GLOBAL COMPETITIVENESS OF U.S. ADVANCED-TECHNOLOGY MANUFACTURING INDUSTRIES: SEMICONDUCTOR MANUFACTURING AND TESTING EQUIPMENT

Report to the Committee on Finance, United States Senate, on Investigation No. 332–303 Under Section 332(g) of the Tariff Act of 1930

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under the direction of
Norman McLennen, Chief, Services and Electronic Technology Division

Project Leader
Nelson Hogge

This report was prepared principally by

William Fletcher, Douglas Puffert, Ruben Moller, John Kitzmiller
John Cutchin, David Slingerland, William Greene, and Laura Stonitsch
Office of Industries

William Gearhart, Wayne Herrington, Katherine Jones, Robin Turner
Office of the General Counsel

Daniel Shepherdson
Office of Tariff Affairs and Trade Agreements

with assistance from
Kathleen Gillen, Kim Oliver, and Elisa Jackson
Office of Industries

Address all communications to
Kenneth R. Mason, Secretary to the Commission
United States International Trade Commission
Washington, DC 20436

PREFACE

This report is one of three on the global competitiveness of U.S. advanced-technology manufacturing industries requested by the Senate Committee on Finance (Finance Committee). In a letter dated September 27, 1990, the Finance Committee directed the Commission, under section 332(g) of the Tariff Act of 1930 (19 U.S.C. 1332(g)), to conduct investigations on the global competitiveness of the U.S. telecommunications, semiconductor manufacturing and testing equipment, and pharmaceuticals industries, and to furnish reports on the results of the three investigations within one year. Following receipt of the letter, the Commission instituted the three requested investigations, Communications Technology and Equipment (inv. No. 332-301), Pharmaceuticals (inv No. 332-302), and Semiconductor Manufacturing and Testing Equipment (inv. No. 332-303). Notice of the Commission's institution of the investigation and scheduling of a public hearing for January 17-18, 1991, in connection with the three investigations was posted in the Commission's Office of the Secretary and published in the *Federal Register* of November 15, 1990 (55 F.R. 47812). A copy of the Finance Committee letter is reproduced in appendix A, and a copy of the Commission's notice of investigation and hearing is reproducted in appendix B.

The three investigations represent the second part of a two-step process. Initially, the Finance Committee, in a letter dated June 21, 1990, asked the Commission to identify for the purpose of monitoring, pursuant to sections 332(b), 332(d), and 332(g) of the Tariff Act of 1930, advanced-technology manufacturing industries in the United States, and from the list compiled to recommend three for in depth study. More specifically, the Committee requested that the Commission (1) within 3 months of receipt of the letter, identify for the purpose of monitoring, using criteria provided by the Committee and any additional criteria of the Commission's choosing, U.S. advanced-technology manufacturing industries, and recommend three of those industries as subjects for comprehensive Commission studies; and (2) within 12 months of the receipt of the Committee's approval (or modification) of the Commission's recommendations, submit its report on three industries the subject of comprehensive studies. In response the Commission, on July 20, 1990, instituted investigation No. 332-294, Identification of U.S. Advanced-Technology Manufacturing Industries for Monitoring and Possible Comprehensive Study. Notice of the Commission's institution of investigation No. 332-294 was posted in its Office of the Secretary and published in the *Federal Register* (55 F.R. 30530) of July 26, 1990. Although a public hearing was not held, all persons were afforded the opportunity to submit written views concerning the industries to be included on the list and that may be the subject of a comprehensive study. A copy of the Finance Committee's letter of June 22 is also set forth in appendix A.

The Commission's report on investigation No. 332-294 (USITC Publication 2319, September 1990) was transmitted to the Committee on September 21, 1990. In its report, the Commission identified ten advanced-technology industries and recommended the following three for comprehensive study: communications technology and equipment; pharmaceuticals; and semiconductor manufacturing and testing equipment. In its letter of September 27, 1990, the Committee acknowledged receipt of the Commission's report and approved the Commission's recommendation concerning the three industries for comprehensive study.

In its June 21 letter, the Committee requested that the Commission, in identifying the industries to be monitored, consider the following criteria as well as any other criteria it might choose—

(1) Industries producing a product that involves use or development of new or advanced technology, involves high value-added, involves research and development expenditures that, as a percentage of sales, are substantially above the national average, and is expected to experience above-average growth of demand in both domestic and international markets; and

(2) benefits in foreign markets from coordinated—though not necessarily sector specific—policies that include, but are not limited to, protection of the home market, tax policies, export promotion policies, antitrust exemptions, regulatory policies, patent and other intellectual property policies, assistance in developing technology and bringing it to market, technical or extension services, performance requirements that mandate either certain levels of

investment or exports or transfers or technology in order to gain access to that country's market, and other forms of government assistance.

The Committee requested that the report of the three industries to be selected include at least the following information—

> Existing or proposed foreign government policies that assist or encourage these industries to remain or to become globally competitive, existing or proposed U.S. Government policies that assist or encourage these industries to remain or become globally competitive, and impediments in the U.S. economy that inhibit increased competitiveness of these U.S. industries.

A consolidated public hearing in connection with investigation Nos. 332-301-303 was held in the Commission Hearing Room on January 17, 1991. Persons appearing at the hearing were required to file requests to appear and prehearing briefs by January 3, 1991, and to file any posthearing briefs by January 31, 1991. In lieu of or in addition to appearances at the public hearing, interested persons were invited to submit written statements concerning the investigations. Interested parties that presented testimony in connection with inv. No. 332-303 included the United States Advanced Ceramics Association of Washington, DC; SEMI/SEMATECH of Austin, TX; National Institute of Standards and Technology of Washington, DC; Etech Systems of Haywood, CA; SVG Lithography Systems, Inc. of Wilton, CT; and Semiconductor Equipment and Materials International (SEMI) of Washington, DC (See app. C).

In the course of this investigation, the Commission compiled data and information published by VLSI Research, Inc., Integrated Circuit Engineering Corp., Semiconductor Equipment and Materials International, Congressional Research Service, General Accounting Office, National Advisory on Semiconductors, U.S. Department of Commerce, SEMI/SEMATECH, and other sources. In addition, information was gathered from interviews with officials from U.S. semiconductor and semiconductor equipment firms and with selected foreign industry/government officials in Western Europe and Asia.[1]

The information and analysis provided in this report are for the purpose of this report only. Nothing in this report should be construed to indicate how the Commission would find in an investigation conducted under statutory authority covering the same or similar subject matter.

[1] Staff traveled to Western Europe (the Netherlands, Germany, Switzerland, and Liechtenstein) and Asia (Japan and Korea) during April/May 1991 to interview industry/government officials.

GLOSSARY

Application-specific integrated circuit (ASIC)

An integrated circuit designed for one narrow use, such as substituting one large integrated circuit for many small ones. Often custom or semi-custom.

Bipolar

One of the two types of transistors and integrated circuits; the other is metal-oxide semiconductor (MOS). They are faster than MOS devices but more difficult to make.

Bit

A zero (0) or one (1) in the binary language of computers.

Byte

Eight (8) bits.

Captive producer

A semiconductor manufacturing firm that produces exclusively for in-house consumption. Contrasts with merchant producer.

Chemical vapor deposition

A process in which insulating films and metals are deposited on a wafer using gases, elevated temperatures, and reduced pressure to obtain a chemical reaction.

Clean room

A confined area in which the humidity, temperature, particulate matter, and contamination are precisely controlled within specified parameters. Federal Standard 209 defines the "class" of a clean room on the basis of the maximum number of particles of 0.5 micron size or larger that may exist in 1 cubic foot of air in the designated area.

Component

An individual electronic part, such as a transistor, diode, or capacitor, that is fabricated in a metal-oxide semiconductor or bipolar process.

Custom circuit

An integrated circuit designed and manufactured for a particular customer. Contrasts with semi-custom, which has only the last few manufacturing steps tailored to customers' specifications. Also contrasts with integrated circuits of standard design, which are produced in volume for many users.

Deposition

An operation in which a film is placed on a wafer without a chemical reaction with the underlying layer.

Die

The small piece of the wafer on which an individual semiconductor device has been formed.

Dielectric

A material that does not conduct electricity, used as an insulating film in integrated circuits.

Diffusion

A process in which desired impurities are introduced into the silicon by baking the silicon wafers at high temperatures and pressures in chemically altered atmospheres. Diffusion is a less precise alternative to ion implantation.

Digital integrated circuit

An integrated circuit that uses binary codes (0's and 1's) to store and manipulate data by using the on/off properties of transistors. Contrasts with linear integrated circuits.

Diode

A semiconductor component that allows electricity to flow only in one direction.

Doping

A process that deposits a chemical impurity onto a wafer surface to change its electrical properties.

Dynamic random access memory (DRAM)

A type of RAM that requires some external support circuitry. Contrasts with static random access memory. Categorized by speed and memory capacity.

Epitaxy

A silicon crystal layer grown on top of a silicon wafer exhibiting the same crystal structure orientation as the substrate wafer with a dissimilar doping type and/or concentration (examples:p/p+,n/n+,n/p, and n/n).

Erasable programmable read only memory (EPROM)

A memory device that can be read but not written to. Unlike other programmable memories, it can be erased (by exposing it to ultraviolet light) and reprogrammed.

Etching

A process in which acid is used to remove previously defined portions of the silicon oxide layer covering the wafer to expose the silicon underneath. Removing the oxide layer permits introducing desired impurities into the exposed silicon through diffusion or ion implantation or the deposition of aluminum paths for electrical interconnection of circuit elements.

Gallium arsenide

A compound semiconductor material that allows transistors and integrated circuits to operate much more rapidly than similar devices made of silicon.

Gate array

A kind of semi-custom circuit.

Geometries

The size of the smallest feature on an integrated circuit, usually the connections between transistors. At present, most new integrated circuit designs have geometries between 1.0 and 1.5 microns, although some new memory devices have smaller geometries.

Integrated circuit

A complete electronic circuit composed of interconnected diodes and transistors and fabricated on a single semiconductor substrate, usually silicon.

Ion implantation

A process in which the silicon is bombarded with high-voltage ions in order to implant them in specific locations and provide the appropriate electronic characteristics.

Lithography

A process in which the desired circuit pattern is projected onto a photoresist coating covering a silicon wafer. When developed, portions of the resist can be selectively removed with a solvent, exposing parts of the wafer for etching and diffusion.

Logic circuit

A type of digital integrated circuit that performs certain logical or mathematical functions and often provides connections between other major parts of computers.

Mask

A glass plate on which single integrated circuit layers are patterned. Typical integrated circuit fabrication requires 10-15 layers.

Memory device

An integrated circuit that stores binary data. Categorized according to accessibility (at random or serially), size, speed, and to whether it can be written to or is read only.

Merchant producer

A semiconductor manufacturing firm that produces primarily for sale on the open market. Contrasts with captive producer.

Metal deposition

The use of sputtering or chemical vapor deposition to deposit conductive materials (i.e., aluminum, tungsten, or titanium) onto the wafer surface.

Metallization

A process in which a layer of metal, such as aluminum, is placed on the wafer to connect the transistors and diodes within an integrated circuit.

Metal-oxide semiconductor

One of two families of silicon transistors and integrated circuits (the other is bipolar) that is simpler to fabricate and hence is often used in manufacturing large, dense integrated circuits.

Metrology

The science of measuring and/or the ability to apply sensors and measurements to equipment and product.

Micron

A micrometer, or one-millionth of a meter.

Microprocessor

An integrated circuit that performs the function of a central processing unit of a computer.

Optical lithography

The use of light waves to transfer integrated circuit patterns from a mask to photoresists on the wafer.

Photoresist

A photosensitive liquid plastic film applied to the surface of a wafer during lithography for micropatterning. (Also called resist.)

Planarization

A process in which a flat layer of glassy material is deposited over the lower layers of an integrated circuit. This step simultaneously creates a flat surface for further processing and isolates the lower layers.

Plasma

Ionized gas used to remove resist, etch, and deposit various layers onto a wafer.

Random access memory (RAM)

A memory device whose individual memory cells can be read from or written to at random (that is, not serially).

Read only memory (ROM)

A memory device whose contents can be read from but not written to.

Semiconductor

A material, typically silicon or germanium, that has four electrons in its outer ring and is a poor conductor of electricity. The term has come to refer to all devices made of semiconducting material, including integrated circuits, transistors, and diodes.

Semi-custom circuit

An integrated circuit that has the initial phases of its fabrication standardized, but allows the later stages to be tailored to suit the individual customer.

Silicon

One of the most common elements found in nature; the basic material used to make the majority of semiconductor wafers.

Solid-state physics

The study of the properties, structure, or reactivity of solid materials, especially relating to the arrangement or behavior of ions, molecules, nucleons, electrons, and holes in the crystal of a substance, such as a semiconductor, or to the effect or crystal imperfections on the properties of a solid substance.

Solid-state products

Products utilizing the electric, magnetic, or photic properties of solid materials, rather than electron tubes.

Sputtering

An operation in which a target material, such as gold or aluminum, is bombarded with argon ions. The displaced molecules of the target material are then deposited on the wafer surface.

Static random access memory (SRAM)

A type of RAM that has self-contained memory circuitry. Contrasts with dynamic random access memory. Categorized by speed and memory capacity.

Stepper

A sophisticated piece of equipment used to transfer an integrated circuit pattern from a mask onto a wafer.

Substrate

(1) The basic material upon which a device, circuit, or epitaxial layer is built; a wafer; (2) photoresist substrate--the material on which a photoresist coating is applied; (3) silicon substrate--the structure on which silicon epi is grown by the process of epitaxy.

Synchrotron

A type of particle accelerator being discussed as a potential source of X-rays for use in X-ray lithography.

Transistor

A three-terminal semiconductor device used mainly to amplify or switch.

Wafer

A thin disk, from 2 to 8 inches in diameter, cut from silicon or other semiconductor material. The wafer is the base material on which integrated circuits are fabricated.

Wafer stepper

A type of lithography equipment that exposes the wafer one die at a time, instead of the whole wafer at once.

X-ray lithography

The use of x-rays to transfer integrated circuit patterns from masks to resist-coated wafers.

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EXECUTIVE SUMMARY

Introduction

In a letter dated June 21, 1990, the Senate Committee on Finance requested the U.S. International Trade Commission to begin a 2-stage investigatory process to (1) identify a list of U.S. advanced-technology manufacturing industries and recommend three industries from the list for comprehensive investigations, and (2) conduct comprehensive investigations with respect to such industries, as approved by the Committee. The Committee requested that the report on these industries include information on the role of the U.S. and foreign governments in assisting these industries to remain or become globally competitive and on impediments in the U.S. economy that adversely affect the competitiveness of these industries.

A report on the first stage was submitted to the Committee on September 21, 1990. In the report, the Commission recommended that the Committee select from the list the semiconductor manufacturing and testing equipment and materials (SEM) industry as one of the three industries. On September 27, 1990, the Committee notified the Commission of its selection of the SEM industry and indicated that the Commission should complete its comprehensive investigation on the industry and submit its report within 12 months. The SEM industry manufactures machines and materials used to produce integrated circuits and other semiconductors from silicon wafers. All forms of productivity in electronics involve the application of semiconductors, and competitiveness in semiconductors depends upon the availability of advanced semiconductor equipment.

This study identifies the principal competitive determinants in the SEM industry and provides an analysis of the factors that shaped the industry during 1980-90. The Commission collected information for the analysis from a variety of sources, including trade associations, interviews with U.S. and foreign industry and government officials, and a review of the literature relating to the SEM and semiconductor industries. In addition, views on the factors that have affected the industry's competitiveness were solicited from interested parties at the Commission's public hearing on January 17, 1991.

Background

The global SEM industry comprises of firms producing semiconductor manufacturing and testing equipment and processing and packaging materials. The global industry is located in Japan, the United States, and to a lesser extent in Western Europe. In 1990, global shipments of semiconductor manufacturing and testing equipment were valued at $9.3 billion and the five largest suppliers were Tokyo Electron Limited (Japan), Nikon (Japan), Applied Materials, Inc. (U.S.), Advantest (Japan), and Canon (Japan). Shipments of processing and packaging materials were valued at $9.2 billion and the five largest suppliers were Kyocera (Japan), Shin-Etsu Handotai (Japan), NTK (Japan), Sumitomo (Japan), and Huels (Germany). U.S. firms supplied 45 percent of the global equipment market in 1990, but only 13 percent of the global materials market. In contrast, Japanese firms supplied 44 percent of the equipment market, and 73 percent of the materials market.

Economic analysis

The principal measures of competitiveness in the SEM industry are industry sales and profitability which are determined by product performance, services to and relationships with users, market conditions, and the level of production costs. Product performance is determined largely by the level of research and development expenditures, the technology capabilities of the firm, and technical cooperation with users.

The competitiveness of the U.S. SEM industry depends upon its ability to bring new products rapidly to market and generate sufficient profits to conduct a high level of research and development to develop future products.

Summary of findings

- **The U.S. semiconductor manufacturing and testing equipment industry is tied in a technology chain with the U.S. semiconductor and electronics industries.**

The U.S. SEM industry is the principal supplier to the $25-billion U.S. semiconductor industry, which in turn supplies many of the most advanced components used by the $266-billion U.S. electronics industry. The three industries support each other not only thorough sales and purchases but also through shared technology. The presence of technologically advanced U.S.-based firms in each of the three industries improves the competitive performance of the others.

- **The U.S. industry lost a significant share of the global SEM market during 1980-90.**

U.S. firms supplied 75 percent of the $2.1-billion global semiconductor manufacturing and testing equipment market in 1980, and the 10 largest equipment producers were located in the United States. In 1990, U.S. firms accounted for 45 percent of the $9.3-billion global equipment market and Japanese firms supplied 44 percent. Japanese firms also supplied 73 percent of the $9.2-billion semiconductor materials market in 1990, increasing from 21 percent in 1980. U.S. firms supplied 13 percent of the global materials market in 1990, and no U.S. firm was among the ten largest suppliers.

- **The Japanese SEM industry benefits from its close relationship with the Japanese semiconductor industry and the resulting availability of funding for R&D.**

Japanese semiconductor firms value their equipment suppliers and work closely with them to develop new machines and processes. Equipment suppliers gain important feedback through this relationship and are able to improve their equipment's operation and reliability. At the same time, details of new requirements are identified and research is directed toward these future equipment needs. Japanese semiconductor and equipment firms usually share in the cost of research and development of new equipment because they recognize that advancements in equipment are in their mutual interests.

- **The U.S. semiconductor and SEM industries, on the other hand, have not developed a close relationship.**

U.S. semiconductor firms have failed to develop close relationships with domestic equipment suppliers, although SEMATECH is serving as an important catalyst to overcome this problem and promote closer ties. U.S. semiconductor firms tend to emphasize the performance and operation of the equipment more than relationships of their suppliers. In the past, equipment suppliers feared that their equipment technology would be transferred by semiconductor firms to other equipment suppliers, and semiconductor firms were concerned that their future development plans would be revealed by equipment suppliers. This mutual distrust limited cooperation.

- **The decline of the U.S. industry's share of the global SEM market is related to a decline in the U.S. industry's share of the global semiconductor market.**

U.S. and Japanese firms supply a large share of their respective SEM markets, but the U.S. producers' share of the global semiconductor market is declining, causing a shrinkage in the total available market for U.S. SEM suppliers. The Japanese SEM market is growing more rapidly than the U.S. market, and U.S. SEM firms' share of the Japanese market is declining.

- **Japanese law permits more liberal depreciation of semiconductor manufacturing equipment than is allowed under U.S. tax law.**

Semiconductor manufacturing and testing equipment purchased by U.S. semiconductor firms can be depreciated for tax purposes over a period of 5 years. In Japan, semiconductor equipment is designated for accelerated depreciation and subject to schedules over a period of 3 or 4 years. However, equipment operated more than 8 hours a day is allowed more rapid deduction in depreciation. Representatives of the SEM industry assert that the difference in depreciation increases the cost of capital and reduces the demand for SEM products in the semiconductor industry.

- **Representatives of the SEM industry indicate that changes in U.S. Government policies would increase the competitiveness of the SEM industry.**

Representatives of the SEM industry indicate that the National Cooperative Research Act of 1984 (NCRA) has been an important development and should be amended to allow for joint production ventures. Other industry recommendations include increased R&D tax credits and fast track remedies under U.S. trade laws.

CHAPTER 1
INTRODUCTION

Purpose of Study

This study is part of a series that attempts to provide a thorough and methodical analysis of the determinants and status of the global competitiveness of U.S. high-technology industries.[1] The study focuses on the semiconductor manufacturing and testing equipment and materials (SEM) industry, which provides the foundation technology supporting the $25-billion U.S. semiconductor industry and the $266-billion U.S. electronics industry.[2]

U.S. firms dominated the global SEM market in the 1970s, but in the decade that followed, the U.S. SEM industry, along with the U.S. semiconductor industry, lost significant market share to Japanese suppliers. The loss of market share in the SEM and semiconductor industries is indicative of a loss in U.S. technological leadership and competitiveness in electronics.

This study examines industry evolution, government policy, and changes in technology and economic conditions to provide an overall assessment of the competitiveness of the SEM industry. The study also examines the prevailing downstream linkages, or economic spillovers, in the SEM industry to view the industry in the context of broader U.S. economic interests.

Scope of Study

Products

The SEM industry produces a variety of machines and materials that are used to manufacture integrated circuits and other semiconductor devices. For the purpose of this study, these include: (1) silicon wafer-manufacturing equipment; (2) wafer-processing (wafer fab) equipment; (3) assembly equipment; (4) testing equipment; and (5) processing and packaging materials (product segments are detailed in fig. 1-1).[3] Wafer-processing equipment, which includes photolithographic apparatus, represents the most critical segment of the industry. The study examines the competitive factors affecting the various segments of the industry and the market shares of firms within these segments.

[1] The series is described in *Identification of U.S. Advanced-Technology Manufacturing Industries for Monitoring and Possible Comprehensive Study*, USITC Publication 2319, Sept. 1990, pp. 15-16.

[2] The reasons for selecting the SEM industry are also described in USITC Publication 2319, *Identification of U.S. Advanced-Technology Manufacturing Industries for Monitoring and Possible Comprehensive Study*, Sept. 1990.

[3] SEM is classified in part in Standard Industrial Classification (SIC) product code 35596. A detailed product description and uses for the types of equipment and materials covered in this study is presented in app. D.

Wafer-manufacturing equipment consists of furnaces, vacuum chambers, saws, and polishing apparatus used to produce silicon wafers from crushed polysilicon crystals. Wafer-processing equipment covers a broad range of apparatus, including photolithographic equipment used to create images of circuit patterns on the wafers, diffusion and oxidation equipment to change the electrical characteristics of the wafers, ion implantation equipment to introduce impurities into the wafers, and etching and cleaning equipment to remove materials from the wafers and prepare them for the next processing step (figure 1-1).

Assembly equipment includes die bonders, wire bonders, encapsulation equipment, and other apparatus used to package semiconductor devices. Testing and measuring equipment include instruments and machines used to discover defects during production and ensure that design dimensions are achieved during the processing steps. Silicon wafers, leadframes, ceramic packages, and encapsulation compounds are the principal types of processing and packaging materials. A detailed description of the products and processes covered in this study is provided in app. D.

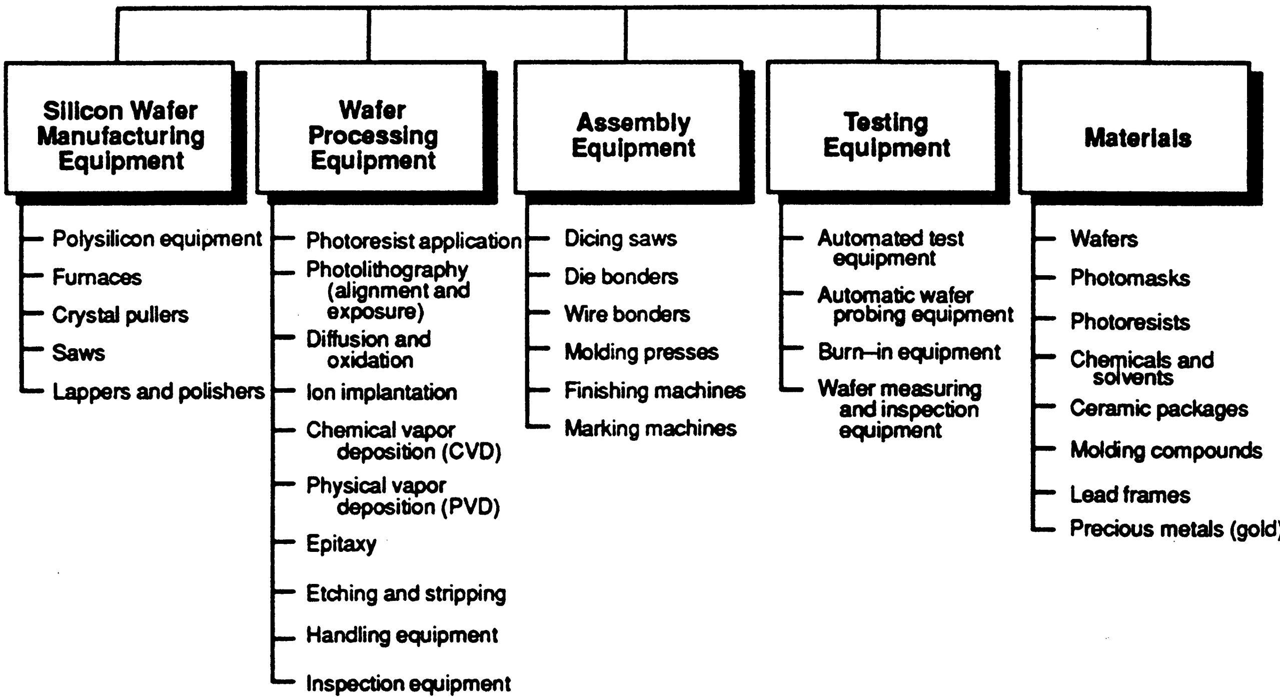
This study assesses the performance of the SEM industry during 1980-90, a period in which four generations of semiconductor devices and three generations of SEM were produced. The study examines the various factors that affected the industry and contributed to the decline of the U.S. industry's competitiveness during the period. The study concentrates on the competitiveness of the U.S. and Japanese industries, which are the principal SEM producers, and to a lesser extent, on the industry in Western Europe.[4]

Competitiveness

Because the recent public discussion of "competitiveness" has used that term in a variety of senses, it is important to clarify what the term means in this report. The competitiveness of particular SEM firms is defined here as ***their ability to sustain relative global market position (sales volume and market share) and profit performance in the context of rapidly changing technology and markets.*** Sales volume, particularly when measured in market share, directly shows the firm's marketing success compared with its competitors. Profitability indicates the firm's business success and determines whether the firm remains in operation. These measures of competitiveness are applied not only to individual SEM firms, but also to the industry as a whole.

[4] The U.S. industry as treated throughout this study encompasses all firms headquartered in the United States. The production and sales of the affiliates of U.S. firms abroad is counted as U.S. production and sales. This same treatment is accorded the industries of foreign countries because (1) major decisions, (2) most R&D, and (3) much of the value in the foreign-made product (R&D, know-how, and critical components) are from/made in the headquarters country. Value data expressed in this study are in nominal terms.

Figure 1-1
Semiconductor manufacturing and testing equipment (SEM) industry[1]: Major product segments and products/processes



[1] See App. D for a detailed description of the principal types of equipment and materials applicable to each of the five segments comprising the SEM industry.

Source: Compiled by the staff of the U.S. International Trade Commission.

