evidence at the start of the project suggested the ATP-funded technology would be rapidly commercialized if it could be successfully developed and demonstrated. Hampshire and MDC planned to sell the new x-ray lithography system in a worldwide market expected, when the proposal was written, to exceed $1.5 billion by 1994. They also hoped to sell the technology in solid-state laser markets.

Soon after the ATP project was completed, Hampshire ran into serious financial problems, declared bankruptcy and was liquidated.

Hampshire, however, ran into serious financial problems and failed to raise the additional funds needed to survive. The company declared bankruptcy and was liquidated. The New York Job Development Authority assumed ownership of practically all Hampshire assets, including its intellectual property. For a time, several organizations expressed interest in acquiring the technology, but none completed the acquisition. MDC intended to commercialize its laser-diode pumps for a variety of applications. With Hampshire's demise, that plan did not materialize. There is currently no effort to commercialize the ATP-funded technology, either by Boeing (MDC) or government agencies. But this may change with renewed interest in x-ray lithography in the future.

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