Competitiveness in the SEM industry is driven partly by customer demands for increasing SEM product performance, which customers seek in order to produce faster and more powerful silicon chips than their competitors. Most of the processing technology for the $61 billion worldwide semiconductor industry is provided by the $19 billion worldwide SEM industry. The cost of developing new generations of SEM products keeps increasing, and research and development expenses must be sustained at high levels even when demand is soft and the industry is not profitable. Competition maintains pressure on the structure and performance of the industry, and a change in technology can often alter the market shares of individual firms and their relative standing in the industry. The survival of a firm can hinge on its ability to be first to bring a new piece of equipment to the market.[5]

Information for the Study

The Commission collected information for this study from primary sources through interviews with key U.S. and foreign government and industry officials and through testimony provided by interested parties appearing at the Commission's public hearing (app. E). Information was also obtained from Semiconductor Equipment and Materials International (SEMI) and SEMI/SEMATECH, industry associations representing the SEM industry. In addition, information was obtained from officials of U.S. and Japanese SEM firms as to how they ranked the relative importance of the external and internal factors affecting the competitiveness of the SEM industry. Similar information was obtained from semiconductor firms as to how they ranked the relative importance of the criteria they used in their purchases of SEM. Reports and documents published by the General Accounting Office, the Congressional Research Service, the Semiconductor Industry Association, the National Advisory Committee on Semiconductors, the U.S. Department of Commerce, Integrated Circuit Engineering Corp., Dataquest, and VLSI Research, Inc. were reviewed for data and background on the industry.

Organization of Study

The remainder of chapter 1 provides an overview of the global SEM industries and background information on the principal producers. Chapter 2 reviews the literature concerning competitiveness in the SEM industry and summarizes industry, government, and academic views on industry competitiveness. Chapter 2 also provide a framework

[5] Congressional Research Service, The Library of Congress, *U.S. Semiconductor Manufacturing and Materials Industries: Economic Condition Since 1980, Prospects for Future Growth, and Policy Options for Strengthening Their Ability to Compete in Global Markets*, Sept. 26, 1989, p. CRS-12.

to analyze the factors affecting competitiveness in the industry.

Chapter 3 of this study assesses country-specific government policies that affect the competitiveness of the SEM industry, and examines U.S. trade and economic policies that have affected both the SEM and semiconductor industries during 1980-90. These include an assessment of relevant antitrust, tax, and intellectual property laws, tax credits for research and development, administration of foreign investment, and enforcement of U.S. trade statutes. Chapter 3 also addresses the issues of export controls and U.S. and foreign tariffs. Chapter 4 details the evolution of the industry over the past decade and analyzes the industry's performance on a global and country basis. Chapter 5 summarizes the study's principal findings.

Overview of the Global Industry

Background

In the early years of the SEM industry, U.S. semiconductor firms developed and produced the equipment they needed or modified standard equipment produced by outside suppliers. As demand for semiconductors increased in the 1960s and early 1970s, independent SEM suppliers emerged, specializing in the various product segments.[6] Over time, semiconductor manufacturing technology shifted away from the semiconductor firms to these more specialized producers of equipment and materials. In 1980, the world's 10 largest semiconductor manufacturing and testing equipment producers were located in the United States.[7]

During the 1970s, Japan recognized the importance of semiconductors to its electronics industries and the critical need to develop a viable equipment industry.[8] Through close cooperation with Japanese semiconductor firms, a number of Japanese SEM producers emerged, specializing in photolithography, testing equipment, automated wire bonders, and other segments of the industry. By 1980, Japanese equipment producers supplied 50 percent of the Japanese semiconductor equipment market and almost 20 percent of the world market.

Producers

Today, virtually all of the world's SEM producers are located in Japan, the United States, and Europe, although there are indications that Korea plans to develop a domestic industry to reduce its dependence on foreign suppliers.[9] The U.S. industry consisted of 850 companies in 1989, 73 percent of which are privately owned and 51 percent of which had sales of $10 million or less.[10] A large number of small firms entered the U.S. industry during the 1980s because of the specialized research and development demands in each of the five industry/product sectors, a mobile labor force that led to rapid diffusion of technological advances, and the initial availability and low cost of investment financing for start-up firms with innovative ideas.[11] Major U.S. firms include Applied Materials, Inc., General Signal Corp., and Varian Associates. These firms are leaders in etching and cleaning equipment, ion implantation equipment, and photolithography. While Applied Materials produces only semiconductor manufacturing equipment, General Signal and Varian produce a variety of other products such as analytical instruments and medical and industrial products.

In Japan, there are less than 100 firms producing semiconductor equipment. A large number of these firms have annual sales of less than $50 million. The structure of the Japanese SEM industry is similar to that of the U.S. industry in that a number of Japanese equipment firms are also large producers of other products. As an example, Nikon Corp., the world's largest producer of photo- lithographic equipment, is also a large producer of optical equipment, and Canon, the world's second largest producer of photolithographic equipment, is a large producer of semiconductors, electrostatic copiers, and consumer electronic products. Other than Nikon and Canon, the largest Japanese SEM firms are Tokyo Electron Limited, Advantest, and Kyocera. Tokyo Electron is world's largest SEM firm and is a major supplier of deposition and etching equipment. Advantest is a leader in semiconductor testing equipment, while Kyocera is a leader in the production of ceramic packages.

In contrast to the diversity and number of SEM firms in the U.S. and Japanese industries, the European industry is small. Less than 50 European firms produced SEM products in 1989. A majority of these firms have sales of less than $50 million, although certain suppliers in the industry are divisions of large European chemical and optical firms. Certain European suppliers are highly competitive, specializing in key technologies, such as the production of silicon

[6] A survey history of the equipment side of the SEM industry is provided by Jay S. Stowsky, "The Weakest Link: Semiconductor Production Equipment, Linkages, and the Limits to International Trade" (Berkeley Roundtable on the International Economy, Working Paper 27, August 1987). A shorter version of the same analysis is presented in Jay S. Stowsky, "Weak Links, Strong Bonds: U.S.-Japanese Competition in Semiconductor Production Equipment," in Chalmers Johnson, Laura D'Andrea Tyson, and John Zysman, ed., *Politics and Productivity: The Real Story of Why Japan Works* (Ballinger, 1989).

[7] These firms in rank order were Perkin Elmer Corp., GCA Corp., Fairchild, Varian Associates, General Signal Corp., Teradyne, Eaton Corp., Applied Materials, Kulicke & Soffa Industries, and Tektronix.

[8] Semiconductor Industry Association, *Japanese Market Barriers in Microelectronics, Memorandum in Support of a Petition Pursuant to Section 301 of the Trade Act of 1974, as ammended*, June 14, 1985, pp. 53-58.

[9] Staff interview with U.S. Minister Counselor for Economic Affairs, U.S. Embassy, Seoul, Korea, May 7, 1991.

[10] Semiconductor Equipment and Materials International, *Challenges Facing the U.S. Semiconductor Equipment and Materials Industry in the 1990's*, Apr. 1990, charts 3 and 4.

[11] Ibid, p. 11.

wafers and measuring, die-bonding, and photolithographic equipment. The largest European firms include ESEC of Switzerland and Wacker Chemical, Wild-Leitz, and Carl Zeiss of Germany.

Shipments and markets

Although Japanese producers significantly increased their share of the global SEM market during 1980-90, U.S. producers maintained a slightly larger share of the global market. U.S. producers supplied more than 45 percent of global shipments of semiconductor manufacturing and testing equipment in 1990, compared with about 44 percent supplied by Japanese firms. The global market for semiconductor equipment totalled $9.3 billion in 1990, and the world's ten largest SEM producers were U.S and Japanese firms as shown in the following tabulation (in percent):[12]

Firm	Share of 1990 global shipments
Tokyo Electron Limited (Japan)	7.8
Nikon (Japan)	7.7
Applied Materials (U.S.)	6.4
Advantest (Japan)	4.7
Canon (Japan)	4.7
Hitachi (Japan)	3.4
General Signal Corp. (U.S.)	3.2
Varian Associates (U.S.)	3.2
Teradyne (U.S.)	2.4
Silicon Valley Group (U.S.)	2.3
U.S. share	45.1
Japanese share	43.9

In contrast to U.S. producers' share of the global semiconductor equipment market, U.S. firms are not large suppliers of semiconductor processing and packaging materials. Japanese and German producers dominate the global materials market, which totalled $9.2 billion in 1990. Of the ten largest suppliers of these products in 1990, eight were Japanese firms and two were German, as shown in the companion tabulation (in percent):[13]

Firm	Share of 1990 global shipments
Kyocera (Japan)	6.8
Shin-Etsu Handotai (Japan)	6.1
NTK (Japan)	3.6
Sumitomo (Japan)	3.5
Huels (Germany)	3.1
Shinko (Japan)	3.1
Wacker Chemical (Germany)	2.9
Jasil-Siltec (Japan)	2.6
Osaka Titanium (Japan)	2.4
Mitsui High-Tec (Japan)	2.2
U.S. share	13.0
Japanese share	73.0

[12] Data for this tabulation was compiled by the staff of the U.S. International Trade Commission from data reported by Tokyo Electron Limited, Prime Data, and VLSI Research, Inc.

U.S. SEM firms are under competitive pressure in all of the semiconductor equipment segments (figure 1-1). U.S. firms no longer have a significant presence in photolithography, the most critical process in the wafer-processing segment of the equipment industry. Nikon Corp. of Japan currently produces about 50 percent of all wafer steppers (the largest product category of photolithographic equipment), which are critical to the production of leading-edge memory and logic chips. The U.S. industry is maintaining its relative market share in deposition and ion implantation equipment, but the U.S. industry's share of the global market for dry etch and diffusion equipment is declining. Foreign suppliers have also increased their share of the global market for assembly and testing equipment, and foreign suppliers dominate the market for processing and packaging materials, such as ceramic packages, lead frames, and silicon wafers. U.S. firms supply much of the domestic market for bulk chemical materials, such as gases, acids, and other chemicals, but the market for these products is relatively small.[14]

The size of the U.S. semiconductor industry increased by more than 50 percent during 1980-90, but the U.S. semiconductor industry's global market share declined substantially during the period. In 1980, U.S. semiconductor producers, including captive producers, supplied about 67 percent of the $17-billion global semiconductor market. In 1990, the global market for semiconductors had increased to $61 billion, but the U.S. industry's share had declined to 40 percent (figure 1-2). A healthy domestic semiconductor market is vital to the U.S. SEM industry because a local market is easier to supply.

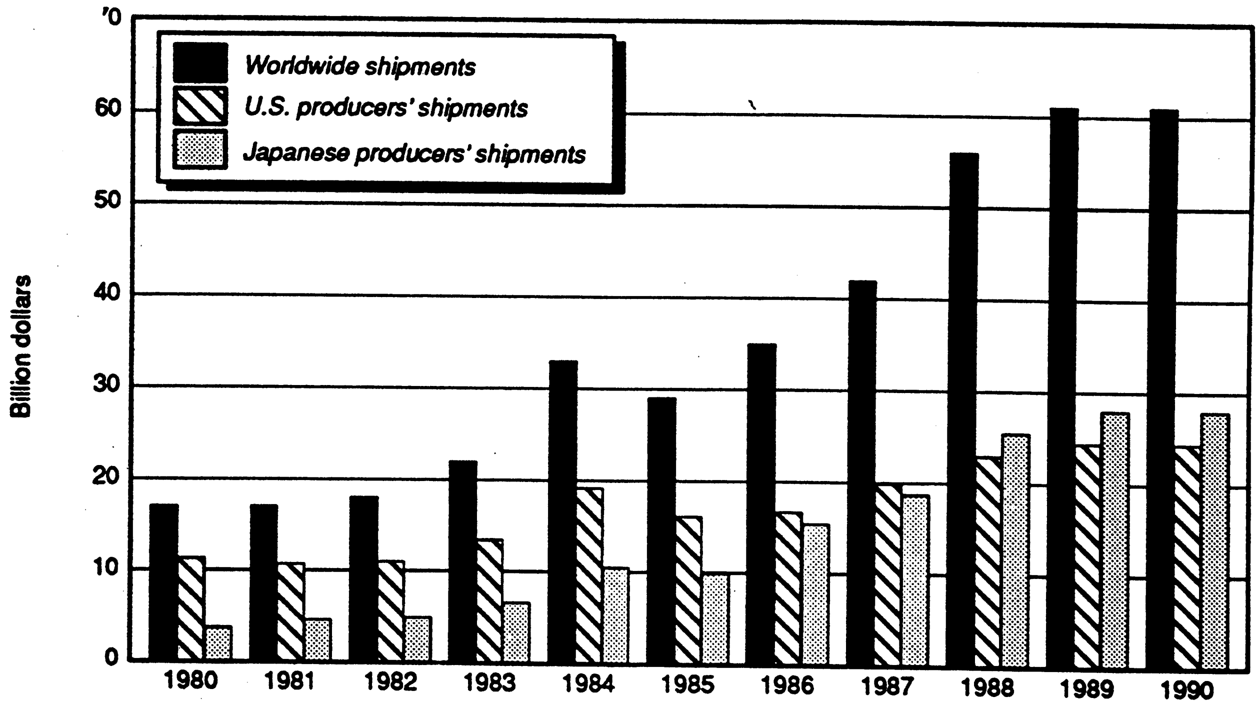
The loss of U.S. global market share in semiconductor manufacturing equipment followed the U.S. semiconductor industry's loss of market share by about four years. U.S. firms supplied about 75 percent of the $2.1 billion global semiconductor manufacturing and testing equipment market in 1980. In 1990, U.S. producers accounted for about 45 percent of global equipment shipments, which totalled $9.3 billion and Japanese producers accounted for 44 percent (figure 1-3).[15]

[13] Data for this tabulation were compiled by the staff of the U.S. International Trade Commission from data developed by Rose Associates and supplied by SEMI/SEMATECH.

[14] Ibid., p. 20.

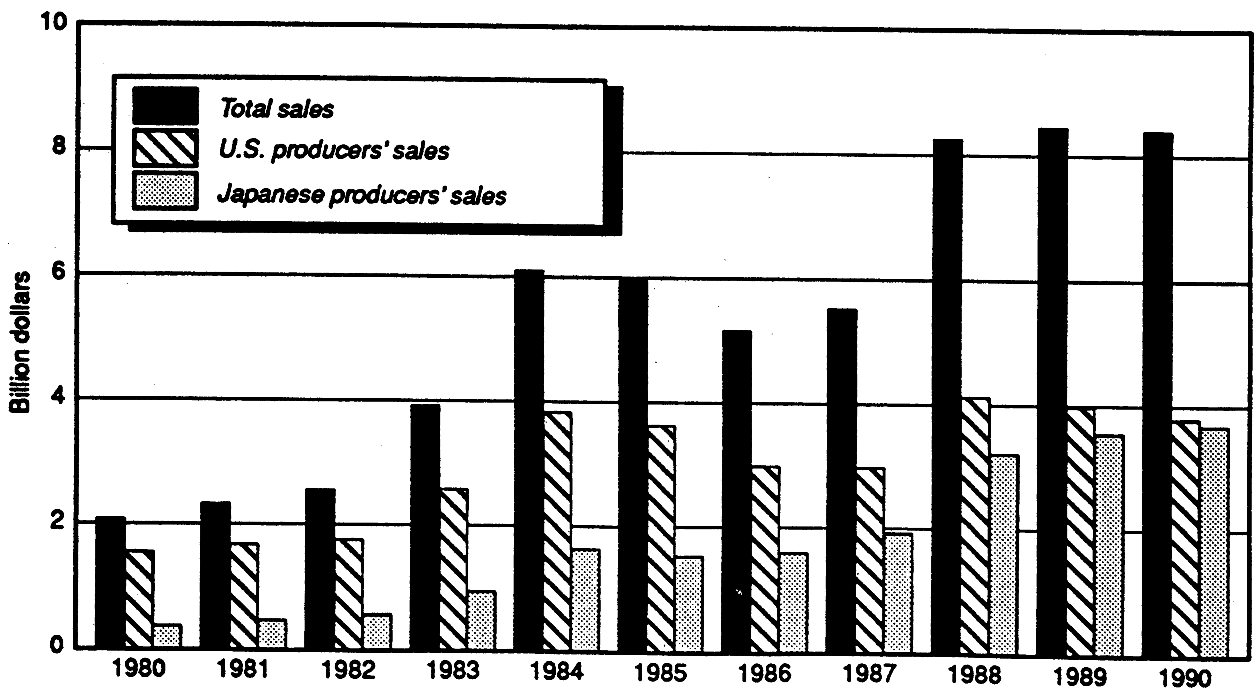
[15] The reported Japanese gain (in dollar terms) in market share during 1980-90 was magnified by a significant appreciation in the value of the yen. When output in Japan is converted from yen to dollars, the exchange rate affects market share and the value of shipments. During the period, the yen appreciated by about 40 percent, ranging from 128 to 168 yen to the dollar during 1986-90 compared with 225 to 248 yen to the dollar in 1980-85. According to a U.S. semiconductor firm, almost one-third of the Japanese gain in global semiconductor market share (when translated into dollars) in 1980 was brought about by the appreciation in the value of the yen.

Figure 1-2
Semiconductors: Worldwide shipments and shipments by U.S. and Japanese suppliers, 1980-90



Source: Integrated Circuit Engineering Corp., Dataquest, and other sources.

Figure 1-3
Semiconductor manufacturing and test equipment: U.S., Japanese, and total producers' sales 1980-90



Source: VLSI Research, Inc., Integrated Circuit Engineering Corp., Prime Data and other sources.

U.S. and Japanese semiconductor manufacturing and testing equipment firms are the largest suppliers in their respective markets, although U.S. firms are also the largest suppliers to third-country markets (figure 1-4). In 1980, the U.S. market for semiconductor manufacturing and testing equipment was twice as large as the Japanese market, but is currently 15 to 20 percent smaller. The U.S. share of the expanding Japanese market declined from 40 percent of sales in the early 1980s to about 15 percent in 1990.

A large number of semiconductor equipment producers serve the global equipment market, but a few firms supply a large share of each of the major product segments of the equipment industry (figure 1-5). In wafer-processing equipment, the top five firms supplied 87 percent of global shipments of photolithographic equipment in 1990, 80 percent of ion implantation equipment, and almost 75 percent of diffusion equipment. Suppliers in other segments of the semiconductor manufacturing and testing equipment industry are less concentrated.

Much of the SEM equipment produced during 1980-90 is installed in wafer-processing (wafer-fab) lines in North America, Europe, and Japan.[16] Of the 752 wafer-processing lines in operation in 1990 in these three regions, 54 percent were in North America, 30 percent in Japan, and 10 percent in Europe. However, a large share of the most advanced semiconductor plants are located in Japan where about 70 percent of the world's computer memory chips (DRAMs) are produced. This issue is addressed later in the report. A detailed breakdown of the location of wafer-fabrication lines by principal countries of origin is shown in figure 1-6.

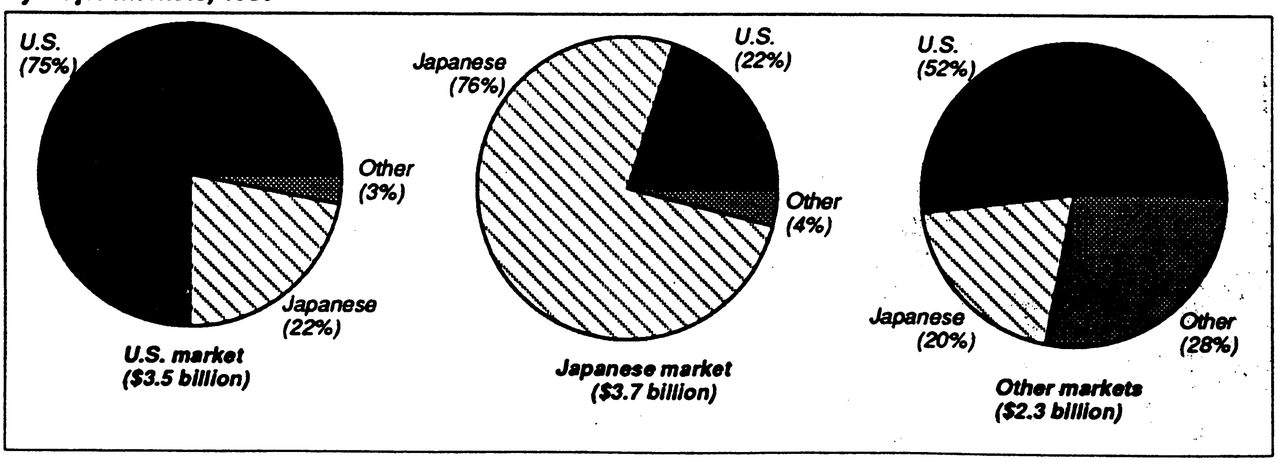
Assembly equipment and certain final testing equipment, on the other hand, are installed principally in developing countries in the Far East. Labor-intensive assembly operations, such as die bonding, wire bonding, and testing have largely been performed by U.S. semiconductor companies in developing countries since almost the beginning of the semiconductor industry in the 1950s.[17]

In response to foreign competition, many U.S. SEM producers continue to compete on the basis of their own resources, but some U.S. firms have entered into joint ventures with Japanese firms, and others have either merged with U.S. suppliers or have been acquired by foreign producers. As an example, Tokyo Electron, the largest firm in the global SEM industry, has entered into joint ventures with a number of U.S. firms. These include 50-50 joint ventures with Varian Associates in ion implanters; Thermco, Inc., in diffusion furnaces and plasma chemical-vapor deposition systems; and Lam Research, in dry-etching equipment. According to Tokyo Electron, 35-40 percent of its revenue is generated from importing products from the United States, including semiconductor manufacturing equipment. Eaton has a similar arrangement with Sumitomo Heavy Industries to produce ion implantation equipment. Examples of U.S. firms being acquired by foreign as well as other U.S. firms include GCA Corp. (photolithography) by General Signal Corp. (U.S.) and Materials Research Corp. (etching equipment) by Sony (Japan). In addition, the semiconductor and SEM industries have

[16] Semiconductor Equipment & Materials International (SEMI) list of semiconductor front-end lines, excluding front-end lines performing R&D, provided to the Commission staff on February 20, 1991, by SEMI.

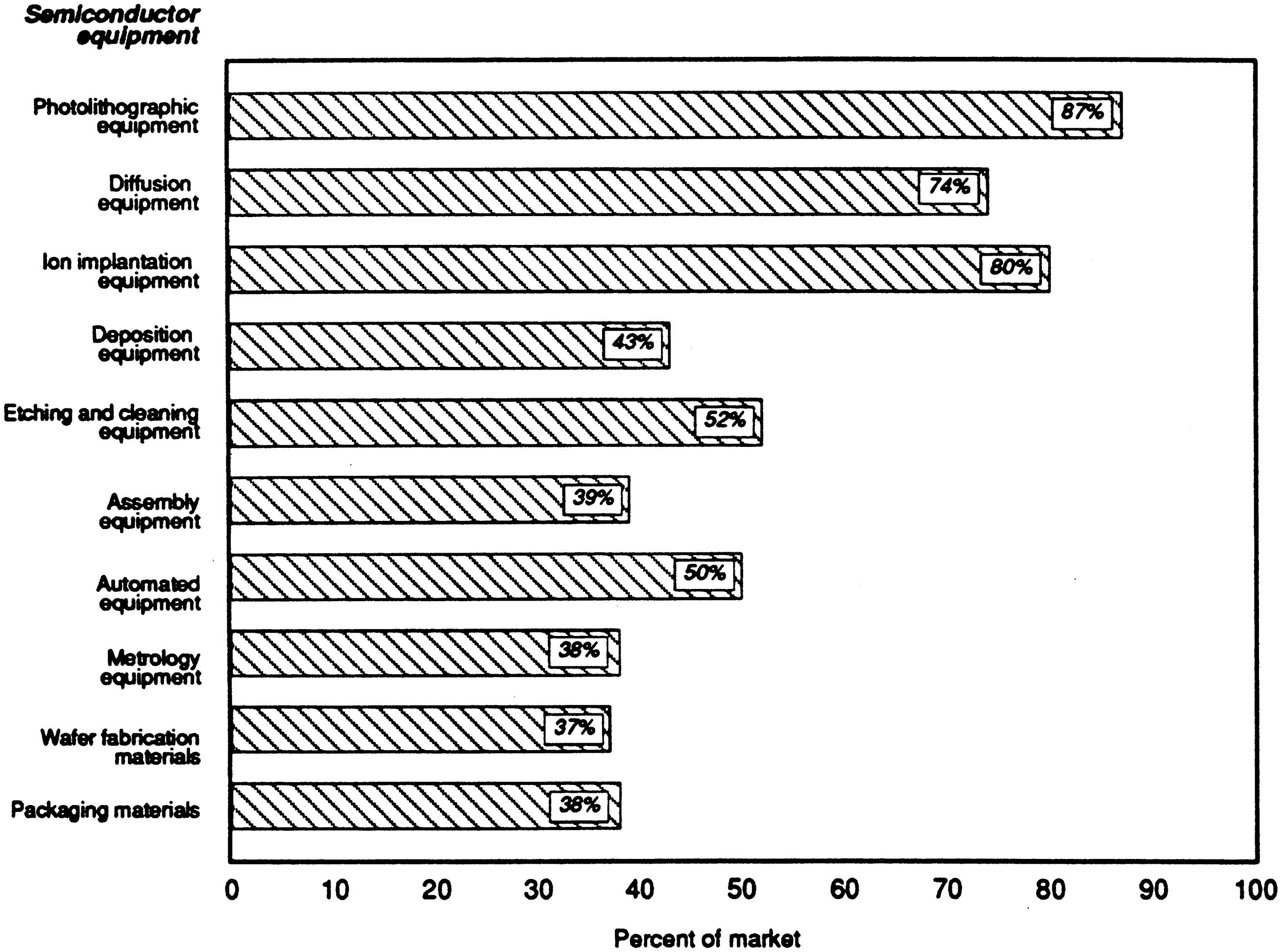
[17] Operations covering wire bonding, encapsulation, and testing of semiconductors are performed largely by U.S. semiconductor firms in Malaysia, Korea, Hong Kong, Singapore, and other developing countries in the Far East.

Figure 1-4
Semiconductor manufacturing and testing equipment: Market share of principal suppliers, by major markets, 1989



Source: VLSI Research, Inc.

Figure 1-5
Semiconductor manufacturing and testing equipment: Share of worldwide sales accounted for by top 5 suppliers, by major product category, 1990



Source: Japan Semiconductor Equipment Association.

established a research consortium (SEMATECH), which is financed jointly by the semiconductor industry and the U.S. Government to improve U.S. excellence in manufacturing technology.[18]

[18] The establishment of SEMATECH was first recommended by the Defense Science Board Task Force in February 1987 in its report on the U.S. semiconductor industry entitled, *Defense Semiconductor Dependency*. Fourteen U.S. semiconductor and computer companies formed SEMATECH in August 1987. These companies included Advanced Micro Devices, AT&T, Digital Equipment, Harris, Hewlett-Packard, Intel, IBM, LSI Logic, Micron Technology, Motorola, National Semiconductor, NCR, Rockwell, and Texas Instruments. Congress authorized the Department of Defense to participate in SEMTECH in December 1987. The objectives of SEMATECH are to develop with the assistance of member companies, universities, and government laboratories, leading-edge processes in 0.35 micron integrated circuit geometries, develop and demonstrate new semiconductor equipment and manufacturing process, and transfers these technologies to member companies. About 126 SEM firms, comprising an organization called SEMI/SEMATECH, are an important part of SEMATECH, supplying information and sharing technology.

Linkages with Semiconductor and Electronic Industries

The U.S. SEM industry provides, in its equipment, much of the processing technology that supports the $25-billion U.S. semiconductor industry. In turn, the semiconductor industry supplies many of the most advanced components that support the $266-billion U.S. electronics industry. The three industries are thus interlinked through both sales and technology (figure 1-7), and the competitiveness of each depends partly on the competitiveness of the others. As an example, the decline of consumer electronics production in the United States reduced sales opportunities for U.S. semiconductor firms. Similarly, the decline in U.S. production of DRAMs (computer memory chips), which require the most advanced equipment and materials, deprived the U.S. SEM industry of opportunities to develop and sell those products.

Furthermore, the presence of technologically advanced U.S.-based firms in each of the three industries improves the technology and competitiveness of the others. Technical cooperation between U.S.-based SEM and semiconductor firms improves the products of the former and the production capabilities of the latter,[19] while cooperation between semiconductor and electronics firms enables the latter to improve product performance by incorporating more electronic functions on increasingly complex silicon chips.[20]

Technological linkages also exist between the SEM industry and other industries. For example, many of the techniques, equipment, and materials used to produce integrated circuits on silicon wafers can also be used to produce flat-panel displays (such as liquid crystal displays) on glass substrates.[21]

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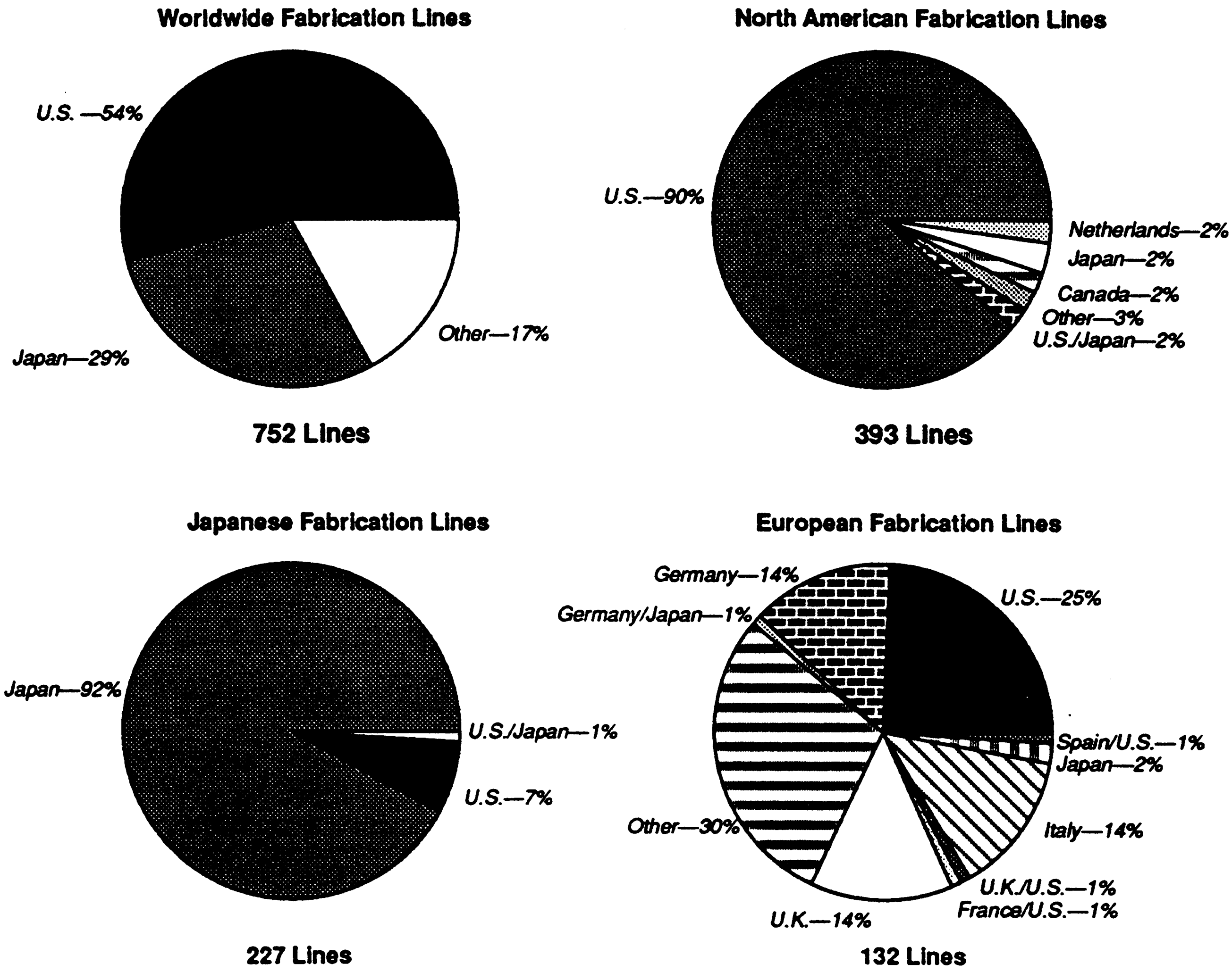
[19] This is discussed further in chapter 4.

[20] According to Integrated Circuit Engineering Corp., the semiconductor content of worldwide electronic equipment increased from 9.4 percent in 1983 to 12 percent in 1990.

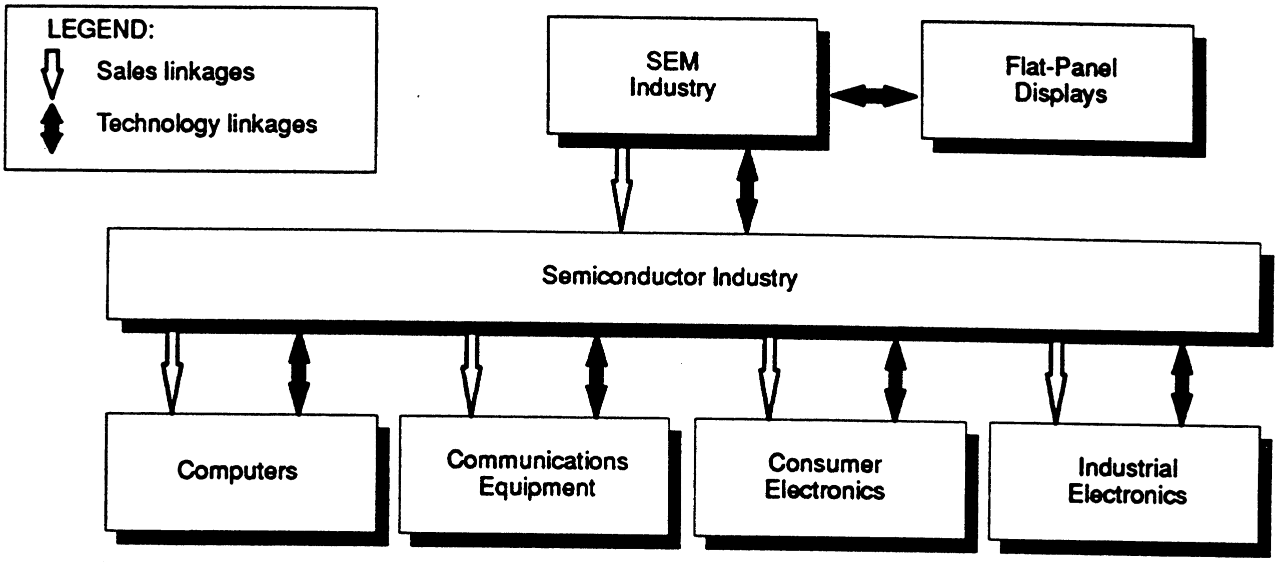
[21] National Advisory Committee on Semiconductors, *Toward a National Semiconductor Strategy* (Washington, 1991), vol. 2, p. 12.

Figure 1-6
Semiconductor fabrication lines: Location and ownership, by major market and principal producers' share, 1990



Source: Semiconductor Equipment and Materials International.

Figure 1-7
Linkages of the SEM Industry



CHAPTER 2
ISSUES IN INTERNATIONAL COMPETITIVENESS IN THE SEM INDUSTRY

Introduction

The international competitiveness of a firm (or a national industry) is essentially its ability to sell its products in head-to-head competition with foreign firms (or foreign national industries) while remaining profitable. The declining performance (both in world market share and in profits) of the U.S. SEM industry is, by definition, a loss of competitiveness. A variety of explanations have been offered to account for this loss. This chapter reviews these explanations and sets forth a framework of analysis for the present study.

The remainder of this introduction offers a brief overview of the general concept of competitiveness and how different factors may contribute to it. The following section focuses on competitiveness in the SEM industry in particular, presenting a framework of analysis that outlines the potential role of a variety of factors in determining competitiveness in the industry. The third section reviews previous studies of both the semiconductor industry and the SEM industry and notes the conclusions that these studies have drawn concerning which competitive factors are most important. The fourth section presents the views of industry participants concerning the factors contributing to the industry's decline. The concluding section summarizes the discussion.

The Meaning and Significance of Competitiveness

The international competitiveness of U.S. industries became a growing concern during the 1980s. Perhaps the most important reason for this concern was the decline in world market share and the palpable loss of U.S. technological leadership in several industries—including semiconductors and semiconductor manufacturing equipment—that were previously considered invulnerable to foreign competition. Other, related reasons include the emergence, during the 1980s, of persistent trade deficits of unprecedented size and the stagnation of real household earnings in the United States at a time when earnings continued to grow in such countries as Japan and Germany.

These developments suggest to some observers that the declining performance of particular U.S. industries may be more than a matter of misaligned exchange rates, high wages in some U.S. industries, and barriers to free trade—as important as any or all of these factors may be. Large segments of U.S. industry seem to have lost their ability to match their foreign competitors in productivity growth, technological change, and responsiveness to the desires of the market. Thus, they cannot be competitive in the price and performance of their products.

Part of this decline in competitiveness appears to have been inevitable. The United States could hardly have expected to hold its position in all the industries it dominated after World War II.[1] Observers increasingly believe, however, that comparative advantage (the economist's usual explanation for patterns of trade) is not simply the result of inevitable economic forces, but is to a large extent created over time through the interplay of three factors: the strategies of firms, the structures of industries and markets, and the policies of governments.[2] This perception has informed the recent discussion of competitiveness.

A nation's competitiveness in particular industries matters because it determines the extent to which the nation's productive resources, particularly its labor and capital, are put to relatively productive and remunerative uses that increase national income and raise the standard of living. In a trivial sense, U.S. industry could be "competitive" in world markets simply by adjusting exchange rates and reducing wages. But the result of these adjustments would be a reduction rather than an increase in U.S. national income. For this reason, the study by President Reagan's Commission on Industrial Competitiveness defined national competitiveness in a way that emphasizes its positive effect on a nation's standard of living:

> Competitiveness is the degree to which a nation can, under free and fair market conditions, produce goods and services that meet the test of international markets while simultaneously maintaining or expanding the real incomes of its citizens.[3]

This definition may be appropriate for defining national competitiveness, but it is unsuitable for the present study in two respects. First, this study does not consider the nation as a whole but rather particular firms and a particular industry. Second, this study considers the performance of SEM firms and the SEM industry under actual market conditions, whether or not these conditions may be characterized as "free and fair."

Measures and Determinants of Competitiveness

The definition of competitiveness as the ability to "produce goods and services that meet the test of international markets" suggests that competitiveness

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[1] Gavin Wright, "Where America's Industrial Monopoly Went," *Wall Street Journal*, December 20, 1990, p. A16.

[2] See Laura D'Andrea Tyson, "Competitiveness: An Analysis of the Problem and a Perspective on Future Policy," in Martin K. Starr (ed.), *Global Competitiveness: Setting the U.S. Back on Track* (Norton, 1988).

[3] U.S. President's Commission on Industrial Competitiveness, *Global Competition: The New Reality*, 1985, p. 6.

can be measured either in terms of results—for example, in sales, export performance, or profitability—or in terms of the factors that lead to competitive success, such as product performance, input factor costs, and productivity.[4] In order to eliminate possible ambiguity, the present study will distinguish between measures of competitive success and the factors that determine it. Thus the competitiveness of particular SEM firms, or the U.S. SEM industry as a whole, is defined here as their ability to sustain relative global market position (sales volume and market share) and profit performance in the context of rapidly changing technology and markets.

Observers generally agree that the competitiveness of a firm depends in large part on its own strategy and practices.[5] A firm becomes more competitive, for example, by improving the technology that is embodied in its products or in its production processes. This, in turn, depends on the firm's spending on research and development (R&D) and on the firm's skill in developing technology. Another factor affecting competitiveness is the firm's responsiveness to the market, i.e., the extent to which its product development takes into account the desires of customers.

A firm's competitiveness also depends on the structures of the firm itself, of its industry, and of its markets. In some industries, small, entrepreneurial firms develop the innovative products that capture markets. In other industries, only large, diversified firms have the financial and technological resources to develop products and establish a marketing presence in world markets. Strong domestic competition and domestic customers that demand superior products can stimulate firms to develop products that also prove competitive beyond the domestic market.[6] In these and other ways, industry and market structure help to determine which firms develop the strategies and practices that make them competitive.

Furthermore, competitiveness depends upon the features of the general economic environment and the policies of domestic and foreign governments. The cost and availability of capital, the cost and skills of the labor force, corporate tax policies, and directed subsidies all affect a firm's costs and its incentives to develop new products and to improve productivity. Trade policy directly affects the relative sales of foreign and domestic firms.

Analysts disagree on the merits of two particular types of policy practiced either by the U.S. Government or by foreign governments: industrial policy that is intended to promote particular domestic industries, and trade policy that restricts imports or promotes exports in particular industries.[7] It is on this point that two different perspectives on competitiveness can be distinguished. First, the laissez-faire approach is based on the presumption that free markets generate the most efficient allocation of resources. In this view, competitiveness is primarily the result of the general economic environment, cost conditions in an industry, and the actions of particular firms. Industrial policy or trade policy that favors one industry over another therefore tends to reduce national welfare rather than improve it. Second, the activist approach, which favors some combination of an industry-specific industrial policy with strategic trade policy, is based on the presumption that free markets do not necessarily select the industries that yield the most benefit for a national economy. As one trade policy expert recently explained, this approach emphasizes

> the reality that a number of high-technology sectors are characterized by imperfect competition that results from high fixed costs (huge costs of R&D and product development), increasing returns from economies of scale and potential to reduce costs through learning-by-doing. Government action on behalf of key sectors, it is asserted, can benefit national economies by (1) achieving "rents" or supranormal profits and higher wages, and (2) the production of externalities, or benefits that spread widely to other sectors of the economy. Also, nations which achieve "first mover advantage" may well be able to remain dominant in a particular technology for the foreseeable future and thus attain a permanent competitive advantage over its competitors.[8]

Advocates of the activist approach differ in their specific policy recommendations. Some emphasize special incentives for particular domestic industries, for example, while others call primarily for "managed trade" in particular industries. Some advocates see strategic industrial or trade policy as valuable no matter what other nations do, while others advocate such policies only as a means of either "leveling the playing field" for U.S. industries or else pressuring foreign nations to open their markets or refrain from unfair competition in the U.S. market.[9]

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[4] For a further discussion, see Gary L. Guenther, "Industrial Competitiveness: Definitions, Measures, and Key Determinants," Congressional Research Service, Feb. 3, 1986.

[5] See, for example, Michael L. Dertouzos, Richard K. Lester, and Robert M. Solow, *Made in America: Regaining the Productive Edge* (MIT Press, 1989); and Michael Porter, *The Competitive Advantage of Nations* (Free Press, 1990).

[6] See Porter, op. cit.

[7] Overviews of the issues in industrial policy and trade policy are provided by Chalmers Johnson (ed.), *The Industrial Policy Debate* (Institute for Contemporary Studies, 1984); and R. Lawrence and C. Schultze (ed.), *An American Trade Strategy: Options for the 1990s* (Brookings, 1990). In recent years there has been much more discussion of trade policy than industrial policy.

[8] Statement by Claude E. Barfield, Director of Science and Technology Policy Studies, The American Enterprise Institute, before the Ways and Means Committee, U.S. House of Representatives, June 4, 1991. It should be noted that Mr. Barfield does not himself advocate this view.

[9] Advocates of laissez-faire policies do not all disagree with the analysis used by promoters of activist policies, but they do disagree with the idea that this analysis can be an effective guide to policy. In the view of many laissez-faire advocates, policy formation is too far removed from detailed

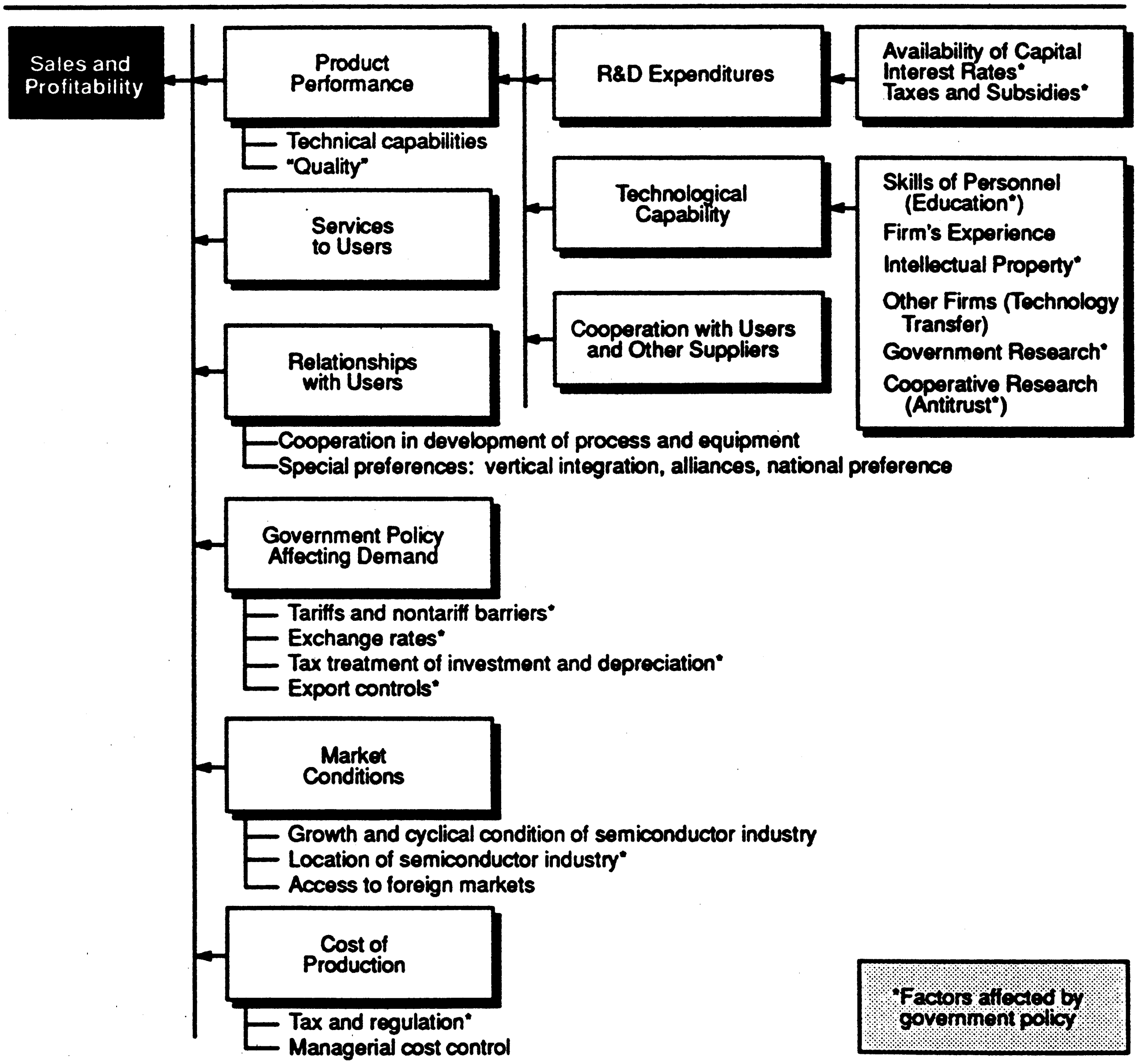
An Analytical Framework for Competitiveness in the SEM Industry

In order to consider the potential role of different determinants of competitiveness for the SEM industry in particular, this section introduces a framework of analysis for competitiveness in the industry. This framework helps to clarify the views of researchers and industry participants discussed later in this chapter, and it is applied more extensively for the analysis in chapter 4.

Figure 2-1 charts potential causal relationships among factors that industry participants and others identify as important for the competitiveness of a typical SEM supplier. The figure presents the sales and profitability of a SEM supplier as the principal measures of its competitiveness. The second column identifies six factors as direct determinants of sales and profitability. The first of these factors, product performance, is itself determined by the factors listed to its right. Items listed below each box describe important aspects of each factor.

9—*Continued*
economic information, and too politicized, to yield effective results.

Figure 2-1
Analytical framework for competitiveness in the SEM industry



The direct determinants of competitiveness are essentially the factors governing demand and supply for a SEM firm's products. The first four factors are the criteria that users of equipment emphasize in choosing among alternative SEM suppliers: the technical performance of the equipment or material, the services that suppliers provide along with their product, long-term relationships between particular suppliers and users, and government policies that affect demand for equipment and materials. The fifth factor, market conditions, affects the overall size of the SEM firm's market. The sixth factor, cost of production, represents part of the supply side of competitiveness.[10] While several of these factors depend primarily on actions by the SEM suppliers themselves, others reflect the structures of markets, the general economic environment, government policy, and other external elements.

Product Performance

Product performance includes, first, the technical capabilities of the SEM product. Among these capabilities are the minimum feature size (or linewidth) that photolithographic equipment and materials are capable of generating, or the wafer size (6 inch, 8 inch, etc.) that any equipment is able to handle. Second, product performance includes several attributes related to "quality." For equipment, these include reliability (often measured in terms of uptime) and throughput (number of wafers processed per hour). For materials, the most important issues of quality are purity, for chemicals, and absence of defects, for other materials.

The development of equipment or materials that perform competitively depends, as shown in figure 2-1, upon the firm's spending on R&D, upon the firm's technological capability (i.e., its ability to develop new technology)[11], and upon its cooperation with users. In turn, R&D expenditures depend, in part, upon the availability of capital, which may come either from the firm's retained earnings, a parent corporation, or capital markets. They also depend on interest rates as well as taxes and government subsidies that apply to R&D. The firm's technological capability is the result of, among other things, the skills of its personnel, the experience of the firm with the relevant technologies, and the firm's acquisition of technology from outside sources (such as other firms, government laboratories, and research consortia). The availability of technology from outside sources depends partly on government policy related to intellectual property rights, government research, and antitrust regulations.

Cooperation with users plays two roles in developing the performance of products. First, suppliers learn of customers' desires for the features of future products. Second, cooperation with users provides an opportunity to test new equipment under operating conditions and improve it before release. Furthermore, feedback from users after release can lead to additional improvements in the equipment.

Other Factors Affecting Choices of SEM Users

The value of a SEM product to users depends not only on the characteristics of the product itself, but also on the package of services offered by the supplier. The quality of product demonstration, training of operators or handlers, and equipment setup and maintenance all contribute to long-term sales performance.

An important extension of an SEM supplier's service to users is cooperation with users in developing both the users' production process and (as noted above) the supplier's product. Increasingly, SEM product users seek help from their suppliers in fine-tuning equipment (or improving materials) in order to improve process control. Cooperation encourages users to orient their process around a particular supplier's product, thus leading to continued sales for that supplier.

Other sorts of relationships between suppliers and users may lead to special preferences for a particular supplier's product. In some cases, users and suppliers are divisions of a vertically integrated firm, or they are involved in a strategic alliance. Common nationality also plays an observable role, although it is disputed whether this is due to factors other than the advantage of local suppliers in offering service and cooperation.

The fourth direct determinant of competitiveness in figure 2-1 covers government policies that affect SEM users' purchases. Tariffs and exchange rates affect the prices of imported products only, thereby influencing customers' choices between imported and domestic products. Tax treatment of capital investment and equipment depreciation affects the net price to the equipment customer of both foreign and domestic products, thereby influencing total purchases. Because equipment users tend to buy more domestic than foreign equipment, this tax treatment affects the domestic SEM industry more than the foreign industry. Other policies that may affect demand include nontariff trade barriers and controls on exports for reasons of national security.

Market Conditions and the Cost of Production

The demand that a SEM firm faces for its equipment also depends on market conditions facing its customers, which are firms in the semiconductor industry. That industry is a fast-growing but highly cyclical one, and its demand for equipment is more volatile than its production. The location of ownership and production in the consuming industry matters as well, inasmuch as SEM suppliers have historically held a greater market share in their local markets. A SEM firm's ability to establish a presence in foreign markets is another factor affecting its competitiveness.

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[10] Other aspects of the supply side are included among factors determining product performance.

[11] The "technological capability" of a firm should not be confused with "technical capabilities", which are characteristics of product performance.

Finally, competitiveness depends upon the cost of production. Lower input costs lead directly to higher profits and indirectly to greater sales, as they enable firms to price their products more competitively. Costs depend in part upon general economic conditions such as wage rates, upon taxes and regulations, and upon the effectiveness of management in controlling costs. What matters with respect to all these factors, of course, is not absolute performance but relative advantage, i.e., how a firm compares to its domestic and foreign competitors.

Firm Strategy, Firm and Market Structure, and Government Policy

Firms in the SEM industry affect their own competitiveness through their R&D efforts, through the quality of their service to and relationships with customers, and through their control over costs. The foregoing discussion suggests, however, that the competitiveness of SEM firms may depend not only upon these actions and strategies of firms, but also upon structural issues, in particular the structures of the firms themselves and of their markets, and upon government policy.

The structure of a firm in the SEM industry, that is, the firm's size and its degree of vertical or horizontal integration, may affect several factors related to the firm's competitiveness: its technological capability, its ability to establish a marketing and service presence in foreign markets, its access to capital, and, in the case of vertical integration, its access to an established customer base within the parent firm. Two potentially important aspects of the structure of a SEM firm's markets are the regional locations of customers and access to foreign markets.

Government policy may affect several of the factors related to competitiveness, as indicated by asterisks in figure 2-1. Trade policy, tax policy, exchange rates, and export controls affect the demand for the products of SEM firms, while taxes and regulations on SEM firms affect their cost of production. The tax treatment of R&D affects incentives to develop new technology. The firm's technological capability depends in part on intellectual property rights, research in government laboratories, government support of private research and antitrust law related to cooperative research. Furthermore, trade agreements and the enforcement of laws against unfair trade practices may affect the location of the SEM industry's customers. These matters are discussed at greater length in chapter 3.

Studies of the SEM Industry and the Semiconductor Industry

The recent decline in market shares of both the U.S. SEM and semiconductor industries has already led to several studies of the industries' decline and their prospects. Some of these studies have viewed recent events as resulting chiefly from differences in the strategies of firms, while others have emphasized factors outside of the control of firms. The biggest difference among the studies has been in their assessment of strategies pursued by the Japanese Government and industry.

This section considers first government studies, then studies by economists and other academic researchers, and then the recent reports of the National Advisory Committee on Semiconductors. This section focuses on both the SEM industry and the semiconductor device industry, because the industries are directly linked, and because similar factors appear to have been involved in the decline in competitiveness of each industry. They are both, for example, R&D-intensive industries facing the relative decline of their domestic downstream markets and a strong challenge from Japanese competitors. In addition, systematic differences between the strategic practices of U.S. and Japanese firms may affect both industries in similar ways.

Government Studies

The U.S. International Trade Commission's 1979 study of the U.S. semiconductor device industry[12] identified three developments that would recur in later discussions of the SEM industry: (1) the difficulty of U.S. firms in financing investment for future growth; (2) the acquisition of U.S. technology by foreign firms through licensing and the purchase of innovative U.S. firms, and (3) the favorable antitrust treatment, research funding, tariff and non-tariff barriers, and other advantages that foreign governments have provided to their domestic industries. The study also reported that foreign firms strategically used the large-scale production of semiconductor memory devices (DRAMs) to gain the experience and capability to manufacture increasingly complex devices. The study also noted the claims of U.S. producers that their Japanese counterparts used unfair trade practices, such as selling below fair market value, in order to gain market share.

The SEM industry has become the focus of interest more recently than the semiconductor device industry. In 1985, the U.S. Department of Commerce surveyed the competitive strengths and weaknesses of semiconductor equipment suppliers in the United States, Japan, and Europe.[13] The study identified

[12] U.S. International Trade Commission, *Competitive Factors Influencing World Trade in Integrated Circuits* (Washington, D.C., 1979).

[13] U.S. Department of Commerce, International Trade Administration, *A Competitive Assessment of the U.S. Semiconductor Manufacturing Equipment Industry*, Washington, D.C., 1985.

several factors that were enabling the Japanese industry to improve its market position relative to its U.S. counterpart. Some of these factors involved the practices and capabilities of firms. For example, the decline in the importance of major equipment design innovations, at which U.S. firms tend to excel, has favored the Japanese skill in incremental improvements in equipment. U.S. firms also suffer in the Japanese market, especially, from a reputation for poor service, slipped delivery schedules, and unmet technical specifications, and from a lack of marketing emphasis on the Japanese market.

Other factors identified in the U.S. Department of Commerce study involved industry structure. Japanese producers were found to benefit from the financial and technological advantages of vertical and horizontal integration, as well as from the economies of scale in marketing and maintenance service enjoyed by firms producing a greater number of products. U.S. firms were also found to be in a weaker financial position than Japanese firms, with the result that cyclical downturns in demand left them without sufficient funds to match their foreign competitors' R&D expenditures for improvements of equipment.

The study also found that Japanese suppliers benefit from the tendency of Japanese semiconductor firms to purchase equipment from other Japanese firms, and the promotion of the industry by the Japanese Government. Although all of these factors were contributing to a relative decline in the U.S. industry, the study observed that the U.S. industry was still the world market leader and concluded that it was likely to hold its position for the foreseeable future.

A 1989 report prepared by Congressional Research Service economist Gary L. Guenther[14] emphasized the impact on relative competitiveness of the locations of SEM markets, the presence of market barriers, fluctuating exchange rates, and differences in the cost of capital between the United States and foreign countries. It attached particular significance to foreign governments' industrial policies, which provide firms with tax breaks and direct financial support and which oversee the organization and partial funding of cooperative R&D programs.

In April 1991, the U.S. Department of Commerce issued a report on the implications for national security of the state of the wafer-processing segment of the U.S. SEM industry.[15] The report identified the location of semiconductor production as the most important factor in the competitiveness of equipment producers. The other major factors cited were the structure of the equipment industry, government support for research, and unfair trade practices in semiconductors and SEM equipment.

[14] Gary L. Guenther, "Economic Condition of U.S. and Foreign Producers of Semiconductor Manufacturing Equipment and Materials Since 1980," Congressional Research Service, Washington, D.C., September 1989.

[15] U.S. Department of Commerce, Office of Industrial Resource Administration, *National Security Assessment of the U.S. Semiconductor Wafer Processing Equipment Industry* (Washington, D.C., April 1991).

Academic Studies

Studies by economists and other academic researchers have addressed the competitiveness of both the semiconductor and SEM industries. A multidisciplinary team associated with the Berkeley Roundtable on the International Economy (BRIE) wrote a report on the semiconductor industry in 1982 for the Joint Economic Committee of Congress.[16] The report argued that a coherent national strategy was rapidly giving Japan a competitive advantage in semiconductor production. Part of this strategy was a focus by the Japanese industry on improving production methods and product quality in DRAMs, a high-volume commodity product, rather than on pioneering new technologies and pursuing rapidly changing markets. Another part of this strategy involved the cooperation of government and industry in controlling the domestic market in order to develop the national industry into a world competitive force:

> The emergence of Japanese competitiveness in world integrated circuit markets, like the more general national goal of creating comparative advantage, rests on a conscious state and industry strategy of controlling access to the domestic Japanese market, structuring the terms of domestic competition, making available stable sources of cheap capital, and using the controlled and structured domestic market as a secure base from [which] to gain entry and competitiveness in international markets.[17]

While the study acknowledged that the Japanese industry has real competitive strengths, it argued that the partial closure of the Japanese market introduced a substantial bias into world competition, favoring Japanese producers.

A 1989 article by another BRIE scholar applied a similar analysis to the semiconductor equipment industry. Jay S. Stowsky[18] explained the relative competitiveness of the U.S. and Japanese industries in terms of the structure of each national industry, relationships of each industry with its customers, and supportive government policies in Japan. The article found that the U.S. equipment industry has been entrepreneurial in character, with small, undercapitalized, financially vulnerable firms.

[16] Michael Borrus, James Millstein, and John Zysman, *International Competition in Advanced Industrial Sectors: Trade and Development in the Semiconductor Industry* (Washington: U.S. GPO, 1982).

[17] Ibid., p. 57.

[18] Jay S. Stowsky, "Weak Links, Strong Bonds: U.S.-Japanese Competition in Semiconductor Production Equipment," in Chalmers Johnson, Laura D'Andrea Tyson, and John Zysman (ed.), *Politics and Productivity: The Real Story of Why Japan Works* (Ballinger, 1989). The article is largely based on an earlier paper, Jay S. Stowsky, "The Weakest Link: Semiconductor Production Equipment, Linkages, and the Limits to International Trade," Berkeley Roundtable on the International Economy, Working Paper 27 (August 1987).

According to the article, problematic relationships with the semiconductor industry had left a legacy of antagonism. In Japan, by contrast, equipment producers have largely been divisions of large, integrated firms, and government-sponsored research projects have fostered productive cooperation between users and suppliers. Indeed, equipment users in Japan have taken the lead in promoting the development of Japanese suppliers. In relating this story, the factors that Stowsky presented as most important were industry structure, the presence of a sophisticated domestic market, close cooperation with customers, and government industrial policy.

In contrast to the 1982 BRIE study, two later studies by economists suggested that the relative competitiveness of the U.S. and Japanese semiconductor industries resulted primarily from differences in the strategies of firms and the respective business environments, rather than from relative access to each other's markets. A 1984 study by a team of both U.S. and Japanese economists, *Competitive Edge*,[19] tended to minimize the differences between the two national industries, and found strengths in both. A 1987 study by U.S. economists, *Microelectronics: An Industry in Transition*,[20] identified important differences between the typical strategies of U.S. and Japanese semiconductor firms. The study found that U.S. firms pursue innovative product design in a broad range of products, while Japanese firms pursue low-cost production of high-volume standardized products. The study also suggested that U.S. firms pioneer new market segments, while Japanese firms pursue a "fast second" strategy of using superior production efficiency to gain market share in these segments. Furthermore, U.S. firms tend to abandon heavily contested markets, while Japanese firms seldom leave a market, even if they lose money for an extended period. The study suggested that the Japanese strategy appears unbeatable, and that U.S. firms may be making a mistake in abandoning the DRAM market, as production of DRAMs gives firms the technical skill to produce other products as well.

More recently, a team of two economists used an economic modelling exercise to demonstrate the potentially great importance of market closure for the competitiveness of the U.S. semiconductor industry. Richard Baldwin and Paul Krugman[21] used a numerical simulation of learning curves in the production of 16-kilobit (16K) DRAMs[22] to consider how Japanese market closure may have changed the relative costs of Japanese and U.S. producers. The study found that restricted U.S. access to the Japanese market may have completely reversed the comparative advantage of the two national industries, so that instead of U.S. firms having the lowest costs and supplying all the 16K DRAMs used in Japan, Japanese suppliers became the low-cost producers and gained both their own domestic market and much of the U.S. market.

A recent article by Gregory Tassey, economist at the National Institute of Standards and Technology,[23] focused on the importance of industry structure, particularly vertical and horizontal integration, in the semiconductor industry. Among the benefits of vertical integration between semiconductor producers and consumers, according to Tassey, are greater volume of production and economies of scale, better market-relevant information for the design of semiconductor devices, and increased financial resources for the R&D needed to remain competitive in technology. Horizontal integration, that is, the production of a wide range of semiconductor and other devices using similar production technology, on the other hand, enables firms to apply their expertise in the production of one product to the production of others as well. Tassey expressed doubts that the U.S. industry can become competitive with Japan in the long run unless there are major structural changes.

National Advisory Committee on Semiconductors

In contrast to reports noted above, the 1989 report of the National Advisory Committee on Semiconductors (NACS), *A Strategic Industry at Risk*,[24] emphasized the roles of factors outside the semiconductor industry itself on competitiveness.[25] The report found, first, that the U.S. industry was at a disadvantage in its business environment. Foreign firms gained advantage from greater access to low-cost

[19] Daniel I. Okimoto, Takuo Sugano, and Franklin B. Weinstein (ed.), *Competitive Edge: The Semiconductor Industry in the U.S. and Japan* (Stanford, California: Stanford University Press, 1984).

[20] Richard N. Langlois (ed.), *Microelectronics: An Industry in Transition* (Unwin Hyman, Winchester, MA, 1988).

[21] Richard E. Baldwin and Paul R. Krugman, "Market Access and International Competition: A Simulation Study of 16K Random Access Memories," in Robert C. Feenstra (ed.), *Empirical Methods for International Trade* (MIT Press, Cambridge, MA, 1988).

[22] A learning curve (or experience curve) plots the average cost of production as a function of the cumulative volume of production. Analysts have discovered downward-sloping learning curves in a wide variety of industries where "learning by doing" takes place on the production line. Baldwin and Krugman apply an estimate by the U.S. Office of Technology Assessment that the cost of producing a given semiconductor device declines by 0.28 percent with every 1-percent increase in cumulative production.

[23] "Structural Change and Competitiveness: The U.S. Semiconductor Industry," *Technological Forecasting and Social Change*, vol. 37 (1990), pp. 85-93.

[24] National Advisory Committee on Semiconductors, *A Strategic Industry at Risk* (Washington, D.C., 1989).

[25] For example, while the report acknowledges that the U.S. industry has suffered from its past lack of attention to quality, and from adversarial relationships between suppliers and customers, it treats these factors as the result of the general business environment rather than the industry's own practices.

capital, from better training of a manufacturing workforce, and from differences in legal practices (particularly in protection of intellectual property and antitrust laws). Foreign firms also benefited from industrial and trade policies, such as market closure in their home markets and dumping abroad, which promoted steady sales and predictable returns for the foreign firms but unstable and unpredictable markets for U.S. firms.

Second, the report found that the U.S. industry was at a competitive disadvantage due to the shift in location of its major customers, principally industries producing electronic products, to the Far East. U.S. semiconductor producers had a relatively low share of the market for their products in Asia, especially in Japan.

Third, the report found that U.S. firms were at a competitive disadvantage in financing the development of technology, particularly in paying for large, long–term investments in technology for products and processes that will be critical in future markets. Much of this development could be done cooperatively at a "pre–competitive" stage of research, but U.S. firms found it difficult to share their research with competitors or equipment suppliers. The report viewed the industry research consortium SEMATECH as a necessary but insufficient response to this problem.

In 1990 and 1991, NACS issued follow–up reports related to each of these three areas. The first, *Preserving the Vital Base*[26] addressed the development of technology in the SEM industry. This report was concerned primarily with documenting the industry's difficulties and pressing the case for government assistance. To the extent that it gave reasons for the U.S. SEM industry's relative decline, it pointed to problems in financing the R&D needed to remain competitive in technology. According to the report, U.S. firms are hindered in this regard due to lower market share, higher costs of capital, and higher required rates of return for the U.S. industry than for foreign competitors.

The second follow–up report, *Capital Investment in Semiconductors*,[27] went into more detail on the provision of low–cost capital. The third follow–up report, *Regaining Markets in High–Volume Electronics*, addressed the importance of, and barriers to, the development of domestic electronics industries that support the U.S. semiconductor industry. This last report appeared as Volume II of NACS's second annual report, entitled *Toward a National Semiconductor Strategy*.[28]. Volume I of that report contained both a summary of the NACS's recommendations to date and a proposal that the U.S. Government facilitate the development of U.S. suppliers in three emerging high-volume electronics industries: (1) broadband communications networks; (2) advanced display systems, incorporating flat-panel displays, microprocessors, and software; and (3) intelligent vehicle and highway systems.

Views of Industry Participants

This section presents the views of persons in the U.S. SEM industry, the U.S. semiconductor industry, and the SEM and semiconductor industries of Europe and Japan on competitiveness in the global SEM industry. It sets forth industry participants' explanations of the relative decline of the U.S. SEM industry, the difficulties of the European industry, and the rise of the Japanese industry. It also presents their views as to what can be done to improve the U.S. SEM industry's competitiveness.

Views of the U.S. SEM Industry

Participants in the U.S. SEM industry acknowledge that the success of their Japanese competitors in the U.S. market is due partly to superior product performance, or, in some cases, to lower prices for comparable performance. Their views therefore emphasize apparent Japanese advantages in the development of product performance. Since the beginning of the Japanese challenge to their industry, U.S. SEM suppliers have pointed to differences between the United States and Japan in the general business climate and the degree of government support. They have suggested, for example, that Japanese suppliers have enjoyed a more available and less costly supply of capital for R&D, as well as greater government–supported R&D. U.S. SEM suppliers have also pointed to Japanese "targeting" of their industry in that the Japanese Government and industry have made a coordinated effort to establish a Japanese presence in the industry. Other factors that they see as having improved Japanese technology and product performance include Japanese purchases of technologically advanced U.S. SEM suppliers and Japanese acquisition of U.S. technology in other ways.

U.S. SEM suppliers generally see access to foreign markets as a problem even where product performance is not. They find it quite costly to establish a marketing and service presence in Japan, and they assert that Japanese SEM users show a strong bias in favor of Japanese suppliers. Until recently, they also viewed U.S. export controls as a major impediment to foreign sales.

In recent years, U.S. SEM suppliers have become increasingly self–critical in their assessment of factors governing competitiveness, particularly in acknowledging shortcomings in their own relationships with customers. Some in the industry also point to poor management and the small, under–capitalized nature of U.S. SEM firms as important sources of difficulty.

[26] National Advisory Committee on Semiconductors, *Preserving the Vital Base: America's Semiconductor Materials and Equipment Industry* (Washington, D.C., July 1990).

[27] National Advisory Committee on Semiconductors, *Capital Investment in Semiconductors* (Washington, D.C., 1990).

[28] National Advisory Committee on Semiconductors, *Toward a National Semiconductor Strategy* (Washington, D.C., 1991).

This section reviews views expressed by U.S. SEM industry participants in hearings before Congress and the U.S. International Trade Commission, in interviews with USITC staff, and in surveys conducted by the U.S. General Accounting Office and the USITC.

Congressional Hearing

In a congressional hearing in May 1990, U.S. SEM industry participants and others cited international differences in business climate, government support, and market access as reasons for the relative decline of the U.S. SEM industry.[29] The President of SEMI/SEMATECH, cited Japanese industrial targeting, the high cost of capital, export controls, and depreciation periods far in excess of equipment's economic life as important factors. An official of Intel Corp. (a seminconductor firm) enunciated several major themes for policy changes: reduction of capital costs (in part through changes in depreciation rules), investment and R&D tax credits, relaxation of antitrust rules, stronger international enforcement of protection for intellectual property, relaxation of export controls, and sponsorship of R&D consortia along the lines of SEMATECH. Other witnesses emphasized the foreign purchases of U.S. firms as a means by which U.S. technological leadership has been lost, and several emphasized the lack of access to the Japanese market as a factor weakening the competitiveness of U.S. SEM suppliers.

USITC Hearing

On January 17, 1991, the U.S. International Trade Commission held a public hearing on the global competitiveness of the U.S. SEM industry and two other advanced-technology manufacturing industries. Statements related to the SEM industry were presented by persons representing the United States Advanced Ceramics Association (USACA), SEMI/SEMATECH, SVG Lithography Systems, Inc., Semiconductor Equipment and Materials International (SEMI), ETEC Systems, Inc., and the National Institute of Standards and Technology (NIST).[30]

The Vice President for Public Policy and Administration of SEMI/SEMATECH cited factors involving both the United States and Japan. High capital costs and limited availability of capital have restricted U.S. R&D expenditures, according to this official, while Japanese competitors have had relatively abundant, low-cost capital, some of it provided by the government-sponsored Japan Development Bank. She also indicated that access to the Japanese market is restricted owing to the vertical integration of the Japanese electronics industry and to Japanese government efforts to make that industry self-reliant in devices and equipment. The U.S. SEM industry itself, according to this official, has been characterized by bad management practices, lack of emphasis on product quality, and poor relationships with its customers (all problems that the industry is working to correct, with SEMATECH's help). Finally, the official suggested, the U.S. Government has taken a laissez-faire attitude to foreign competitive strategies, not recognizing their long-term effect on U.S. high-technology industries and national economic welfare.

The SEMI/SEMATECH official made a number of specific recommendations for Government policy. In the area of capital costs and availability, she called for action on an investment tax credit, accelerated depreciation, improving the R&D tax credit, and providing low-cost Government financing. In the area of R&D, the official recommended coordinating the work of national laboratories, involving U.S. semiconductor equipment companies in the laboratories' programs and providing test facilities for their products, encouraging "teaming" (i.e., cooperative relationships between SEM suppliers and users), and continuing funding for SEMATECH. She recommended a new government policy on manufacturing to facilitate joint manufacturing efforts and remove the threat of treble damages under antitrust laws. In the area of market access, she indicated, the U.S. Government should institute a policy of reciprocity to limit imports from countries that restrict access of U.S. products to their markets, should monitor SEM imports to prevent unfair market practices, and should take fast action when such practices are found. Finally, the official recommended that, for the purposes of monitoring foreign acquisitions of U.S. companies, the U.S. Government should amend the definition of national security to include "economic stabilization and technological developments."[31]

The testimony of SEMI, presented by SEMI's Chairman of the Board (along with the Director of North American Operations and the Manager of Government Relations), emphasized the relative

[29] Subcommittee on Commerce, Consumer Protection, and Competitiveness of the Committee on Energy and Commerce, House of Representatives, *Decline of U.S. Semiconductor Infrastructure*, hearing May 9, 1990 (Washington, D.C.: U.S. GPO [Serial No. 101-149], 1990).

[30] See app. C for a list of persons representing these organizations. All of these witnesses represented the SEM industry itself except for Robert I. Scace of NIST. Scace argued that the SEM industry's competitiveness depends chiefly on the attributes of firms themselves, particularly in "technically competitive, high quality products at competitive prices; superior customer service; fiscal conservatism; and stable management with realistic objectives" (NIST testimony, p. 3). Government, by contrast, can do relatively little for the industry's competitiveness. It can alter the financial environment, make export controls easier, respond to cases of foreign discrimination against U.S. products, conduct relevant research in Government laboratories, and support technical education. Scace's policy recommendations emphasized

[30]*—Continued*

two areas: attracting students, both in public schools and universities, to technical careers; and conducting and sponsoring research, particularly in areas that prove to enhance industrial productivity and competitiveness.

[31] See Chapter 3 for information on foreign investment and acquisition.

decline of the U.S. market for SEM products and the rapid growth of overseas markets. SEMI indicated that Japanese dominance, particularly in DRAMs, leads to a strong demand for SEM equipment there and stimulates the development of the most advanced SEM products. The lack of a U.S. consumer electronics industry has also led to a lack of U.S. demand for semiconductors and, ultimately, for SEM products. In the broader U.S. economy, SEMI's testimony suggested, "the most serious problem is the short-term view of U.S. capital markets,"[32] so that investors lack the patience to support the development of new technologies or to sustain short-term losses in the course of competition. Furthermore, the U.S. tax structure discourages purchases of semiconductor equipment through the lack of an investment tax credit and unfavorable depreciation rules. U.S. tax treatment of capital gains and R&D were also felt to be problematic.

In general, SEMI's testimony did not give much attention to the importance of the U.S. SEM industry's own practices. It did, however, note that past problems in relationships between U.S. SEM suppliers and their customers made it difficult for SEM suppliers to maintain state-of-the-art technology, and that arm's length relationships left U.S. SEM firms to bear all the costs and risks of their own R&D. The latter factor was said to pose a particular problem for smaller U.S. firms given their dependence on current earnings. However, SEMI did not present this small size as a problem in itself but rather viewed firm size as an impediment to an adequate supply of funds for SEM suppliers' R&D. SEMI's recommendations for Government policy were general in scope, emphasizing four areas to be addressed: tax policy to stimulate demand for SEM products, government support of R&D in SEM products and new electronics technologies, trade policy that promotes exports rather than restricts imports, and improving the availability of capital at costs similar to those faced by foreign competitors.

An official of the United States Advanced Ceramics Association (USACA) emphasized his view of the importance for national security of maintaining domestic capabilities in ceramic packaging materials for semiconductor devices, particularly for military applications. (Ceramic packaging materials are supplied principally by Japanese-owned suppliers. One U.S. firm is seeking to reestablish a U.S.-owned presence in this product segment.) USACA recommended government support of the domestic advanced-ceramics industry through procurement policies (involving both domestic content and supportive prices), tax incentives for both suppliers and users, funding for government-sponsored R&D, and scrutiny of market segments dominated by foreign suppliers.

The President of SVG Lithography Systems, Inc., (SVGL) testified that the critical factors for competitive success in the SEM industry are, first, "sustained R&D investment to produce leading technology," second, "lasting partnerships to translate the technology into successful production systems" and, third, "global market access to gain critical market share to sustain continued R&D investments."[33] According to the official, Japan developed its SEM industry by applying this model, by acquiring technologies from the United States, and by nurturing local suppliers in segments where there previously were none.

The SVGL official's first recommendation for revitalizing the U.S. SEM industry was to build a consensus that the industry is critical for the United States and obtain an "endangered semiconductor equipment species act." Second, he recommended that the U.S. Government facilitate U.S. SEM technology by funding applied research, by making permanent an R&D tax credit, by improving review of sales of U.S. technologies to foreign firms, and by coordinating work on R&D and facilitating cooperative R&D. Third, he called for government incentives for partnering, both through funding for SEMATECH and other consortia that facilitate partnering, and through tax credits. Finally, he made two recommendations pertaining to market access: assistance to U.S. suppliers in investigating and documenting cases where they lacked equal access in foreign markets and provision of tax credits for the purchase of U.S. semiconductor equipment used in the United States.

The Chairman and CEO of Etec Systems, Inc., emphasized his view that, in several respects, U.S. SEM suppliers compete under rules that are disadvantageous relative to their foreign competitors. The problematical areas that he cited were export controls under COCOM, intellectual property rights, internal tax policy, technical education at all levels, and antitrust laws. He recommended the internationalization of the patent and copyright process, reduction of taxes for industries requiring large investments in R&D, an ROTC-like program to support college students pursuing training in science and engineering, and the reduction of antitrust-related restrictions on the cooperative actions of firms in the SEM and semiconductor industries.

USITC Staff Interviews

A roundtable discussion with U.S. SEM industry executives in November 1990 identified the cost and availability of capital, tax treatment of R&D and investment, and restrictive export control regulations as among the key factors affecting their competitiveness. By general agreement, the cost and availability of capital were viewed as the key determinants in the development of a new generation of semiconductor equipment. According to one participant, the supply of venture capital to the U.S. SEM industry has dried up in response to a perception that Japan has "targeted" the industry; that is, that Japanese suppliers intend to

[32] SEMI testimony p. 40.

[33] SVG Lithography testimony, p. 8.

take over major segments of the industry and will therefore offer stiff competition to U.S. suppliers.

Another problem cited by the participants is that U.S. purchasers of SEM products buy from all sources on the basis of economic criteria such as technology and price, while Japanese purchasers have a strong bias in favor of local suppliers. Furthermore, Japanese semiconductor manufacturers that produce in the United States use the same equipment (primarily Japanese) that they use in Japan. The participants also noted the lack of cooperation between U.S. SEM suppliers and users, a fact they attributed to fears that semiconductor manufacturers would share proprietary information with competing suppliers.

Further views from participants in the U.S. SEM industry were elicited in informal discussions during a SEM industry conference in January 1991.[34] Along with the adverse impact of U.S. tax laws relating to investment and R&D, two issues were raised often by those interviewed. First, U.S. investors are impatient for a return on capital investment. Both independent investors and parent corporations (where applicable) demand good financial performance on a short-term basis, thereby preventing firms from investing sufficiently in R&D to remain technologically competitive for the long term. Second, Japanese firms and the Japanese Government operate differently from U.S. firms and the U.S. Government. Japanese SEM suppliers sacrifice short-term profits in order to gain market share; Japanese SEM users tend to support their domestic suppliers even if it costs more, unless U.S. products are substantially better; and the Japanese Government takes a more pro-industry approach than the U.S. Government. Several industry executives suggested that these actions are to be admired and copied rather than complained about.

Conference participants cited several other factors as well: industry structure (the small size of many U.S. firms), which makes it difficult for U.S. SEM suppliers to establish a world-wide marketing and service network; antitrust laws that inhibit both mergers and cooperative research; the near total loss of DRAM production in the United States, which reduces demand for leading-edge products; and inferior quality-control and servicing on the part of U.S. SEM suppliers.

A subsequent letter from a SEM industry participant[35] focused on the implications of "the U.S.'s natural advantage [in] creativity, innovation, and rapid adaptivity to technical change" and Japan's relative advantage in "improving on the basic innovations done in the U.S. or other countries." As a result, U.S. firms compete best in an environment of rapid technological change, while a slower rate of change gives Japanese engineers an opportunity to "study, characterize, and improve upon the U.S. inventions." The writer suggested that his own company's success, even in Japan, was due to its strong efforts in R&D and to the continuing performance advantage of its products over competing Japanese products. "The U.S. loses ties in Japan; just as the Japanese lose ties in the U.S. To keep from having 'commodity' products which lose in Japan, the U.S. companies need products which have an advantage. This advantage will only come from superior research, development and manufacture of products that offer something more than is obtainable from Japanese manufacturers."

The writer argued that U.S. tax policy, particularly R&D tax credits for the SEM industry, can have a powerful effect in encouraging and facilitating R&D spending in the industry. He stated that an R&D tax credit would enable his own firm to expand R&D expenditures by several percentage points of sales. "We could be even stronger and participate in more related markets if we were able to pursue all the available ideas and enhancements which are known to us; but, of course, to do so now would cause us to become unprofitable. If, through R&D tax credits, [the firm] could increase its spending to about 30% of sales without it costing more than about 15% in real reportable costs, we could insure our leadership of the industry and pursue some very promising research proposals which would provide the industry with even greater capabilities. This same formula would work for other companies in the ... industry."

The writer also cited industry structure as a problem for U.S. SEM suppliers, but he suggested that little could be done to improve it. "American attitudes being what they are, most small companies won't surrender their independence, and loss of their control of their destiny, until there is no other choice. At this point, it is usually too late."

GAO Survey

A 1990 survey by the U.S. General Accounting Office (GAO) elicited the views of U.S. SEM suppliers concerning the relative importance of seven factors that have contributed to the decline of their industry.[36] The two highest rated factors, as noted in table 2-1, were the high cost of capital in the United States and poorer relations between U.S. SEM suppliers and users than between Japanese suppliers and users. These factors, rated between 7 and 8 on a scale of 1 to 10 (with 10 indicating the greatest importance), were followed by five factors rated between 5 and 6: low levels of investment by U.S. SEM firms, the structure of the U.S. SEM industry, the cyclical nature of the semiconductor market, low levels of R&D expenditure, and trade barriers. These eight factors, it may be noted, were selected by the GAO and do not reflect the full range of factors that the industry itself finds significant.

USITC Survey

During February-August, 1991 the staff of the ITC surveyed a broad range of U.S. and Japanese SEM

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[34] SEMI Information Services Seminar (Forecast Conference), Newport Beach, California, Jan. 21-23, 1991.

[35] Dated July 3, 1991.

[36] The survey drew responses from 31 of the 142 members of SEMI/SEMATECH, the organization of SEM suppliers that work with SEMATECH.

Table 2-1
Perceptions of U.S. SEM executives about factors contributing to the decline of their industry

Factor	*Rating (Scale of 1 to 10)*
High cost of capital in the United States	7.9
Poor relations between U.S. SEM users and their suppliers (compared to relations between Japanese SEM users and suppliers)	7.4
Low levels of investment in plant and equipment by U.S. SEM suppliers (compared to Japanese SEM suppliers)	5.9
Structure of U.S. SEM industry (i.e., a large number of small companies)	5.8
Cyclical change in the semiconductor market	5.6
Low levels of R&D expenditures by U.S. SEM suppliers (compared to Japanese SEM suppliers)	5.4
Trade barriers imposed by Japan and other foreign countries	5.1
Unfair pricing strategies by foreign competitors	4.2

Source: U.S. General Accounting Office, *SEMATECH's Efforts to Strengthen the U.S. Semiconductor Industry* (September 1990), p. 22.

suppliers on the factors that determine their competitiveness. Unlike the GAO survey, this survey did not ask specifically for factors that led to the U.S. SEM industry's decline, but respondents evidently emphasized the factors that have recently caused the greatest problems or advantages. Table 2-2 presents the average ratings given to various factors, with 1 indicating the greatest importance and 10 the least.[37] The responses of U.S. firms are discussed here, and responses of Japanese firms below.

The U.S. SEM industry generally gave its highest ratings to factors involving product performance and technology, followed by factors related to financial viability and factors related to market conditions. Product performance, technology, and R&D took three of the top five positions in the ranking, indicating the fundamental importance that SEM suppliers attribute to product performance and the activities that lead to it.

[37] This is the reverse order of the GAO survey.

Table 2-2
SEM industry ratings of factors in its competitiveness

Factors	*U.S. firms* Rating (1-10)	*U.S. firms* Rank Order	*Japanese firms* Rating (1-10)	*Japanese firms* Rank Order
Price/performance	1.66	1	3.63	6
Industry structure	2.00	2	5.43	13
Cutting edge technology	2.66	3*	3.08	3*
Market share	2.66	3*	4.52	8
Research and development	2.66	3*	2.92	2
Relations with semiconductor industry	3.25	6	3.08	3*
Foreign market access	3.50	7	5.52	15
Profitability	3.66	8	3.79	7
Health of domestic electronics industry	4.25	9*	3.17	5
Health of domestic semiconductor industry	4.25	9*	2.54	1
Loss of domestic DRAM industry	4.25	9*	6.86	19
Cost of capital	4.50	12	5.48	14
Availability of capital	5.00	13	5.38	12
Depreciation schedule	5.25	14*	7.13	21
Unfair trade practices (including dumping)	5.25	14*	7.26	22
Growth of domestic GNP	5.33	16*	4.70	9
Turnover of skilled labor	5.33	16*	4.88	11
Protection of intellectual property	5.50	18	6.43	18
Business cycle	5.66	19	4.71	10
R&D tax writeoff schedule	6.00	20	6.96	20
Export controls	7.00	21*	7.48	23
Lack of dependence on foreign firms	7.00	21*	5.57	16
Exchange rates	8.00	23	6.00	17

*Ties
Source: USITC survey.

Industry structure ranked second, apparently showing a belief that the small size of many U.S. SEM firms inhibits the firms from financing the R&D and other activities needed to compete. Two other factors related to the financial viability of firms, market share and profitability, ranked third (in a tie) and eighth, respectively. Two factors related to outside sources of finance, the cost and availability of capital, ranked somewhat lower, in 12th and 13th place. In the 1990 GAO survey, by contrast, cost of capital ranked first while industry structure was rated as less important. Two developments may account for this shift: the recent convergence of U.S. and Japanese interest rates, and a growing perception the U.S. SEM industry that its financial difficulties are due more to internal factors, especially industry structure, than to external factors.

Relations with the semiconductor industry ranked sixth in importance, reflecting the perceived value of technical feedback and a loyal customer base. The rating given this factor is approximately the same in this survey as in the 1990 GAO survey. Foreign market access ranked seventh, much higher in importance than the analogous factor in the GAO survey, trade barriers. Industry sources suggest that the difference here reflects the interpretations that respondents put on the listed factors: "trade barriers" are the result of government actions only while "market access" refers to a broader range of barriers arising from the structure of foreign SEM markets and the behavior of SEM purchasers.

Ranked slightly below access to foreign markets are three factors related to the strength of the domestic market for SEM products: the health of the U.S. electronics and semiconductor industries,[38] and the loss of domestic DRAM production. Other factors affecting the domestic SEM market—the depreciation schedule, growth of GNP, and the business cycle—receive a somewhat lower rating. Two factors affecting demand in foreign markets, export controls and exchange rates, ranked still lower. The low rating given to export controls seems to reflect a belief that the current process of revisions in export controls greatly reduces past problems in this area, while the last-place ranking of exchange rates probably reflects the favorably low value of the U.S. dollar at the time of the survey.

The rating (5.25) given to unfair trade practices suggests that the U.S. SEM industry does view this as a real problem, but not among the most important ones. Turnover of skilled labor, protection of intellectual property, and R&D tax writeoff were ranked further down. Dependence on foreign firms was ranked second lowest among surveyed factors, perhaps because sales to foreign purchasers are considered increasingly necessary.

[38] The Japanese SEM industry, by contrast, rated the health of its customer industry as the single most important factor. This may reflect a stronger linkage between the two industries in Japan than in the United States.

In general, the USITC survey results suggest that factors related either to the practices and structure of the SEM industry itself, or to conditions in markets, are viewed as more directly important for competitiveness than factors related to government policy. This may suggest that industry participants do not see government actions alone as likely to maintain or restore their competitiveness. However, it is also important to note that government policy can affect several of the more highly rated factors, such as technology, R&D, foreign market access, and the health of downstream industries.

Views of the U.S. Semiconductor Industry

The views of the U.S. semiconductor industry on the competitiveness of U.S. SEM suppliers are largely similar to those of the suppliers themselves. While participants in the semiconductor industry are less concerned than suppliers with the suppliers' difficulties in financing R&D, they emphasize equipment performance and quality, customer service, and supplier–user relationships as important factors in competitiveness. Significantly, they report that Japanese suppliers are often better in these matters than U.S. suppliers.

Through SEMATECH, the U.S. semiconductor industry has taken the lead in emphasizing to suppliers the importance of product quality and close supplier–user relationships. SEMATECH together with several major equipment users—notably IBM, Motorola, and Micron—also emphasize the importance of the U.S. semiconductor industry's support for its domestic supplier base with orders of equipment. In the 1990 congressional hearings cited in the previous section, Dr. Robert Noyce, the late President of SEMATECH, stressed that U.S. semiconductor manufacturers must both buy domestic equipment and provide feedback to their suppliers so that the suppliers might make incremental improvements to their products.

One U.S. semiconductor manufacturer reported that it chooses its equipment suppliers only 40 percent on the basis of its product and 60 percent on the basis of its responsiveness to the customer in service support, teamwork, and openness to change. This SEM customer also noted other factors affecting the competitiveness of U.S. SEM suppliers, including the perception of U.S. SEM purchasers that Japanese suppliers are more likely to survive, labor laws and work rules that prevent efficient allocation of workers, and the lack of education in math and science.

The USITC staff surveyed U.S. semiconductor manufacturers on the importance of various factors for the competitiveness of their U.S. suppliers (emphasizing equipment suppliers rather than materials suppliers). The results of this survey are presented in table 2–3.[39] The factors evaluated are those of direct concern to purchasers rather than the factors evaluated in table 2–2 above, which are of concern to suppliers.

[39] Survey covered 8 U.S. semiconductor producers.

Table 2-3
U.S. semiconductor industry's rating of factors affecting competitiveness of SEM suppliers

Factors	*Average rating*
System performance and flexibility	1.0
Customer support	2.0
Uptime	2.1
Serviceability	2.4
Throughput	2.7
Life cycle costs	2.8
Ability to work with supplier	3.3
Cost	3.3
Installation expense	4.5
Expansion capability	4.8
Size of each manufacturer's installed base	5.7
Financing terms	6.0
Breadth of product line	6.9

Source: USITC survey.

All the companies surveyed gave the top rating, 1, to equipment performance (meaning overall performance, including both technical capability and attributes of quality). The second-highest rating went to customer support. The four factors pertaining to equipment quality ranked next in importance, followed by the ability of suppliers and users to work together. The initial cost (price) of equipment ranked below all the factors pertaining to equipment performance and supplier-user relationships.

Views of Japanese SEM and Semiconductor Industries

In interviews and public comments bearing on competitiveness in the SEM industry, Japanese SEM and semiconductor firms tend to emphasize the role of SEM suppliers' own efforts rather than factors outside the supplying firms. In their judgment, Japanese SEM suppliers gained most of their home market from U.S. suppliers because U.S. suppliers failed to keep up in technology, failed to develop equipment with high reliability and throughput, failed to provide adequate after-sales service in Japan, failed to respond adequately to problems as they emerged, and failed to provide equipment adequately customized for customer needs. Japanese suppliers did these things, and they won their domestic market in successive segments of the industry as they overcame the technological lead of U.S. suppliers.[40]

Japanese suppliers and users generally disagree with the view that their market is closed to U.S. suppliers, although they acknowledge that many users prefer to buy from familiar sources, a practice that effectively favors Japanese suppliers. In order for U.S. suppliers to provide adequate customer service and respond to the needs of Japanese customers, they must establish a strong physical presence in Japan, either through a distributor that undertakes both service and engineering (largely customization), a joint research and production venture with a Japanese supplier, or a wholly owned subsidiary, preferably one that undertakes both R&D and production in Japan.

Japanese suppliers also reject the common view that government assistance plays a substantial role in their success. They emphasize that, while the Japanese government facilitated and provided some funding for the VLSI cooperative research project of 1975–79, for example, nearly all R&D has been carried out by private Japanese industry.

Other factors cited by Japanese suppliers and users as sources of competitiveness include placing engineers on the production line to note opportunities for improvement, the practice of making continual, incremental improvements in products rather than waiting for a new product generation to make changes, and nonlegalistic, supportive relationships between suppliers and users.

Japanese SEM suppliers and users also acknowledge the role of a wider variety of factors in determining competitiveness. Table 2-2, above, presents the ratings by Japanese SEM suppliers of the same factors rated by U.S. SEM suppliers. The differences between the two groups in their ratings are instructive.

Like the U.S. suppliers, Japanese suppliers ranked the three factors involving product performance,

[40] These factors are largely included among those to which Tokyo Electron Limited (TEL), the world's largest supplier of semiconductor equipment, attributes its success: (1) technological leadership, (2) strong bonds with customers, (3) joint development with customers, (4) credibility with customers, (5) the quality of after-sales service, and (6) quick customization of equipment (USITC staff interview in Japan, May 1991).

technology, and R&D within the top six places.[41] The first and fifth rankings, however, go to factors rated much lower by U.S. firms: the health of domestic semiconductor and electronics industries. Japanese suppliers evidently have a stronger sense of linkage between their industry and downstream industries, which may indicate that the actual linkage is stronger in Japan than in the United States. Similarly, Japanese SEM firms rank relations with the semiconductor industry third rather than sixth among the factors.

Japanese suppliers rank their industry structure 13th among the factors, which compares to a second-place ranking for the factor by U.S. suppliers. This suggests that Japanese suppliers may experience less of a constraint due to their industry structure than what U.S. firms experience. Another difference suggesting the contrasting situations of the two national industries is in foreign market access, ranked 15th by the Japanese and seventh by U.S. firms.

Views of European SEM and Semiconductor Industries

The European SEM industry's views about competitiveness are conditioned by the relatively small size of their local user base and the consequent urgency of selling in foreign markets. Thus, although European suppliers acknowledge the necessity of offering strong product performance and services to customers, they emphasize the importance of access to foreign markets and support from the domestic user base that they do possess.

In their view, the U.S. market is relatively open to their products, but the Japanese market is essentially closed. They believe that the high costs of establishing a presence in the Japanese market cannot, in most cases, be justified by the likelihood of sales success. Japanese semiconductor manufacturers will buy European (or U.S.) SEM products only if no Japanese supplier offers a comparable product. Furthermore, in the view of many European suppliers, if Japanese users do buy imported products, they seek to transfer the embodied technology to Japanese suppliers and then switch to Japanese suppliers at the earliest opportunity. Some European suppliers therefore scrutinize potential Japanese buyers and refuse to sell to those they deem interested primarily in passing machines on to potential Japanese suppliers (those that seek to purchase only one machine, for example). In this way they seek to prevent the establishment of a competitor that will later enter the European and U.S. markets. Other European suppliers accept copying as inevitable and expect to make only a limited number of sales before the market closes. Still others pursue a strategy of maintaining a technological lead over potential copiers.

European SEM suppliers see the rise of the Japanese semiconductor and SEM industries as the result, in part, of a "Silicon Valley Effect": that is, the mutual support of technologically inter-linked industries and product segments. In a similar way, they see the key to their long-term competitiveness (and that of U.S. SEM suppliers as well) in, first, the maintenance of a large, technologically advanced semiconductor industry in Europe and the United States and, second, in a commitment by that industry to support its U.S. and European supplier base, rather than purchase its most advanced equipment and materials from Japan. Without a strong U.S. or European technological capability and market share in all aspects of semiconductor and SEM technology, in the European view, the United States and Europe will fall further behind Japan in both industries and ultimately stand in danger of losing their competitive advantage in a broad range of electronics-using industries. While this will happen to Europe first, it will happen to the United States eventually as well, unless the U.S. and European industries form an alliance of mutual support.

European SEM suppliers also propose a U.S.-European alliance in government-assisted cooperative research. Both the Joint European Submicron Silicon Initiative (JESSI) program and the U.S. SEMATECH program are proving insufficient to match Japanese advances in technology, but by cooperating, the programs can reinforce each other.

Several European SEM suppliers noted that the European-based operations of IBM Corp. (and to some extent U.S.-based operations of IBM) have played a vital role in supporting their technological development both through purchases of products and through technical assistance. European-owned semiconductor manufacturers, by contrast, have often purchased Japanese SEM products rather than support their local suppliers. SEM suppliers acknowledge that these purchases have sometimes been by necessity, in that European semiconductor manufacturers have needed the best Japanese equipment for the sake of their own competitiveness. They warn, however, that reliance on Japanese suppliers will leave European users permanently behind their Japanese counterparts in the equipment available to them.

One major European semiconductor manufacturer agreed with this point, stating that Japanese equipment suppliers serve their major domestic customers first while other customers wait one to two years before getting new models of equipment. This manufacturer also noted that it has sometimes had difficulty getting timely delivery from Japan of SEM products that are not available from non-Japanese sources.

[41] The Japanese firms placed these factors in a different order than U.S. firms, however, emphasizing R&D efforts over their results in technology, and technology over its results in product performance. This suggests, possibly, that Japanese suppliers place greater emphasis on the process of product improvement while U.S. firms place greater emphasis on the result. (Whether this leads in practical ways to greater success in product improvement must remain a matter of conjecture.)

Conclusion

Observers of and participants in the U.S. SEM industry agree that the industry is continuing to decline in competitiveness. Outside observers explain this as the result of both external factors that favor the Japanese SEM industry, particularly the growth of the semiconductor industry in Japan, and differences in the practices of the U.S. and Japanese industries. In the past, the U.S. SEM industry explained its decline chiefly as the result of a more favorable business climate and government support in Japan, as well as the inaccessibility of the Japanese market. Increasingly, the U.S. industry sees its own practices, particularly its failures in quality control and relationships with users, as an important source of its problems. The Japanese deny that their market is closed and explain the difficulties of the U.S. SEM industry in Japan as the result of the industry's failure to meet Japanese users' expectations. Europeans acknowledge the importance of suppliers' practices and other factors in promoting competitiveness, but their emphasis is on the broader strategic implications of international competition. In their view, like that of researchers associated with the Berkeley Roundtable on the International Economy, Japan's great advantage is in the mutual support of its SEM, semiconductor, and electronics industries. According to this view, the United States and Europe together need technology and market share comparable to that of Japan in order to remain competitive in any aspects of the SEM and semiconductor industries, or ultimately in high–technology electronics as a whole.

This report will not be able to resolve all the tensions among these differing analyses. It will, however, examine in some detail the role of differences among the United States, Japan, and Europe in each of the factors identified as affecting competitiveness, including the technological and other linkages among industries emphasized by several observers and participants.

CHAPTER 3
GOVERNMENT POLICIES

The ability of government policies to influence, direct, foster, or impede the growth of high-technology industries has been debated among representatives of the business, government, and academic communities. The extent and type of attention which national governments pay to the SEM industry, or to industry in general, varies considerably among countries. Such variation may create important distinctions in the endowments of nationally-based companies as they enter the international market. To some degree, these variations reflect historical circumstances and cultural differences.

Some government laws and policies concerning national security, support for science and technology, and strategic industrial policy appear to have played a role in the development of the SEM industry. Among other things, these laws and policies have sought to encourage new product development, foster export growth, encourage the transfer of technology, and otherwise increase the competitiveness of domestic companies. Other laws such as those concerning unfair trade practices, export controls, and antitrust policies, while not designed specifically to affect the SEM industry, may also influence the competitiveness of the SEM industry.

This section discusses some of the principal government laws and policies that, according to U.S. industry representatives, affect the competitiveness of the U.S. SEM industry in the global marketplace. These include enforcement of trade laws, antitrust laws, export controls, and treatment of intellectual property.

Tax Law and Policy

The main components of U.S. tax law that were identified as affecting the SEM industry are corporate tax rates, depreciation schedules, research and development tax credits, and treatment of long-term capital gains. Of the four, research and development tax credits and depreciation schedules were identified as the most influential.

Because the industry is both a consumer and a producer of capital equipment, certain tax provisions affect the industry both directly and indirectly. For example, depreciation schedules affect the ability of SEM firms to write off the capital equipment they purchase as well as affect the ability of their principal customers, manufacturers of semiconductors, to write off the equipment they purchase.

The R&D tax credit, depreciation schedules, and treatment of long-term capital gains are regarded as important to investment, and hence to the competitiveness of manufacturers of SEM equipment. An R&D tax credit provides an incentive for research leading to new and better products. Depreciation schedules set out the recovery period for investment; generally, the shorter the cost recovery period, the faster the purchaser can recover the cost of new equipment purchase. Reduced tax rates for long term capital gains increase the attractiveness of equity investments and tend to decrease the cost of capital to firms.

R&D Tax Credit

The U.S. tax law allows a 20-percent tax credit on qualified research expenses which exceed the average amount of the taxpayers' yearly qualified research expenses in the base period. Generally the base period is the preceding 4 taxable years.[1] The term "qualified research" covers both in-house research and contract research expenses.[2] To be eligible for this credit, substantially all of the research must constitute elements of a process of experimentation related to a new or improved function, performance, reliability, or quality.[3] The credit is not allowed for such activities as research after commercial production, marketing surveys, foreign research, and computer software.[4]

The law is temporary and the provision was extended in 1990 for an additional year. The law is presently scheduled to expire on December 31, 1991. Industry representatives have argued that a long-term investment such as research is not encouraged by a temporary credit that may disappear in any given legislative year.

Depreciation

Rules regarding depreciation can have an important impact on the capital spending of both the SEM industry and its principal customer, the semiconductor industry. Shorter depreciation periods allow a firm to recover the cost of capital investment over a shorter period and facilitate quicker replacement of wornout or technologically obsolete equipment. Some countries, particularly Japan, allow faster write-offs than the United States. Representatives of the U.S. SEM industry have asserted that this difference places the U.S. SEM industry at a competitive disadvantage because it increases the cost of capital and reduces the demand for SEM products in the semiconductor industry.[5]

U.S. rules regarding the depreciation of tangible personal and real property have changed significantly several times since 1981. Most notably, the Tax Reform Act of 1986 supplanted the depreciation rules of the Accelerated Cost Recovery System (ACRS)[6] with the generally less generous rules that are known as the Modified Accelerated Cost Recovery System (MACRS).[7] Under MACRS, the cost of any semiconductor manufacturing equipment is generally

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[1] 26 U.S.C. 41(a) and (c).
[2] 26 U.S.C. 41(b)(1).
[3] 26 U.S.C. § 41(d)(3)(A).
[4] 26 U.S.C. § 41(d)(4).
[5] *Depreciation Schedules: Their Impact on the International Competitiveness of Semiconductor Manufacturers*, VLSI Research, Inc., 1990, pp. 1.3 and 1.4.
[6] ARCS was enacted in 1980.
[7] 26 U.S.C. 168(b)(4).

recovered over a 5-year period using the 200-percent declining-balance method and the half-year convention,[8] with a switch to the straight-line method in order to maximize the deduction.[9]

Capital Gains

Since passage of the Tax Reform Act of 1986, most capital gains have been taxable at ordinary income rates. Many companies have argued that they would benefit from lower long-term capital gains rates because lower rates would make equity capital investments more attractive to investors and reduce the amount of funds that had to be borrowed in capital markets.

Foreign Tax Policy[10]

Like the United States, Japan has adopted tax policies designed to stimulate research and development. However, Japanese incentives reportedly tend to be more directed to specific sectors.[11] The dispensation of tax incentives permits the Japanese Government to allocate incentives to achieve industrial policy objectives it deems appropriate, a practice that it has used to favor high-technology industries and encourage the modernization of declining industries. Japan reportedly has 19 different tax incentive systems to encourage technological innovation, including an R&D tax credit similar to that of the United States. In addition, since 1985, it has had a Key Technologies Tax Credit, equal to 7 percent of the acquisition cost of assets used in specified technologies or 15 percent of the corporate income tax, whichever is smaller. The list of research technologies eligible during the period of April 1, 1990 to March 31, 1993 reportedly includes a total of 132 different technologies, 30 of which have been identified as relating to semiconductor manufacturing equipment and production. [12] [13]

In contrast to U.S. rules, Japanese rules allow faster depreciation of semiconductor manufacturing and testing equipment, generally over a period of 3 or 4 years.[14] Moreover, Japan allows even more rapid depreciation for semiconductor manufacturing equipment that is operated more than eight hours a day.[15] A comparison of U.S. and Japanese depreciation schedules for a typical piece of semiconductor manufacturing equipment, wire-bonding equipment, is shown in figure 3-1.

Unlike the United States, most developed countries either do not tax individuals on their long-term capital gains[16] or tax them at a rate substantially below that for ordinary income[17] However, most developed countries tax corporations on their long-term capital gains at ordinary income rates.

Industry Views

Several industry groups have addressed the relationship between tax issues and the semiconductor

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[8] The half-year convention treats all property placed in service during any taxable year (or disposed of during any taxable year) as though it were placed in service (or disposed of) on the mid-point of such taxable year (e.g., July 1 in the case of a calendar year tax year). 26 U.S.C. 168(d)(4)(A).

[9] Using this method, the depreciation rate would be 20 percent in the first year, 32 percent in the second year, 19.2 percent in the third year, 11.52 percent in each of the fourth and fifth years, and 5.76 percent in the sixth year. The final amount is deducted in the sixth year because the half-year convention is applied in the case of the first year—the taxpayer is regarded as having placed the property in service at the mid-point of the first year regardless of when it was placed in service.

[10] Direct comparisons between U.S. and foreign tax laws, particularly those with respect to general corporate tax rates, or industry specific deductions, such as depreciation, tend to be difficult, if not placed in the broader context of the whole tax system.

[11] The material in this paragraph is from T. Howell et al., *The Microelectronics Race: The Impact of Government Policy on International Competition*, 1988, pp. 67, 132-33; and from John P. Stern, Vice President of the American Electronics Association, Technotax: How Japan's Tax System Spurs Technology," April 1991, pp. 5-12.

[12] The Key Technologies Center was created under the joint jurisdiction of MITI and the Ministry of Post and Telecommunications after Nippon Telephone and Telegraph (NTT) was "privatized". It is reported that Japanese officials wanted to avoid the loss of basic research funding that had characterized Bell Laboratories after the breakup of AT&T. The Japanese Government currently controls 90 percent of the shares of NTT, and must by law maintain ownership of two-thirds of the shares. Dividends paid on government-owned shares are funneled to the Key Technologies Center, which finances 60-70 technologies each year by making loans or by purchasing stock in companies. Capital equipment used in Japan in joint-research ventures may be written off in one year and donations to joint-venture research may be written off entirely as a tax loss.

[13] USITC field interview in Japan with staff of the American Electronics Association, May 14, 1991.

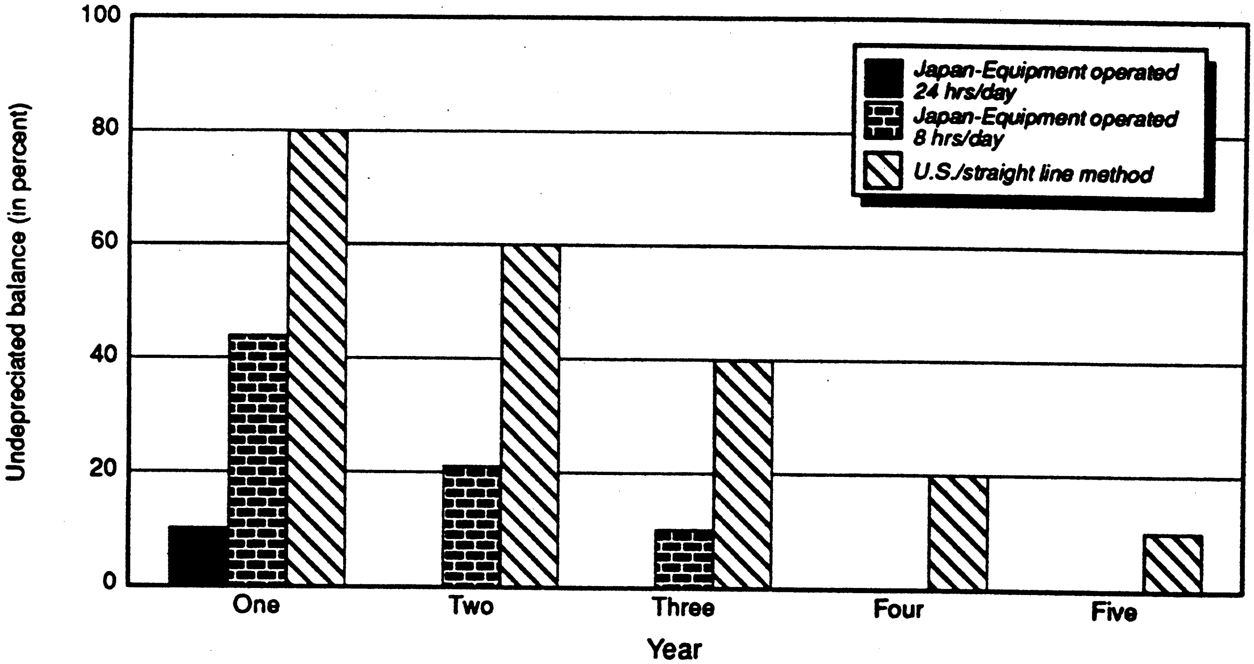
[14] Japanese depreciation schedules for certain semiconductor manufacturing equipment are as follows: 3-year depreciation schedules: diffusion furnaces; wire bonders; 4-year depreciation schedules: aluminum furnaces: burn-in furnaces; comparators; CVD devices; developing equipment; epitaxial growth equipment; glow bars; grinding equipment; IC testers; mask aligners; mask design equipment; mold presses; mounters; other inspection equipment; oxidizing equipment; precision reducing equipment; sputtering equipment; stepper equipment; temperature controllers; clean benches; 5-year depreciation schedules: developers; scribers; high-temperature baths; low-temperature baths; and 8-year depreciation schedule: other testing equipment.

[15] If a machine with an eight-hour official usage (substantially all semiconductor manufacturing equipment) is run twenty-four hours a day every day of the year, the excess depreciation allowed is roughly 5.6(16 x.35). Reizo Nakase, ed., Tables of Depreciable Assets (Genka shokyaku shisan taeyo nensu hyo) (Tokyo: Nozei kyokai rengokai, 1990), pp. 115-120 and pp. 368-369, as cited by Stern, p. 10.

[16] Germany, Switzerland, Korea, Taiwan, Italy, Belgium, and the Netherlands.

[17] Japan taxes long-term capital gains at a rate of 5 percent.

Figure 3-1
Wire-bonding equipment: Typical income tax depreciation schedules, U.S. and Japan, 1990



Source: American Electronics Association.

and the SEM industry. Tax policies are important to the SEM industry because they can have a direct bearing on the cost and availability of capital for investment and R&D expenditures.[18] The after-tax cost of U.S. capital reached a high of 13 percent in 1980, compared with only 3.5 percent in Japan.[19] While the difference in cost of capital between the United States and Japan had decreased by the late 1980s, the availability of much lower-cost capital in Japan during most of the decade probably enabled Japanese firms to make investments that would have been too costly to make in the United States. The cost of capital also affects investor time horizons. In general, the higher the cost of capital (particularly when coupled with a requirement to pay interest from the outset), the more investors are likely to favor investments with potential for short-term profits over those with potential for long-term profits.

In the fall of 1990, the National Advisory Committee on Semiconductors (NACS) published a working paper that recommended four actions in the area of taxation to facilitate the formation of capital and strengthen the U.S. semiconductor industry.[20] The four actions included: (1) making the research credit more effective by enacting it permanently and increasing the amount of the credit; (2) reducing the tax on long-term capital gains; (3) increasing personal savings incentives; and (4) improving semiconductor manufacturing equipment depreciation rules.

The NACS paper recommended that the depreciation schedules for semiconductor equipment be further shortened from the present level of 5 years.[21] Although the paper noted that the depreciation period had been shortened from 8 years to 5 years by the Tax Reform Act of 1986, it indicated that it was not uncommon in the semiconductor industry for firms to write off such equipment over 3 or 4 years for book purposes. The paper suggests that the industry "may not always be reaping advantages from accelerated depreciation, but rather paying a penalty for decelerated depreciation rates."[22] The Ad Hoc Electronics Tax Group expressed the view that equipment used in the electronics industry should "ideally" be depreciated over a 4-year rather than 5-year period.[23]

[18] The Federal Reserve Bank has reported that the cost of capital (discount rate) in the United States was higher than in any other industrial country in the 1980s. The Federal Reserve Board defines the cost of capital as "the minimum before-tax rate of return that an investment project must generate in order to pay its financing costs after tax liabilities." See "Explaining International Difference in the Cost of Capital", *Federal Reserve Bank of New York Quarterly Review*, Summer 1989, pp. 7-27. The discount rate, or cost of capital, is an indicator of investor expectations and the limitations governing an expected level of performance or profitability.

[19] Id.

[20] National Advisory Committee on Semiconductors, "Capital Investment in Semiconductors," Sept. 1990, pp. 1-3.

[21] Id., pp. 8-9.

[22] Id., p. 9.

[23] Ad Hoc Electronics Tax Group, "Working Paper on Research and Development/Capital Formation," Spring 1990, p. 14.

A study conducted by Quick, Finan & Associates for NACS indicated that shorter depreciation schedules would have a significant impact on the cost of U.S. capital and capital investment. Using a 3-year depreciation schedule, the study estimated that the cost of U.S. capital would decrease by 16 percent below current levels and that U.S. capital investment would increase by 11 percent. If a firm were allowed to write off in full the cost of equipment in the year the equipment was placed in service, the cost of capital would decrease by 29 percent and capital investment would increase by 26 percent. NACS concluded that shorter depreciation schedules would benefit both the semiconductor and SEM industry.[24] Another study of the semiconductor industry concluded that the country with the shortest depreciation schedules provides its industry with a significant competitive advantage.[25]

The NACS paper made three points with respect to the research credit.[26] First, the temporary nature of the credit makes it difficult for businesses to rely on it in their long-term planning, thus reducing its effectiveness. Second, the fixed-based percentage used to calculate the credit encompasses a period in which the U.S. semiconductor industry had an abnormally high ratio of R&D to sales, making it difficult for firms to qualify for the credit.[27] Third, the credit should apply to total R&D, with higher credit rates for firms that raise their ratio of R&D spending relative to sales by more than a certain percentage.

A working paper of the Ad Hoc Electronics Group on R&D and Capital Formation expressed similar concerns:

> Inconsistencies and uncertainties in U.S. tax provisions relating to R&D expenditures do not permit American industry to plan for R&D investments over the long run. Short-term extensions of the credit, sometimes after it has already expired, undermine industry's ability to plan for the future.[28]

The Ad Hoc Electronics Group asserted that the value of the credit was further diminished by the inability to use it to offset the alternative minimum tax and the inability to use the credit for certain types of R&D expenditures.[29]

Enforcement of Trade Remedy Laws

The U.S. Government uses a number of tools to respond to unfair trade practices, such as dumping and subsidies in world markets. The trade laws have also been used to address barriers to U.S. industries' access to foreign markets. The key laws that have been used to date by the semiconductor equipment manufacturers and their customers, the semiconductor producers, are the antidumping law and section 301 of the Trade Act of 1974. This section of the report provides a brief description of these provisions and identifies industry concerns regarding their effective enforcement.

Foreign investment in the U.S. industry has also been the subject of investigation under the Exon-Florio provision of the Omnibus Trade and Competitiveness Act of 1988. Accordingly, a brief description of this provision and industry concerns regarding foreign investment in U.S. firms is provided.

Trade Remedy Laws

Antidumping

Dumping generally refers to a form of international price discrimination whereby goods are sold in one export market at a price below the price at which such goods are sold in the home market of the exporter, or in its other export markets. Antidumping laws have been enacted by national governments to address this form of practice. Article VI of the General Agreement on Tariffs and Trade (GATT) and the GATT antidumping code provide international standards for antidumping actions.[30]

Trade Policies Governing Market Access

Access to foreign markets is important for the competitiveness of the SEM industry and its related industries. While the U.S. market is considered to be relatively open and free of barriers to foreign firms, the SEM and semiconductor industries have reported difficulties in gaining access to certain foreign markets.[31] The semiconductor industry has used the U.S. trade laws, such as section 301 of the Trade Act of 1974,[32] in an attempt to open markets. One of the key issues addressed in the 1986 U.S.-Japan Semiconductor Agreement was the opening of the Japanese market to foreign (U.S., European, etc.) semiconductors. The

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[24] *Capital Investment in Semiconductors, The Lifeblood of the U.S. Semiconductor Industry,* A Working Paper of the National Advisory on Semiconductors, Sept. 1990, p. 8.

[25] *Depreciation Schedules: Their Impact on the International Competitiveness of Semiconductor Manufacturers,* VLSI Research, Inc., 1990, pp. 1.3 and 1.4.

[26] U.S.C. 41(c)(3) states that "the fixed-base percentage is the percentage which the aggregate research expenses of the taxpayer for taxable years beginning after December 31, 1983, and before January 1, 1989, is of the aggregate gross receipts of the taxpayer for such taxable years." The fixed-base percentage is combined with the average annual gross receipts of the taxpayer for the 4 taxable years preceding the taxable year for which the credit is being determined to calculate the base amount which is used to determine the R&D tax credit. 26 U.S.C. § 41(a) and (c).

[27] *Id.*, p. 6.

[28] Electronics Tax Group, "Working Paper on Research and Development/Capital Formation," Spring 1990, p. 1.

[29] *Id.*

[30] Article VI of the GATT states—

> ...dumping by which products of one country are introduced into the commerce of another country at less than the normal value of the products, is to be condemned if it causes or threatens material injury to an established industry in the territory of a contracting party or materially retards the establishment of a domestic industry.

[31] More specifically, the industry has alleged problems with access to the Japanese market and, to a lesser degree, with access to the European Community.

[32] Section 301 of the Trade Act of 1974. 19 U.S.C. § 2411 (1991).

1986 Agreement was the result of negotiations undertaken after the U.S. semiconductor industry filed a section 301 petition.[33]

Sections 301-310 of the Trade Act of 1974 provide the President with the authority to enforce U.S. rights under international trade agreements and to respond to certain unfair foreign practices.[34] The Omnibus Trade and Competitiveness Act of 1988 ("1988 Trade Act")[35] amended section 301 to make it mandatory for the U.S. Trade Representative (USTR) to take action in cases of trade agreement violations or other "unjustifiable" practices.[36] In addition, USTR has discretionary authority to take section 301 action if it determines that "an act, policy, or practice of a foreign country is unreasonable or discriminatory and burdens or restricts United States commerce."[37]

The 1988 Trade Act also added additional authorities to section 301 commonly named "Super 301"[38] and "Special 301."[39] Under Super 301, USTR was required in 1989 and 1990 to identify trade liberalization priorities, including listing major barriers and trade distorting practices, designating "priority" foreign countries, and estimating the impact on U.S. exports of these practices by the identified priority foreign countries.[40] USTR was required to initiate section 301 investigations for all foreign countries identified and had discretionary authority to initiate similar investigations on the priority practices listed.[41] Similarly, Special 301 deals with identifying foreign countries that deny adequate and effective protection of intellectual property rights or fair and equitable market access to U.S. persons that rely upon intellectual property protection, with a similar requirement to undertake section 301 investigations.[42]

[33] The Agreement also includes provisions intended to prevent dumping of EPROMs and DRAMs settling dumping cases filed by the industry and self-initiated by the Commerce Department in the same time period as the section 301 action.

[34] 19 U.S.C. § 2411-2420 (1991).

[35] Public Law 100-418, approved August 23, 1988.

[36] 19 U.S.C. § 2411(a). The statute defines "unjustifiable" acts to mean any act, policy, or practice which "is in violation of, or inconsistent with, the international legal rights of the United States...[and] which denies national or most-favored-nation treatment or the right of establishment or protection of intellectual property rights." 19 U.S.C. § 2411(d)(4).

[37] 19 U.S.C. § 2411(b). The Act defines "unreasonable" acts to include "acts, policies, or practices, which— (i) denies fair and equitable— opportunities for the establishment of an enterprise,...protection of intellectual property rights, or market opportunities,...(ii) constitutes export targeting, or (iii) constitutes a persistent pattern of conduct that denies workers the right of association...." 19 U.S.C. § 2411(d)(3).

[38] Section 310 of the Trade Act of 1974, 19 U.S.C. § 2420.

[39] Section 182 of the Trade Act of 1974.

[40] 19 U.S.C. § 2420(a).

[41] 19 U.S.C. 2420(b).

[42] 19 U.S.C. § 2242.

Industry Views

Semiconductor producers and equipment manufacturers have recommended that the current antidumping law be amended to improve its effectiveness relative to high-technology products by speeding up the investigative process,[43] imposing special additional duties in the case of repeat dumping,[44] and establishing new safeguards to prevent and to address evasion of dumping remedies (anti-circumvention and third-country dumping).[45]

These producers and equipment manufacturers contend that enforcement of an effective antidumping law is important to the semiconductor equipment and its related industries.[46] The semiconductor producers indicate that dumping was the reason six of eight U.S. merchant DRAM producers exited the market during

[43] The semiconductor industry contrasts their continued success in EPROMs with their loss of DRAM share to illustrate the need to be able to obtain dumping relief on a timely basis where product life cycles are short (under four years). The U.S. industry continues to hold about 48 percent of worldwide market share in EPROMs despite findings of dumping in the 1985-86 period, on a scale similar to the DRAM case. The difference in outcome was reportedly due to the fact that the EPROM dumping case was filed and preliminary duties were imposed on Japanese firms at a point when the U.S. industry still had a significant share of the EPROM market. The industry recommends that a "fast track procedure be devised to provide for suspension of customs liquidation within 60-70 days of the filing of the petition, following an accelerated preliminary dumping determination." Semiconductor Industry Association, "Antidumping Law Reform and the Semiconductor Industry — A Discussion of the Issues," February 1990, pp. 29 and 30. (Under current law, generally if the administering authority and the Commission make affirmative preliminary determinations, suspension of liquidation of all subject imports occurs within 160-210 days of the filing of the petition. 19 U.S.C. § 1673b. If critical circumstances are alleged or short-life cycle products are involved, the suspension of liquidation may occur sooner. 19 U.S.C. § 1673b(b) and (e)).

[44] The semiconductor industry contends that U.S. antidumping laws have not deterred the Japanese firms which were held to have dumped DRAMs at margins greater than 50 percent (dumping margins of 74.35 percent to 106.72 percent were found for four firms) from dumping other electronics products. Between 1980-89, these four Japanese firms were found to have dumped in multiple cases at substantial margins. The industry has recommended that "to deter repeated and severe dumping, a firm that has dumped in the same product area (4-digit SIC industry definition) before and is now dumping at a margin that is significant, substantial, and severe (greater than 50 percent) should face additional penalties escalating with each repeat offense." Id, p. 32.

[45] Id., pp. 33 and 34.

[46] According to the industry, in the short product life-cycles of high-technology industries, the lag that presently occurs between the time when foreign firms begin "dumping" and when offsetting antidumping duties are imposed may well be long enough to drive domestic firms out of business. *Id.*, pp. 12-13.

1985 and 1986,[47] pointing out that this development was accompanied by a decline in U.S. worldwide market share from 59 percent in 1980 to 17 percent in 1988.[48]

According to these firms, the history of dumping had an adverse effect on major investment decisions under consideration by the semiconductor producers and their suppliers, the equipment manufacturers.[49] The semiconductor industry points to its experience as an illustration of the need for constraints on unfair trade practices and an indication of the need to "reform" the current law.[50]

In addition, these industries have sought U.S. Government action to open foreign markets. According to the semiconductor industry, limited access to the world's largest market, Japan, has placed the U.S. semiconductor industry at a distinct competitive disadvantage in continuing to attain the technological advances associated with high-volume production in the semiconductor industry.[51]

In efforts to seek stronger enforcement of the market access commitments in the 1986 Semiconductor Agreement, the Semiconductor Industry Association (SIA) filed petitions with the USTR requesting designation of Japan as a "Super 301" priority country and of semiconductors as a "Super 301" priority practice, in 1989 and 1990. In both instances, USTR declined to name semiconductors, stating that enforcement of the Semiconductor Agreement was already, and would continue to be, a priority for the U.S. Government.[52]

Representatives of both industries have also asked Congress to amend section 306[53] to allow interested parties to formally request reviews for compliance with trade agreements.[54] Under the proposed amendment, USTR would be required to undertake the review and to publically report on whether there was compliance with an agreement. USTR would still have discretionary authority to determine if section 301 actions would be appropriate. As the U.S. Government enters into a new agreement with Japan involving access to the semiconductor market,[55] the semiconductor industry continues to support enactment of a "mechanism for the U.S. to review compliance with trade agreements by our international trading partners."[56]

Foreign Investment and Acquisition

In general, there are few restrictions on direct foreign investment in the United States. However, during the 1980s, concern was expressed regarding whether technologies advanced in the United States were being acquired through direct foreign investment to benefit foreign industries in their home markets. Particular concern arose over the issue of concentration of Japanese firms in the semiconductor and SEM industries and whether such concentration posed a potential threat to U.S. national security.

In response to these concerns, Congress included the Exon-Florio provision in the 1988 Omnibus Trade and Competitiveness Act.[57] Under this provision, the President was authorized to suspend or prohibit any foreign investments if (1) there is "credible evidence" that a foreign investor might take action to impair the national security, and (2) provisions of laws, other than this section and the International Emergency Economic Powers Act, do not in the judgment of the President, provide "adequate and appropriate authority" to protect national security. In December 1988, the President delegated to the Committee on Foreign Investment in the United States (CFIUS)[58] the task of implementing the legislation.

During the period that the Exon-Florio provision was in effect, a total of 540 investments were reported to CFIUS, and of these investments, 46 were related to semiconductors, 37 to semiconductor equipment, and 39 to advanced materials.[59] Japan accounted for 41 of the investments in semiconductors, 27 in semiconductor equipment, and 28 in advanced materials. During the period, CFIUS initiated 12 formal investigations and made a negative determination in one case, which involved a Chinese firm attempting to acquire a U.S. aerospace company. Also, it should be noted that in at least one case involving a proposed foreign acquisition of a semiconductor equipment operation, CFIUS review resulted in its purchase by U.S. firms. At the January 17, 1991 U.S. International Trade Commission public hearing on global competitiveness, the SEMI/

[47] SIA, "Antidumping Law Reform," p. 6. The eight U.S. DRAM producers in 1985 were Advanced Mirco Devices, AT&T, Intel, Micron Technology, Mostek, Motorola, National Seminconductor, and Texas Instruments. By 1987, only Micron Technology and Texas Instruments still produced DRAMs; Motorola reentered the market in 1989.

[48] Dataquest.

[49] SIA, "Antidumping Law Reform," p. 5.

[50] Id, p. 1.

[51] SIA Public Policy Priorities for 1990: Maintaining U.S. Leadership in Electronics, February 1990, p. 3.

[52] USTR statements identifying "Super 301" priorities, May 1989 and April 1990.

[53] Section 306 of the Trade Act of 1974, as amended, directs USTR to monitor the implementation of each measure undertaken or agreement entered into by a foreign country under Section 301. 19 U.S.C. § 2416.

[54] H.R. 1115 and S. 388, "The Trade Agreements Compliance Act of 1991." According to the industry, the foundation for the legislation is that foreign nations should abide by their commitments, in short, "a deal is a deal."

[55] The new agreement was effective on August 1, 1991.

[56] Statement of the SIA represented by James P. Gradoville before the House Ways and Means Subcommittee on Trade, July 15, 1991, p. 3.

[57] Public Law 100-418, section 5021, approved Aug. 23, 1988, 102 Stat. 1425.

[58] The Ford administration created the Committee on Foreign Investment in the United States (CFIUS) in May 1975 to monitor trends in foreign investment in the United States and make policy recommendations regarding the effects of foreign investments on national security.

[59] Economic Strategy Institute, *Foreign Investment in the United States Unencumbered Access*, May 1991, pp. 1-2.

SEMATECH representative recommended that for the purposes of monitoring foreign acquisitions of U.S. companies, the U.S. Government should amend the definition of national security to include "economic stabilization and technological developments."[60] See appendix F for additional information on CFIUS.

Antitrust Issues in the Semiconductor Manufacturing and Testing Equipment Industry

To the extent that semiconductor manufacturing equipment companies operate internationally, they may be subject to the antitrust laws of countries in which they produce and market their products, as well as the antitrust laws of their home country. Areas in which antitrust laws are likely to be relevant to such companies include governmental policy regarding mergers between companies, and rules prohibiting monopolization and collusion among competitors.[61] In evaluating the possibility of collusion among competing companies, antitrust authorities in a number of countries, including the United States, evaluate the potential for anticompetitive effects in such activities as joint ventures, including cooperative research or production, or possible anticompetitive intellectual property licensing arrangements.

Joint Ventures and Cooperative Research

An area that is often raised as a candidate for reform is the antitrust treatment of joint ventures. A joint venture is essentially any collaborative effort among firms, short of a merger, with respect to R&D, production, distribution, or the marketing of products or services.[62] Should a joint venture be challenged as In response to concerns that U.S. antitrust rules governing joint ventures were discouraging procompetitive joint research by U.S. firms, Congress an unreasonable restraint of trade under the Sherman Act, it will be analyzed under the "rule of reason" to determine its likely competitive effects.[63]

In response to concerns that U.S. antitrust rules governing joint ventures were discouraging procompetitive joint research by U.S. firms, Congress passed the National Cooperative Research Act of 1984 ("NCRA"), which clarifies substantive application of the U.S. antitrust laws to joint research and development ("R&D") activities.[64] The NCRA requires U.S. courts to judge the competitive effects of joint R&D in relevant technology markets under a rule of reason standard that balances the procompetitive effects of joint R&D against any potential anticompetitive effects. The NCRA also limits the monetary relief that may be obtained in civil suits against participants in joint R&D to actual, rather than treble damages, where the challenged conduct is within the scope of the joint R&D venture notification filed with the Attorney General and the FTC.

The passage of the NCRA appears to have been an important development which aided the formation of collaborative efforts on the part of the semiconductor industry and its supplier firms.[65] In December 1987, the U.S. Congress passed legislation authorizing the partial funding by the U.S. Government for the SEMATECH consortium. SEMATECH is jointly funded by 14 of the largest semiconductor producers in the United States, and by matching funds from the Department of Defense. The Congress has appropriated about $100 million for SEMATECH's use over each of the past four fiscal years. Total funds made available to SEMATECH from Federal, state, and local governments for any fiscal year for support of R&D activities cannot exceed 50 percent of the total cost of such activities. In April 1988, the Secretary of Defense delegated to the Defense Advance Research Projects Agency (DARPA) authority to oversee the activities of SEMATECH.

SEMI/SEMATECH, Incorporated is an association of U.S. semiconductor manufacturing equipment, processing materials, software, and service suppliers.

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[60] Statement of SEMI/SEMATECH at the U.S. International Trade Commission public hearing on the global competitiveness of the U.S. SEM industry, January 17, 1991.

[61] Two antitrust statutes, the Webb-Pomerene Act of 1934 and the Export Trading Company Act of 1982 deal specifically with U.S. export trade. The principal purpose behind granting special treatment to export trade is to promote U.S. exports in industries where foreign competitor cartels or foreign buying cartels exist. The Webb-Pomerene Act provides a limited antitrust exemption for the formation and operation of associations of otherwise competing businesses to engage in collective export sales. The exemption applies only to the export of "goods, wares, or merchandise." It does not apply to conduct that has an anticompetitive effect in the United States or that injures domestic competitors of the members of an export association.

[62] Guide to International Operations, Antitrust Division, U.S. Department of Justice, 1989, p. 15.

[63] In determining these likely competitive effects, one factor a court or enforcement agency may take into consideration is the effect on competition of any intellectual property licensing arrangements.

[64] 15 U.S.C. §§ 4301-4305 (Supp. II 1984). In 1961, Japan enacted legislation to encourage joint R&D by establishing R&D joint ventures as a new legal form, providing tax preferences, government funding and antitrust relief. See 101st Cong., 2d Sess, June 1, 1990, Report 101-516 to accompany H.R. 4611, The National Cooperative Production Amendments of 1990.

[65] In testimony presented before the House Judiciary Subcommittee, SIA and the American Electronics Association (AEA) indicated that: "It is generally recognized that SEMATECH . . . would not have happened without the NCRA. The uncertainty and risk of potential liability under the antitrust laws would have been overwhelming without the assurances afforded the U.S. industry by the NCRA." Statement of SIA and AEA represented by Gordon E. Moore before the House Judiciary Subcommittee on Economic and Commercial Law, July 26, 1989, p. 13.

It was established in September 1987 to provide a direct conduit between its members and their customers, especially SEMATECH.[65] SEMI/SEMATECH membership is limited to suppliers to the semiconductor industry who are majority-owned and controlled by U.S. citizens and whose research and development are predominantly performed in the United States.[66]

More recently, in response to developments which include the loss in market share of the U.S. semiconductor industry to Japanese manufacturers, Congress has held hearings on the possible need for legislation similar to the NCRA for production joint ventures. On June 12, 1990, the House Judiciary Committee reported favorably on a bill to amend the NCRA to reduce the risk of antitrust liability for joint ventures entered into for the purpose of joint production. The report stated that while production joint ventures had rarely, if ever, been challenged under existing antitrust laws, the legislation nevertheless was desirable because some in the business community either erroneously perceive that the antitrust laws generally discourage all collaborative activity, irrespective of its procompetitive benefits, or fear antitrust suits will be filed by competitors against joint ventures for harassment purposes. The bill was designed to address these concerns by providing clarification of existing law, but makes no changes in substantive antitrust law.[67] Some commentators have argued that the NCRA needs to be extended to joint production ventures because it currently extends only to research and downstream commercial activity "reasonably required" for research and is narrowly confined to marketing intellectual property developed through a joint R&D program.[68]

Commentators have argued that passage of the NCRA as well as the Export Trading Company Act of 1982[69] signals a more pragmatic approach by the U.S. Government toward joint ventures on the theory that harm from any anticompetitive effects of those joint ventures in domestic markets will be offset by increased international competitiveness, and that such moves by the United States make U.S. antitrust law correspond more closely to that of other countries, such as the EC which have traditionally looked more favorably upon joint ventures involving research, development and production.[70]

Competition Policy in the European Community

Within the European Community, antitrust laws, or competition policy as it is also known, are administered on both the national and EC level. EC antitrust law is designed to prevent conduct by businesses that adversely affects competition within the Common Market, or trade between EC member states.[71]

In 1968, the European Commission issued a "Notice of Cooperation between Enterprises" that indicated that horizontal collaboration for purposes of R&D normally falls outside of the scope of Articles 85 and 86. In addition, in 1984, the European Commission adopted a regulation expanding the favorable antitrust treatment of R&D. For firms whose total market share does not exceed 20 percent, it provides blanket exemptions for horizontal R&D arrangements, including commercialization - which the EC Commission views as "the natural consequence of joint R&D" - up to the point of distribution and sales. In addition, the Commission is authorized to grant

[65] SEMI/SEMATECH Annual Report 1990, p. 5. SEMI/SEMATECH is headquartered in Austin, Texas and shares facilities with SEMATECH. *Id.*

[66] *Id.* As of December of 1990, membership in SEMI/SEMATECH totaled 135 companies representing approximately 90 percent of the total U.S.-owned and controlled equipment and materials production sales to the semiconductor industry. *Id.*

[67] The bill contains one provision not in the NCRA that would apply only to production joint ventures. That provision states that no more than 30 percent of the beneficial ownership of the voting securities and equity of such venture be controlled by foreign entities. There is also a requirement that all the facilities of such joint venture be located within the United States or its territories. The report points out, however, that the provision creates no special antitrust exemption for American-dominated production joint ventures not enjoyed by those with substantial foreign ownership. The only advantage received by a qualifying venture is that its participants will receive reduced liability exposure if their disclosed activities are found to be anticompetitive.

[68] Professors Jorde and Teece argue that it should also cover joint manufacturing and production which they contend are often necessary to provide the cooperating ventures with significant feedback to aid in further innovation and product development and to make the joint activity profitable. *Id.* at 41. They also argue that the Act does not provide sufficient guidance with respect to how the rule of reason is to be

[68]*—Continued*
carried out and they urge the complete elimination of treble damage awards for registered ventures.

[69] The Export Trading Company Act of 1982 (the "ETC Act") is designed to increase U.S. exports of goods and services by encouraging more efficient provision of export trade services to U.S. producers and suppliers, by reducing restrictions on trade financing provided by financial institutions, and by reducing uncertainty concerning application of the U.S. antitrust laws to U.S. export trade. Title III of the ETC Act establishes a procedure by which persons engaged in U.S. export trade can obtain an export trade certificate of review. Persons named in the certificate obtain limited immunity from suit under state and federal antitrust laws for activities that are specified in and comply with the terms of the certificate.

[70] *See,* Overton, "Substantive Distinctions Between United States Antitrust Law and the Competition Policy of the European Community: A Comparative Analysis of Divergent Policies," Volume 13, No. 2, Houston Journal of International Law, Spring 1991.

[71] The Treaty of Rome itself prohibits conduct falling into two categories. Article 85(1) prohibits agreements and concerted practices between two or more enterprises and decisions by associations of enterprises. Article 86 prohibits conduct by individual companies holding a dominant position in a relevant market that constitutes an abuse of that dominant position.

exemptions for cooperative efforts that do not fall within the automatic safe harbor.[72]

The policies underlying U.S. antitrust law and EC competition law differ to some degree. The economies of many European countries have traditionally been more concentrated than the U.S. economy and subject to a greater degree of governmental regulation.[73] In addition, the goals of articles 85 and 86 of the Treaty of Rome include economic integration and creation of a common market among the member states, as well as that of protecting competition. Thus, EC enforcement authorities may tolerate a degree of anticompetitive behavior that would not be tolerated in the United States if the activities are perceived to facilitate economic integration in the EC.[74]

One difference between EC law antitrust law and U.S. law is that when two firms agree to form a joint venture in the EC, they must first obtain approval of the proposed transaction from EC authorities, or risk an antitrust violation. Under U.S. law, while unreasonable restraints of trade are illegal, no specific governmental clearance is required for cooperative endeavors between competitors. Thus, if U.S. antitrust authorities disapprove of private joint commercial activities, they must go to court to seek an injunction to prevent the activity from taking place or from continuing if it is ongoing.[75] A second difference between U.S. and E.C. antitrust law is that, while in the United States 90 percent of the antitrust claims brought to the court are private actions, most antitrust enforcement actions in the EC have been brought by the EC Commission.

Japanese Antitrust Law

In contrast to the U.S. Government, Japanese governmental policy has tended to favor cooperative effort among firms in high-technology fields and to frown upon "excessive competition" among firms in the same industry. The Japanese legal system has traditionally discouraged litigation to pursue individual rights, including business rights, because such litigation is seen as disruptive to social harmony.[76] These two factors have functioned to make the role of antitrust law in the Japanese economy less significant than in the U.S. economy.

In Japan, the principal antitrust statute is The Law Relating to Prohibition of Private Monopoly and Methods for Preserving Fair Trade of 1947, commonly called the Antimonopoly Law. Originally passed after World War II, the Antimonopoly Law is based, in large part, on provisions of the U.S. antitrust statutes.[77] The act is enforced by the Japan Fair Trade Commission (JFTC), an independent administrative and quasi-judicial body, responsible directly to the Prime Minister.[78]

Since its enactment, Japan's Antimonopoly Law has undergone several revisions. The first major amendment to the law, which occurred in 1949, removed the ban on intercorporate stock ownership, eased the restrictions on mergers and acquisitions, and relaxed the restrictions on interlocking directorates. The approval authority of the JFTC over mergers was also changed to require prior notification rather than prior approval of proposed transactions. In 1953, additional substantial revisions to the Antimonopoly Law further weakened the law. In addition to further easing the provisions on intercorporate stock ownership and interlocking directorates, the amendments legalized certain types of cartels ("depression" and "rationalization" cartels), legalized resale price maintenance contracts in connection with certain consumer goods in daily use (as well as for copyrighted and trademarked goods), and abolished the Trade Association Act by incorporating its provisions concerning illegal cartel activities into the Antimonopoly Law.[79]

The Antimonopoly Law was revised in 1977 and its provisions strengthened. Amendments included the imposition of surcharges on undue profits arising out of illegal price-fixing arrangements and increased fines, and required leading enterprises in concentrated industries to report parallel price increases. In addition, the JFTC was authorized to order corporate dissolution or divestiture if concentration in an industry was accompanied by barriers to entry, lack of downward price movements, and unusually high

[72] *See* Jorde and Teece, Regulation Magazine, p. 43.
[73] Overton, p. 318.
[74] *Id.*, p. 323.
[75] Rosenthal, "Competition Policy," in *Hufbauer*, ed., 1992: An American Perspective.
[76] Phase I: Japan's Distribution System and Options for Improving U.S. Access, Report to the House Committee on Ways and Means on Investigation No. 332-283 under Section 332(g) of the Tariff Act of 1930, USITC Pub. 2291 (June 1990), p.10.

[77] *Id.* While based in large part on U.S. antitrust law, in many of its original provisions the Antimonopoly Law was more restrictive than U.S. law. For example, in Japan, monopolies were illegal *per se* while the U.S. evaluates monopolies under a "rule of reason" standard.
[78] Its members are appointed by the Prime Minister, with the consent of both houses of the Diet.
Article 1 of the Antimonopoly Law sets forth its overall objectives:

> This Law, by prohibiting private monopolization, unreasonable restraints of trade and unfair methods of competition, by preventing excessive concentration of power over enterprises and by excluding undue restriction of production, sale, price, technology, etc. through combinations and agreements, etc. and all other unreasonable restraints of business activities, aims to promote free and fair competition, to stimulate the initiative of entrepreneurs, to encourage business activities of enterprises, to heighten the levels of employment and national income and, thereby, to promote the democratic and wholesome development of the national economy as well as to assure the interest of the general consumer.

[79] Phase I: Japan's Distribution System and Options for Improving U.S. Access, Report to the House Committee on Ways and Means on Investigation No. 332-283 under Section 332(g) of the Tariff Act of 1930, USITC Pub. 2291 (June 1990), p. 64.

profits.[80] The JFTC has become more active in investigating and prosecuting violations of the law since this revision, but the organization is still widely perceived as "lacking teeth." Recently, the Government of Japan has also committed itself to taking a more active stance against business practices that impede foreign entry into Japanese markets.[81]

Some legal commentators have argued that while there is no specific legislative exemption for joint innovation arrangements under the Antimonopoly Law, Japan's Fair Trade Commission exempts joint ventures from the scope of the law as a matter of enforcement policy.[82] When MITI seeks to encourage cooperative R&D activities, the JFTC is consulted in advance, making it unlikely that it will later seek to halt the activity on antitrust grounds.

Japanese SEM suppliers are bound together through keiretsus, or networks of customers, suppliers, and distributors that may serve to diminish competition from outsiders.[83] These networks are organized as financial or conglomerate keiretsus, which are formed around trading companies or banks, or as vertical keiretsus formed around large industrial enterprises. The vertical groups are distinguished by their close relationships with their suppliers, which participate in product design, manufacturing processes, and quality control.[84] With respect to vertical keiretsu, Japan's Antimonopoly Law prohibits practices such as resale price maintenance, exclusive dealing stipulations, and customer restrictions. Weak sanctions and a low level of enforcement by the JFTC appear to have hindered the law's effectiveness, however. In the event that a company is successfully prosecuted, the penalty is usually a cease-and-desist order rather than a fine.[85]

In June 1990, the Governments of the United States and Japan concluded talks known as the Structural Impediments Initiative ("SII"). The SII was a series of international trade negotiations that were unique in that most of the SII negotiations concerned matters of domestic policy and regulations including restrictive business behavior, inter-corporate relationships in Japan, and the Japanese system for distribution of goods. In the SII, President Bush and Japanese Prime Minister Uno established a joint task force to investigate formal and informal trade barriers between the two countries. The task force published a final report on June 28, 1990 that contains recommendations that both governments are urged to implement. This report lists six areas in which the Japanese Government is urged to undertake reform: saving and investment patterns, land policy, the system of production distribution, exclusionary business practices, keiretsu relationships, and pricing mechanisms.[86] With respect to exclusionary business practices, the report recommends that Japan more strictly enforce the Anti-Monopoly Law, introduce greater transparency in administrative guidance, issue government recommendations to private enterprises to purchase parts and components on a non- discriminatory basis, and shorten the examination period for patents in Japan.[87] The U.S. Government has stressed the importance of stricter enforcement of the Anti-Monopoly Law, claiming that although the provisions of the law are well drafted, enforcement has been lax, thereby creating rigidity and exclusivity in the Japanese market and making it difficult for foreign enterprises to penetrate the market.

In addition, the U.S. Government argued in the talks that keiretsu relationships among Japanese companies can "promote preferential group trade, negatively affect foreign direct investment in Japan, and give rise to anticompetitive business practices."[88] Under the SII, the United States and Japan agreed that the Japanese Fair Trade Commission would announce guidelines on the enforcement policy directed toward businesses linked by stock-ownerships and related matters and exclusive relationships among enterprises.[89] Recommendations for the United States arising from SII have included abolishing treble damage suits under the antitrust laws for production joint ventures.[90]

Export Controls

Many high-technology industries in the United States have long complained about the U.S. export control regime, while nevertheless recognizing and supporting the fundamental national security interest in ensuring that strategic technology does not fall into the wrong hands. Most often, an industry argues that certain controlled goods or technology are not truly strategic, that they are not state-of-the-art, or that they are available from competitors in other countries.

In particular, the semiconductor manufacturing equipment and materials (SEM) industry maintains that it has been subject to a particularly heavy burden in the

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[80] Phase I: Japan's Distribution System and Options for Improving U.S. Access, Report to the House Committee on Ways and Means on Investigation No. 332-283 under Section 332(g) of the Tariff Act of 1930, USITC Pub. 2291 (June 1990), p. 64.

[81] *Id.*, at p. ix.

[82] Thomas M. Jorde and David J. Teece, "Innovation, Dynamic Competition, and Antitrust Policy," *Regulation Magazine*, p. 42.

[83] Commentators have indicated that: "One important effect of the 'keiretsu', however, is to exclude outsiders, particularly foreign companies." Nanto, Japan's Industrial Groups, the Keiretsu, p. 10, *see also*, *Id.*, infra p. 4-43 footnote 42.

[84] *Id.*

[85] *Id.*, at p. 7.

[86] Joint Report of the U.S.-Japan Working Group on the Structural Impediments Initiative, June 28, 1990.

[87] *Id.*, at Section IV.

[88] *Id.*, at V-1.

[89] *Id.*, at Section V. These Guidelines were issued on July 11, 1991.

[90] *Id.*, at Structural Impediments in the U.S. economy, p. 13.

1980s.[91] More recently, however, multilateral decontrol efforts have followed the fall of the Berlin wall and the restructuring of the Soviet Union and Eastern Europe. Although it is difficult to quantify the competitive impact of past controls, the recent, multilateral liberalization of controlled SEM technology should improve the trading environment for the industry in the 1990s.

U.S. exports of semiconductor manufacturing equipment are controlled under export commodity control number ECCN 1355A. The number of licenses filed under this control number with the U.S. Department of Commerce during 1984-90 and the average number of days taken by Commerce to process each application are shown in table 3-1. Information in table 3-1 indicates that a large share of U.S. production of semiconductor manufacturing and testing equipment was exported during 1984-90, and the average time taken by Commerce to process each application decreased significantly during the period. Detailed information on U.S. export controls affecting the SEM industry is contained in appendix G.

Intellectual Property

The following is a synopsis of the intellectual property laws of the United States, the European Community, and Japan, as they relate to patents and mask works. Patent rights and mask works are important to the semiconductor industry, but tend to be less important to the SEM industry. Technology in the SEM industry changes rapidly and often firms may decide not to file for a patent because the filing procedure may reveal much of the technology and enable other firms to design around the patent. Further, semiconductor manufacturing machines are often complicated apparatus, which makes reverse engineering relatively difficult.

Patents

United States

The patent law of the United States is contained in Title 35, United States Code. There are three categories of patents: utility patents (by far the most common and most important), design patents, and plant patents.[92] All patents are issued on the basis of applications which are examined by the U.S. Patent and Trademark Office (PTO) for formal and substantive compliance with the law. Unlike most countries, the United States uses a first-to-invent system, i.e., as between two applicants for the same invention, the applicant who establishes the earliest invention date will receive the patent (assuming it claims a patentable invention).

Utility patents are granted for new and useful processes, machines, manufactures, compositions of matter, and improvements thereof, and are issued for terms of 17 years from the date of issuance. The term of any individual patent may be extended by Act of Congress, though this is rare. Actions for patent infringement are brought in the United States district courts, which may adjudicate both validity and infringement and award damages and an injunction. During the pendency of the action, the district court may issue a preliminary injunction. Appeal of the district court's judgment is to the United States Court of Appeals for the Federal Circuit. Further appeal can be had only by grant of a petition for writ of certiorari by the United States Supreme Court. An administrative proceeding may be brought against infringing imports in the U.S. International Trade Commission and may result in an order excluding those imports from entry, a cease and desist order, or both.

European Community

There is no comprehensive, Community-wide patent law. However, the member states of the EC have concluded (but not yet ratified) a Community Patent Convention which would create such a system. Furthermore, most of the member states of the EC (and several non-member states) are signatory to the European Patent Convention, which provides for

[91] See, e.g., Semiconductor Equipment and Materials International, *White Paper: Export Control*

91—Continued
Recommendations for Semiconductor Equipment and Materials [White Paper] (Mar. 1990).

[92] Design patents are granted for new, original and ornamental designs for articles of manufacture. Plant patents are granted for distinct and new variety of a sexually-reproduced plant. Design and plant patents are not applicable to the SEM industry.

Table 3-1
Semiconductor manufacturing and testing equipment: Applications filed under ECCN 1355A and average number of days required to process applications, 1984-90

Year	*Number of Applications*	*Value (millions of dollars)*	*Average number of days to process each application*
1984	2,070	743	44
1985	2,561	992	47
1986	3,197	958	34
1987	2,950	1,285	21
1988	2,853	1,171	18
1989	3,004	1,632	17
1990	2,718	1,965	14

Source: U.S. Department of Commerce.

centralized examination for patents, under uniform standards, at the European Patent Office. However, what the European Patent Office issues is not a supra-national European patent, but a bundle of national patents.

All of the member states grant patents, whose issuance is based on an application which is given at least a formal examination in the national patent office (or, alternatively, an examination in the European Patent Office). The criteria for patentability in most member states is novelty, inventive step, and capability of industrial application. Some member states exclude certain subject matter from patentability. The most important examples are computer programs and certain biotechnology inventions. However, the EC Council has adopted a directive requiring the member States to provide copyright protection for computer software. The EC Commission has proposed a directive which, if adopted, would require national patent laws to be amended to permit patenting of many kinds of biotechnology inventions. With few exceptions, the term of patents in the member states is twenty years from the date of filing. Like most countries, all of the EC member states use a first-to-file system, i.e., as between two applicants for the same invention, the applicant who files his application first will receive the patent (assuming it claims a patentable invention).

Actions for infringement are usually begun in the national trial courts, sometimes called courts of first instance, with the possibility of appeal. Remedies for infringement nearly always include a permanent injunction and damages and may include a preliminary injunction and seizure and destruction of the infringing articles as well. In some member states, criminal proceedings may be brought for patent infringement.

Japan

Japan grants patents on most subject matter.[93] Applications for patents are made to the Japanese Patent Office, which conducts a formal and, after request by the applicant, a substantive examination. If the applicant does not file a request for substantive examination within 7 years of the application date, the application will be deemed abandoned. If, after substantive examination, the application appears otherwise allowable, it will be published for opposition prior to grant. In any event, the application will be laid open for public inspection 18 months after application. Certain rights accrue to the applicant on publication. The average time for issuance of a Japanese patent is about 5 years from application, compared with about 20 months in the United States. Among the reasons for this is the relatively small number of examiners in the Japanese patent office and the pre-grant opposition procedure. Like most countries, Japan uses a first-to-file system.

The claims allowed in Japanese patent applications tend to be narrower than those allowed in U.S. applications and the doctrine of equivalents, as it is known in the United States, is not applied in Japan.[94] The narrowness of the claims allowed in an individual application opens the possibility that competitors may obtain numerous patents on relatively small variations of the claimed invention, a practice referred to by some as "patent flooding."[95] This practice can result in a patentee being hemmed in by a competitor's patents even in a technology in which he has pioneered, and he may face cross-licensing. An alternative course for the patentee is to himself apply for several patents to obtain more complete coverage of his technology.

The term of Japanese patents is 15 years from the date of publication but no longer than 20 years after application. Annual maintenance fees must be paid to keep the patent in force. Compulsory licenses may be granted if the patented invention is not worked or if necessary in the public interest. Actions for patent infringement are begun in the high court. There is the possibility of appeal. Remedies include permanent injunctions and damages.

Mask Works

United States

"Mask works" are a unique form of intellectual property first recognized by the United States in the Semiconductor Chip Protection Act of 1984, Public Law 98-620, Chapter 9 of Title 17, United States Code (SCPA).

Protection under the SCPA extends to three-dimensional images or patterns formed on or in the layers of metallic, insulating, or semiconductor material and fixed in a semiconductor chip product, i.e., the "topography" of the "chip." The type of protection afforded by the SCPA is somewhat similar to that provided by the copyright law, and both statutes are administered by the Copyright Office. However, the two types of protection differ from each other in many respects, including eligibility, ownership, term, scope and limitation of rights, remedies, and registration procedures.

In general, the term of protection for a mask work is ten years. Owners of mask work rights may bring an action for infringement in a United States district court, with appeal to the appropriate United States Court of Appeals. Further appeal is by way of a petition for writ of certiorari in the United States Supreme Court. Remedies include preliminary injunctions, permanent

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[93] Japan also grants utility models (sometimes called "petty patents") for subject matter not rising to the level of patent protection, but justifying some protection.

[94] Under United States practice, an accused device may be found to infringe even if it does not precisely meet the terms of a patent claim, if the patentee can show that the accused device performs substantially the same function in substantially the same way to achieve substantially the same result as the claimed invention.

[95] See, National Trade Estimate Report on Foreign Trade Barriers (Office of the U.S. Trade Representative 1991), p. 129. For a specific complaint by a U.S. company, see, e.g., D.M. Spero, "Patent Protection or Piracy-A CEO Views Japan," *Harvard Business Review*, September-October 1990.

injunctions, and damages, as well as seizure and destruction. An administrative proceeding for infringement by imports may be begun in the U.S. International Trade Commission, with the possibility of the issuance of an order excluding the infringing articles from entry.

European Community

The EC Council has adopted a directive requiring the member states to enact laws for the protection of topographies of semiconductor products ("mask works"). These laws must conform to minimum standards set forth in the directive. Member states must, among other things, provide for the exclusive right to reproduce the topography, to commercially exploit it, or to import for commercial exploitation the topography or a semiconductor product made by using it. Certain exceptions are provided for.

Member states may make registration and/or deposit a prerequisite for protection. Generally, the term of protection must be ten years. There was no previous EC law on semiconductor topographies, though a few member states provided some protection under their own national copyright laws. Most member states have complied with or are complying with the directive.

Japan

Japan has a mask work law similar to that of the United States and the member states of the EC. Mask work rights are established for registration, for which application must be made. Rights are granted for ten years from registration. The principle right granted is that of sole use of the mask work for business purposes. Unauthorized use of the mask work constitutes infringement. In addition, the manufacture, sale, or importation of items for use in imitating a mask work constitutes an infringement. Remedies for infringement include an injunction and damages. There is also the possibility of criminal actions being brought for infringement.

Tariffs

The United States, the European Community, and Japan maintain little or no import tariffs on semiconductor equipment and materials. However, Korea, which is an emerging competitor in the semiconductor industry, maintains high tariffs on imports of these products (table 3-2). In addition, the United States and Japan jointly eliminated tariffs on imports of semiconductors during the mid-1980s, but the European Community maintains a high tariff of 14-percent on imports of these devices. A reduction of tariff is likely to promote growth in trade and has been seen by some as beneficial to the health of the U.S. industry.

Table 3-2
Semiconductor manufacturing and testing equipment and materials: U.S., EC, Japan, and Korean duty rates

Subheading No.	*U.S.*	*EC*	*Japan*	*Korea*
2804.61.00.00	3.7	6.0	Free/3.9	10.0
2851.00.00.10	2.8	2.7	3.9	20.0
3818.00.00.10	Free	7.6	Free/3.8	10.0
3818.00.00.90	Free	7.6	Free/3.8	10.0
3823.90.11.11	Free	5.7	3.8	5.0
3823.90.11.19	Free	5.7	3.8	5.0
8424.89.00.40	3.7	4.4	Free	20.0
8456.90.10.20	4.4	4.4	Free	20.0
8456.90.50.40	3.0	4.4	Free	20.0
8464.10.00.40	3.0	3.8	Free	20.0
8464.90.00.40	3.0	3.8	Free	20.0
8464.90.00.60	3.0	3.8	Free	20.0
8479.89.90.72	3.7	4.4	Free	20.0
8479.89.90.74	3.7	4.4	Free	20.0
8479.89.90.76	3.7	4.4	Free	20.0
8479.89.90.78	3.7	4.4	Free	20.0
8479.89.90.80	3.7	4.4	Free	20.0
8514.30.00.40	2.5	4.1	Free	20.0
8543.10.00.40	3.9	7.0	Free	20.0
9010.20.60.10	3.7	4.9	Free	20.0
9010.20.60.20	3.7	4.9	Free	20.0
9010.20.60.30	3.7	4.9	Free	20.0
9010.20.60.50	3.7	4.9	Free	20.0
9017.20.80.70	5.8	5.3	Free	20.0
9030.89.00.40	4.9	—	Free	20.0
9031.40.00.20	10.0	5.8	Free	20.0
9031.40.00.40	10.0	5.8	Free	20.0
9031.40.00.60	10.0	5.8	Free	20.0

Source: Douanes International Customs Journal, No. 14, ed. 16.
Customs Tariff Schedule of Japan, 1991.
Tariff Schedules of Korea, 1988.
Harmonized Tariff Schedule of the United States, 1990.

CHAPTER 4
ANALYSIS OF THE COMPETITIVE PERFORMANCE OF THE U.S. SEM INDUSTRY

This chapter evaluates the competitive performance of the U.S. SEM industry, assesses factors that have proven most important for its competitiveness in the past, and draws inferences about prospects for the industry's future.

The first section of this chapter presents an overview of the U.S. SEM industry's performance in the measures of competitiveness: sales, export performance, and profitability. The second section examines both the sales performance of particular industry segments and reasons for differences in their competitive success. The clearest direct reason for these differences proves to be product performance, and this in turn depends upon such factors as R&D expenditure, the technological capabilities of firms, firms' responsiveness to customers' needs, relationships with customers, and the changing location of the market.

The third section of this chapter applies the analytical framework introduced in chapter 2 to analyze information on the industry's product performance, service, relationships with customers, cost of production, R&D expenditures, and technological capability. The impact on the industry of external factors such as tax policy, the location of its markets, access to foreign markets, cost and availability of capital, and government policy affecting technology are also examined.

Sales, Export Performance, and Profitability of U.S. SEM Suppliers

A SEM firm's competitiveness is indicated in large measure by sales, export performance, and profitability. Sales volume, particularly when measured in market share, directly shows the firm's marketing success compared with its competitors. Export performance (sales in foreign markets) shows the firm's success in markets where it lacks a home-market advantage. Profitability indicates the firm's business success and determines whether the firm remains in operation; an unprofitable firm with large market share will normally not remain in business for long. These measures of competitiveness apply not only to individual SEM firms, but also to the industry as a whole.

The following discussion considers, first, the sales and export performance of U.S. equipment suppliers compared with Japanese and other foreign equipment suppliers; second, the profitability of U.S. equipment suppliers; and third, the salés and profitability of materials suppliers.

Sales and Export Performance of Equipment Suppliers

Table 4-1 compares the sales of the U.S. semiconductor equipment industry with sales by its foreign competitors during 1985-90 (see also figure 4-1). The table presents results both for the world market as a whole and for the U.S., Japanese, and third-country markets. The table shows that the U.S. industry has a large lead in the U.S. domestic market, with an estimated 75 percent share in 1990, while the Japanese industry had a similar advantage, 76 percent, in its domestic market. The U.S. industry had a substantial lead in third-country markets, with 47 percent, while the Japanese industry trails both U.S. and third-country suppliers in these markets. In the world market as a whole, U.S. sales were slightly greater than Japanese sales in 1990.

The trend over the period 1985-90, however, is toward strongly increasing sales for Japanese and third-country suppliers while sales of U.S. suppliers failed to grow at all in real terms. The data indicate that the world market grew by 60 percent in nominal terms during the period, but U.S. sales grew by only 17 percent. Because cumulative inflation amounted to approximately 18 percent over the period (using the U.S. GNP deflator as a measure), the real (i.e., inflation-adjusted) value of U.S. sales actually declined. Japanese sales grew by 137 percent in nominal, dollar-valued terms, and third-country sales grew by 216 percent.[1] [2]

The U.S. SEM industry's decline in world market share over 1985-90 was accounted for partly by a decline within each of the regional markets, but it was due largely to the change in the relative sizes of the regional markets. The U.S. industry has its greatest share in its domestic market, which has grown more slowly than the other regional markets. The largest annual decrease in the U.S. SEM industry's world market share, from 57 percent in 1987 to 51 percent in 1988, coincided with a decline from 51 percent to 38 percent in the share of world purchases made by U.S. users of semiconductor equipment. As the data on regional purchase volumes suggest, 1988 marked the beginning of a major boom in construction of new semiconductor manufacturing plants in Japan and third-country markets, including Korea and other countries in the Far East.

Because the data in table 4-1 are unadjusted for inflation or exchange-rate fluctuations, they do not fully reflect changes in the real value of shipments by U.S., Japanese, and other SEM suppliers. Table 4-2

[1] The value of sales by U.S.-Japanese joint ventures in Japan declined by 15 percent in nominal dollar terms.

[2] Adjustment of Japanese and third-country sales for inflation is complicated by the need to account for exchange-rate fluctuations as well. An attempt to account for both variations is made below.

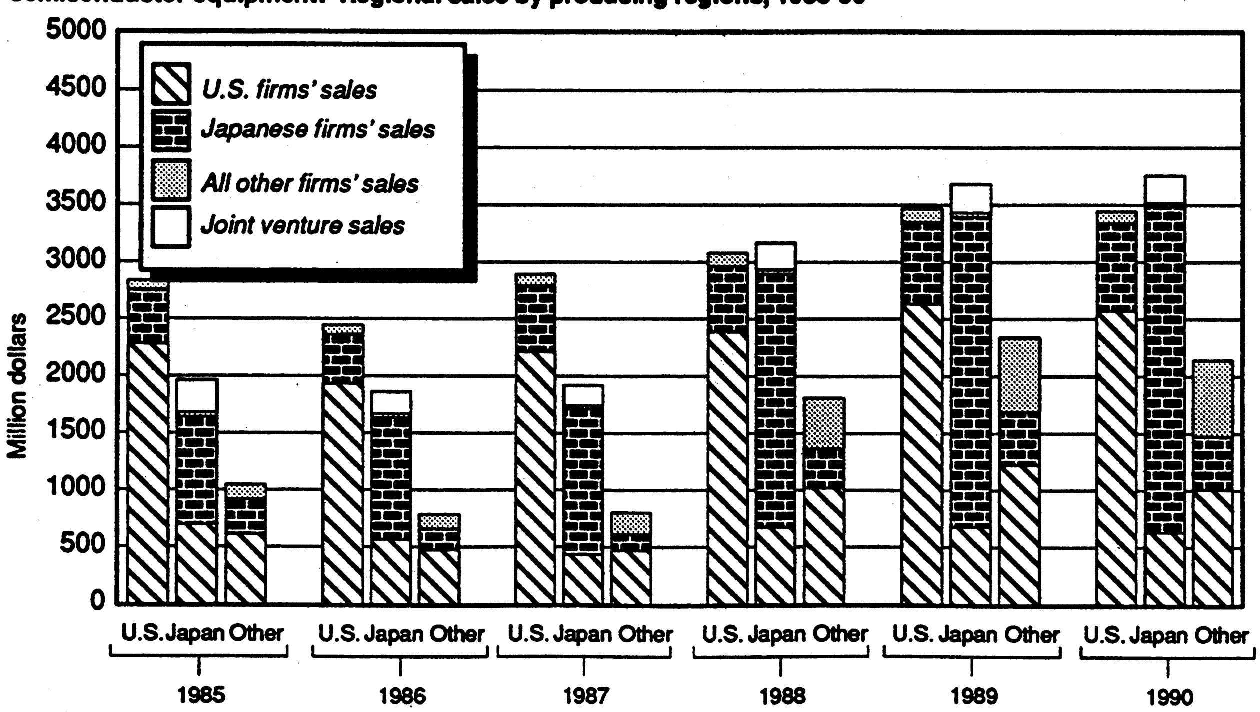
Table 4-1
Semiconductor equipment supplier shares in major markets, 1985-90: By country of ownership
(All figures based on current dollars and current exchange rates)

	1985	1986	1987	1988	1989	1990[1]
World purchases ($ million)	5850	5104	5492	8063	9492	9349
U.S. sales (%)	61	58	57	51	48	45
Japanese sales (%)	30	33	34	39	41	44
Joint-venture sales[2] (%)	5	4	3	3	3	3
Third-country sales (%)	4	5	6	7	8	9
U.S. purchases ($ million)	2839	2447	2828	3079	3471	3445
Share of world market (%)	48	48	51	38	36	37
U.S. sales (%)	80	79	78	78	76	75
Japanese sales (%)	17	18	18	19	21	22
Third-country sales (%)	3	3	4	4	4	3
Japan purchases ($ million)	1964	1869	1861	3170	3681	3756
Share of world market (%)	33	36	33	39	39	40
U.S. sales (%)	36	30	24	21	18	17
Japanese sales (%)	48	57	66	70	74	76
Joint-venture sales[2] (%)	14	10	10	7	7	6
Third-country sales (%)	2	2	2	1	1	1
Third-country purchases ($ m)	1048	789	803	1813	2340	2147
Share of world market (%)	18	15	15	22	25	23
U.S. sales (%)	59	60	58	56	52	47
Japanese sales (%)	29	23	19	19	20	22
Third-country sales (%)	12	16	23	25	28	31

[1] 1990 figures are estimates.
[2] Joint U.S.-Japanese ventures in Japan.

Source: VLSI Research Inc., 1990.

Figure 4-1
Semiconductor equipment: Regional sales by producing regions, 1985-90



Source: VLSI Research, Inc.

Table 4-2
Semiconductor equipment supplier shares in major markets, 1985-90: By country of ownership (Based on constant 1989 currencies and constant 1989 exchange rates)

	1985	*1986*	*1987*	*1988*	*1989*	*1990**
World purchases ($ million)	8088	5928	5860	8018	9492	9139
U.S. sales (%)	51	56	57	53	48	44
Japanese sales (%)	38	35	34	37	41	46
Joint-venture sales** (%)	6	4	3	3	3	3
Third-country sales (%)	5	5	5	7	8	7
U.S. purchases ($ million)	3582	2776	3024	3141	3471	3342
Share of world market (%)	44	47	52	39	37	37
U.S. sales (%)	72	77	79	79	76	74
Japanese sales (%)	24	19	18	17	21	24
Third-country sales (%)	4	4	3	3	4	3
Japan purchases ($ million)	3046	2239	1990	3060	3681	3795
Share of world market (%)	38	38	34	38	39	42
U.S. sales (%)	26	28	24	23	18	16
Japanese sales (%)	55	59	66	69	74	77
Joint-venture sales** (%)	16	11	10	7	7	6
Third-country sales (%)	2	2	1	1	1	1
Third-country purchases ($ m)	1461	913	846	1817	2340	2002
Share of world market (%)	18	15	14	23	25	22
U.S. sales (%)	48	58	59	58	52	49
Japanese sales (%)	37	25	19	18	20	24
Third-country sales (%)	15	17	22	24	28	27

*1990 figures are estimates. **Joint U.S.-Japanese ventures in Japan.

Sources: Table 4-1 and International Monetary Fund. See text for method.

reflects a series of adjustments that attempts to correct this problem, although for technical reasons it probably overcorrects.[3] Because the dollar declined in value substantially against the yen and other major currencies between 1985 and 1987, results for the first two years of the period are altered considerably. Compared with the unadjusted values in table 4-1, the adjusted values represent Japan's market share as higher, and the U.S. market share as lower, in all regional markets for 1985 and 1986. Other results are less affected. Also, the adjusted values indicate sales of U.S. producers in terms of constant dollars and sales of Japanese firms in terms of constant yen. The figures imply that U.S. sales declined 1 percent over the period as a whole, while Japanese sales rose 36 percent over the period. Third-country sales rose 53 percent in terms of constant German marks, but results for each actual producing country cannot be determined.

Another perspective on the relative competitiveness of U.S. and Japanese suppliers is presented in table 4-3. Panel A of the table presents statistics that compare U.S. sales performance to Japanese sales performance in the world market as a whole and in different regional markets. These statistics are defined as the ratio of U.S. industry sales to U.S. GNP divided by the ratio of Japanese sales to Japanese GNP. Dividing by GNP controls for the fact that the U.S. economy is larger than the Japanese economy, so that the comparison is on a relatively even basis.

[3] The data are adjusted as follows. The value of U.S. suppliers' production is corrected for inflation by means of the GNP deflator. The value of Japanese production is corrected for inflation using the Japanese GNP deflator, and for exchange rate fluctuation by using a constant rather than varying yen/dollar exchange rate. The value of third-country production is corrected in the same manner as Japanese production, but uses the German GNP deflator and a constant mark/dollar exchange rate. Information on the specific countries reflected in third-country data is not available. In all cases 1989 was used as the base year, primarily because later sections of this chapter emphasize 1989 data. Use of other base years (especially 1985 or 1986, when the dollar had a much higher value relative to other major currencies) would change the relative market shares of producing regions, but it would not greatly affect trends.

Correction for exchange-rate fluctuations is justified especially by the fact, observable in table 4-1, that the majority of sales by each of the three regions is within the home market. This fact suggests that prices of semiconductor equipment are not likely to change enough from year to year to fully reflect changes in exchange rates. Nevertheless, because the pressure of international competition is likely to lead suppliers to change prices to some extent in response to changing exchange rates, the correction is likely to overstate the needed adjustment, especially for each region's sales in foreign markets.

Table 4-3
The competitiveness of U.S. semiconductor equipment suppliers relative to Japanese suppliers by world and selected regional markets, 1985-90

	1985	*1986*	*1987*	*1988*	*1989*	*1990*
A. Relative sales performance index[1]						
World market	.67	.81	.88	.78	.65	.56
U.S. market	1.59	2.08	2.33	2.46	2.01	1.85
Japanese market	.26	.27	.22	.20	.16	.14
Third-country markets	.69	1.24	1.64	1.76	1.44	1.16
B. Relative export performance index[2]						
World market (based on table 4-1)	1.32	1.54	1.29	1.43	1.32	.89
World market (based on other sources[3])	NA	2.08	2.89	1.69	1.49	NA
C. Net exports (as a percentage of total world sales)						
United States	13	10	5	12	11	8
Japan	1	0	4	3	5	6

[1] Sales index = (U.S. sales/U.S. GNP) / (Japanese sales/Japanese GNP).
[2] Export index = (U.S. equipment exports/U.S. total exports)/(Japanese equipment exports/Japanese total exports).
[3] Based on value of export licenses issued by the U.S. Department of Commerce under ECCN 1355A for 1986-89 and Japanese exports of semiconductor equipment reported by the Japan Economic Institute in its June 7, 1991 report, *U.S.-Japan Semiconductor Manufacturing Equipment: The Consequences of Shifting Positions*, app. 1 p. 2.

Sources: Table 4-1, International Monetary Fund, U.S. Department of Commerce, and Japan Economic Institute.

The statistics for the world as a whole show that the sales of the U.S. semiconductor equipment industry have been smaller than those of the Japanese industry, relative to the sizes of each national economy, over the whole period, with a fast decline since 1987. (The rising trend from 1985 to 1987, on the other hand, largely reflects the decline in the value of the U.S. dollar relative to the Japanese yen in that period, rather than a reflection of trends in the industry.[4]) The U.S. industry's decline relative to the Japanese industry dates from 1986 within the Japanese market, and from 1988 within both the U.S. and third-country markets.

Within the U.S. market, the sales performance of the U.S. industry has generally been a little over twice that of the Japanese industry. In Japan, by contrast, the Japanese industry has advanced from about four times the sales performance of the U.S. industry at the beginning of the period to seven times at the end of the period. (Four and seven are the approximate reciprocals of .26 and .14, respectively.) This difference between the United States and Japan could be interpreted as reflecting the relative ability of the two national industries to offer competitive products and/or the relative openness of the two national markets. One way to distinguish between these two interpretations is to consider the sales performance of both the U.S. and Japanese industries in third-country markets. Apart from 1985, the relative sales performance of the U.S. industry compared to the Japanese industry has been greater than 1.0 in third-country markets, indicating a better performance by the U.S. industry. However, the extent of this competitive advantage has fallen quite dramatically since 1988.

Item B of table 4-3 evaluates the relative export performance of the U.S. and Japanese semiconductor equipment industries. It presents the ratio of U.S. exports in the industry to total U.S. exports, divided by the ratio of Japanese industry exports to total Japanese exports. Total exports is used to adjust for the fact, again, that the U.S. economy is larger than that of Japan. By this measure, in contrast to the previous one, the U.S. industry appears more competitive than the Japanese for the period through 1989, although this changed in 1990. Using the same methodology, but substituting Japanese exports reported by the Japan Economic Institute from Japanese industries sources and U.S. exports reported by the U.S. Department of Commerce under export control licenses,[5] the ratio indicates that the U.S. industry had a better performance during 1986-89 although the ratio had decreased to its lowest point in 1989.

Item C of table 4-3 presents the net exports (exports minus imports) of the United States and Japan in semiconductor equipment. Both countries were net exporters of semiconductor equipment throughout the period, with the United States usually showing a much higher trade balance than Japan. The rise in U.S. net exports in 1988 reflects the strong increase in overseas equipment purchases during that year, even though the U.S. share of overseas markets declined. Since 1988, net U.S. exports have fallen by four percentage points of world sales, while Japanese net exports have risen by three percentage points. As a result, the United

[4] Both sales and GNP data, of course, reflect the same dollar-yen exchange rate. Because a large fraction of semiconductor equipment is traded internationally, however, its prices and reported sales vary less with exchange rate fluctuations than does GNP.

[5] See chapter 3 for additional information on export controls of semiconductor manufacturing equipment.

States and Japan were nearly tied in net exports in 1990.

While detailed data are lacking for the period prior to 1985, industry analysts agree that the recent pattern continues previous trends. In the 1970's, a substantial majority of equipment sales were within the U.S. market, and U.S. equipment suppliers led in all three regional markets.

Profitability of Equipment Suppliers

There are no comprehensive data on the profitability of U.S. semiconductor equipment suppliers, primarily because most suppliers (particularly small ones) are either privately held or, in some cases, are parts of large corporations that do not report financial results separately for the relevant divisions. The tabulation at the bottom of the page, however, presents information on nine of the larger firms in the U.S. industry.[6] All but one of these firms is publicly held, and all but one had sales in 1990 of $100 million or more. Together, these firms supplied approximately 45 percent of U.S. production of semiconductor equipment in 1990.[7] The period covered represents approximately one industry business cycle.

The data presented include net sales, cost of goods sold, gross profit (i.e., sales minus cost of goods), R&D expenditure, and pretax earnings. R&D expenditure is included to illustrate how the cost of developing future competitive products reduces current profitability. Costs of administration, customer service,[8] depreciation, and debt service are not shown. The tabulation presents pretax earnings rather than net (after-tax) profit because loss carry-forwards and other adjustments make the latter measure a more ambiguous indicator of current profitability.

The tabulation shows that, as a group, the nine firms reported losses during the industry recession in 1986-87, returned to positive pretax earnings during the expansion of 1988 and 1989, and experienced declining profits in 1990, when sales expansion slowed. Data for the individual firms indicate that three firms had positive pretax earnings in 1986 and 1987,[9] eight in 1988 and 1989, and six in 1990. One firm had negative earnings throughout the period, while three had positive earnings each year.

These three firms, with pretax earnings averaging about 9 percent for the group over the period, appear on the basis of this financial analysis to be competitive at present and likely to remain so in the immediate future. A fourth firm, which reported losses in 1987 (its start-up year) but has reported pretax earnings averaging 30 percent since then, also appears likely to remain competitive. Four of the remaining five firms reported losses over the period as a whole, and the fifth just broke even on average.

The tabulation at the top of the next page, from a recent survey by the U.S. Department of Commerce, presents a similar picture of profitability for a different group of firms.[10] The sample apparently includes several privately held firms.

According to the report that presents these data, only one of the three surveyed firms with annual sales under $20 million earned a profit in any year during the period, while all five firms with sales of over $20 million earned a positive profit in at least two years. This corroborates the view of many industry participants and analysts that profitability varies with size, and that many small firms in the industry are unprofitable and may be unable to continue in the industry in their present form.

[6] The firms included are Applied Materials, Genus, KLA, Kulicke and Soffa, LAM, LTX, Novellus, SVG, and Teradyne.

[7] In earlier years they supplied smaller fractions of U.S. output, ranging from 27 percent in 1986 to 39 percent in 1989. This increase over time reflects primarily the fact that the firms selected for inclusion here are those that are currently the largest. Due to relatively rapid changes in the relative sizes of firms in the industry, this means that the firms selected tend to be those that have recently grown the fastest.

[8] While it would be of interest to know costs of customer service, this information is not provided separately in corporate financial statements.

[9] One firm included in the tabulation, Novellus, did not exist in 1986 and had losses of $3.2 million associated with start-up operations in 1987.

[10] U.S. Department of Commerce, Office of Industrial Resource Administration, *National Security Assessment of the U.S. Semiconductor Wafer Processing Equipment Industry*, April 1991, pp. 33, 37. As the data were derived from a confidential survey, it is not known which firms are included.

Profitability of leading U.S. semiconductor equipment suppliers, 1986-90
(Total for nine firms, $ millions and percent of sales)

	1986	*1987*	*1988*	*1989*	*1990*
Net sales	826	911	1395	1785	1882
Cost of goods	465 (56%)	520 (57%)	759 (54%)	972 (56%)	1069 (57%)
Gross profit	361 (44%)	392 (43%)	636 (46%)	812 (44%)	813 (43%)
R&D expenditure	153 (18%)	153 (17%)	180 (13%)	245 (14%)	298 (16%)
Pretax earnings	-29 (-4%)	-44 (-5%)	91 (7%)	144 (8%)	52 (3%)
Number profitable	3	3	8	8	6

Profitability of U.S. wafer-processing equipment producers, 1985-89

(Total for eight firms, $ millions and percent of sales)

	1985		*1986*		*1987*		*1988*		*1989*	
Net sales	351		248		250		357		529	
Cost of goods	182	(52%)	132	(53%)	136	(55%)	199	(56%)	304	(58%)
Gross profit	169	(48%)	116	(47%)	113	(45%)	158	(44%)	225	(42%)
R&D expenditure	54	(15%)	60	(24%)	54	(22%)	53	(15%)	55	(10%)
Net (after-tax) profit*	27	(8%)	-13	(-5%)	-8	(-3%)	28	(8%)	49	(9%)

Sales of Materials Suppliers

In the world market for semiconductor materials, U.S.-owned firms supplied about 13 percent of world consumption in 1990, while Japanese firms supplied 73 percent and European firms supplied 14 percent. The semiconductor materials industry involves a substantial amount of production outside the country of ownership. In 1990, about 23 percent of global production took place in the United States, 64 percent in Japan, 7 percent in Europe, and 6 percent elsewhere.[11] While data on market shares of producing regions in different consuming regions are unavailable, the tabulation below indicates that the United States is a substantial net importer of semiconductor materials.[12] Analysts believe that most U.S. suppliers produce almost exclusively for the domestic market, so that there is little U.S. export of semiconductor materials. As a result, U.S. semiconductor materials suppliers appear to be less competitive than Japanese suppliers both as measured by market share and as measured by export performance.

A large part of U.S. semiconductor materials production is undertaken either by small, privately held firms or else by divisions of larger firms that do not report financial data for the relevant divisions. Therefore, it is not possible to assess the general profitability of U.S. materials suppliers.

Production and consumption of semiconductor materials, 1990

(Percentage of world total[13])

Region	*Sales (location of ownership)*	*Sales (location of production)*	*Consumption (location of ownership)*
United States	13	23	38
Japan	73	64	47
Europe	14	7	10
Other countries	(1)	6	5

[1] Less than 0.5 percent.
Source: See table 4-5.

The Competitiveness of U.S. SEM Industry Segments

In the 1970s, U.S.-owned firms were the market leaders in each segment of the global SEM industry. During the 1980s market-share leadership in several segments passed to Japan, while U.S. firms retained the leadership in several other segments. This section focuses both on important developments over the past 10 years in each major segment and on the current state of competitiveness in each segment.

As table 4-4 and figure 4-2 indicate, 1989 sales by the U.S. SEM industry trailed sales by the Japanese industry in three major segments of semiconductor equipment: photolithographic equipment, diffusion and oxidation equipment, and assembly equipment. In other equipment segments, the United States retains a market share comparable to or greater than that of Japan. In all segments the U.S. market share declined during the 1980s, but in some segments the U.S. lead increased in nominal value terms. In materials, however, the U.S. SEM industry trails the Japanese industry by a substantial margin in each of the four largest product categories, as well as in most of the smaller ones.

The following discussion treats first the two segments of wafer-processing equipment in which U.S. suppliers have lost their leading position: photolithographic equipment and diffusion and oxidation equipment. It then considers the other major categories of wafer-processing equipment, as well as assembly equipment and testing and measuring equipment. The section concludes with a discussion of the two major segments of semiconductor materials, wafer-processing materials and packaging materials.

Photolithographic (Wafer Exposure) Equipment

Photolithographic equipment is the largest product category within semiconductor equipment, accounting for about 20 percent of total wafer-processing

[11] The semiconductor equipment industry, by contrast, involves substantially less offshore production.

[12] Data on consumption of semiconductor materials are based on the location of ownership of materials-using firms, not location of use.

[13] Location for ownership of suppliers is based on information for $7.5 billion in sales. Location for production

13—*Continued*

is based on information for $8.2 billion, and location for consumption is based on information for $7.7 billion. Total production and consumption of semiconductor materials in 1990 is estimated as $9.3 billion. For further explanation see notes to table 4-5.

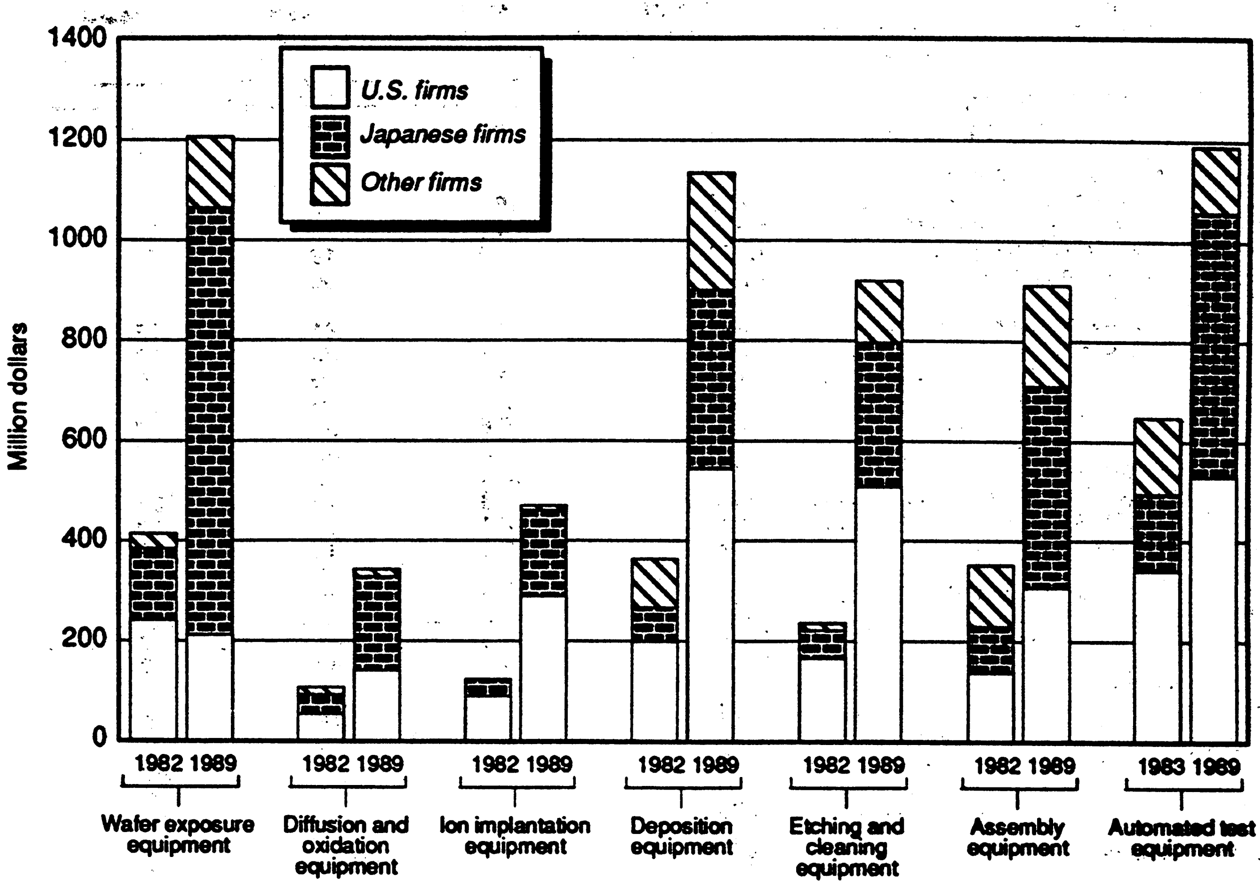
Table 4-4
Semiconductor equipment: World sales and U.S. and Japanese market shares, 1989

Product category	World sales (1989) ($ millions)	Share of total	U.S. market share	Japanese market share
		Percent		
Silicon Wafer Manufacturing Equipment	54	0.6	42	6
Wafer Processing Equipment:				
Photolithographic equipment	1,647	19.5	26	63
Photoresist processing equipment	382	4.5	33	57
Wafer exposure equipment[1]	1,207	14.3	18	71
Mask-making equipment	59	0.7	96	4
Diffusion and oxidation equipment	343	4.1	41	55
Diffusion furnaces[1]	300	3.5	36	60
Other	43	0.5	79	17
Ion implantation equipment[1]	471	5.6	62	37
Deposition equipment[1]	1,135	13.4	49	33
Chemical vapor deposition[1]	621	7.3	59	22
Physical vapor deposition[1]	346	4.1	28	52
Epitaxy	166	2.0	45	22
Etching and cleaning equipment[1]	920	10.9	59	38
Total	4,516	53.4	43	47
Assembly Equipment:[1]				
Dicing	81	1.0	29	64
Die bonding	93	1.1	29	40
Wire bonding	293	3.5	40	50
Molding and sealing	315	3.7	34	42
Finishing and marking	129	1.5	40	45
Total	911	10.8	36	47
Test And Measuring Equipment:				
Test equipment	1,235	14.6	NA	NA
Automated test equipment[1]	1,190	14.1	45	45
Other	45	0.5	NA	NA
Wafer measuring & inspection equip	438	5.2	67	20
Burn-in equipment	65	0.8	88	12
Other	[2]1,237	14.6	NA	NA
Total	2,975	35.2	NA	NA
Total Semiconductor Equipment	8,456	100	NA	NA

[1] Product categories treated in text.
[2] Includes mask and reticle inspection equipment, laser repair equipment, wafer probing equipment, materials handling equipment, process monitoring equipment, and materials monitoring equipment.

Source: VLSI Research, Inc., Prime Data, and other sources.

Figure 4-2
Semiconductor equipment: Worldwide sales of producing regions in major product segments, 1982(3) and 1989



Source: VLSI Research, Inc., Prime Data, and other sources.

equipment sales in 1989. Photolithographic equipment includes equipment for mask-making and applying photoresist to wafers, but its major component is wafer exposure equipment.

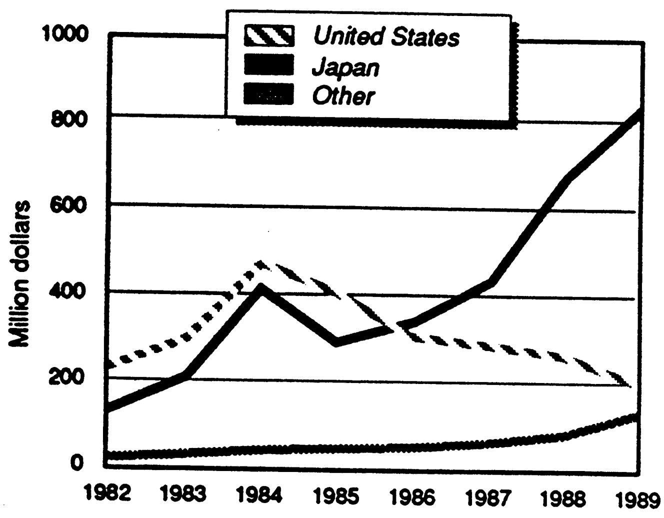
From 1982 to 1989 world sales of wafer exposure equipment nearly tripled, from $415 million to $1.2 billion, but sales by U.S. companies declined from $240 million to $215 million[14] and their market share dropped from 58 percent to 18 percent, as shown in figures 4-2 and 4-3 and the following tabulation.

Photolithographic (Wafer Exposure) Equipment

1982	*World Sales $ 415 million*
1. Perkin Elmer (U.S.)[1]	32.6%
2. Canon (J)	15.8%
3. Nikon (J)	13.5%
4. GCA Corp. (U.S.)	10.4%
5. Eaton (U.S.)	5.6%
U.S. companies total	58.3%
Japanese companies total	34.5%
1989	*World Sales $ 1,207 million*
1. Nikon (J)	37.9%
2. Canon (J)	24.1%
3. General Signal (U.S.)	[2]9.3%
4. ASM Lithography (N)	8.8%
5. Silicon Valley Gr (U.S.)	5.8%
U.S. companies total	17.6%
Japanese companies total	70.7%

[1] The following terms are used to describe firm ownership in the tabulations on the various equipment and materials segments: U.S. - U.S.-owned firm; J - Japanese-owned firm; N - Netherlands-owned firm; G - German-owned firm; and F - French-owned firm.
[2] Now owns GCA Corp. and Ultratech.

Figure 4-3
World sales of wafer-exposure equipment by major producing countries, 1982-89



Source: VLSI Research, Inc.

[14] These and subsequent figures are reported in current dollars.

The market share of Japanese companies doubled from 35 percent to 71 percent, and their sales rose by a factor of nearly six. GCA Corp. and Perkin Elmer Corp., the U.S. suppliers that dominated the market at the beginning of the 1980s, lost their position to Nikon and Canon of Japan.

The changing competitive success of different suppliers of wafer exposure equipment can be attributed largely to the relative performance of their products. Perkin Elmer's Micralign projection aligner, introduced in 1973, led to a great improvement in the quality and productivity of semiconductor manufacturing compared with the established wafer-exposure technology, proximity aligners. As a result, the Micralign became "the single most successful line of semiconductor production equipment ever produced."[15] GCA became a major supplier as a result of its introduction in 1976 of the first stepping aligners (steppers), which were capable of a higher resolution than projection aligners, although at the cost of slower throughput and much higher purchase price. For most of the next decade, the two firms led their competitors in their respective technologies, with stepping aligners gradually overtaking projection aligners as the technology of choice due to the movement toward narrower linewidths. Perkin Elmer's last major improvement in projection aligners, introduced in 1982, briefly enjoyed substantial sales (as reflected in the tabulation above) but represented an increasingly outmoded technology. GCA held a market share of 48 percent in stepping aligners as late as 1984, but it failed to keep up technologically with Nikon and soon lost sales dramatically.

During the mid-1980s Perkin Elmer invested well over $100 million (by most estimates) in an attempt to develop a new type of wafer exposure equipment, step-and-scan aligners, which were thought potentially able to outperform stepping aligners. The failure of this effort eliminated Perkin Elmer as a major supplier in optical wafer exposure systems, although it continued as a supplier in the smaller product sub-category of electron-beam lithographic systems.

Canon entered the wafer exposure business in 1979 with an automated version of the proximity aligner, the technology that Perkin Elmer's Micralign system had done much to render obsolete. Canon's machine represented such a great improvement over previous products of its type that it enabled many semiconductor manufacturers to use it instead of the more expensive projection or stepping aligners. Over the next several years Canon applied the technical know-how it gained from its proximity aligner to the development of projection and stepping aligners as well.

Nikon began its development of wafer exposure equipment in 1976, and in 1981 it brought to market its first product, a stepping aligner. The product outperformed GCA's model and soon captured a large

[15] Jay Stowsky, "The Weakest Link: Semiconductor Production Equipment, Linkages, and the Limits to International Trade," (Berkeley Roundtable on International Economics Working Paper no. 27, August 1987).

volume of sales, first within the Japanese market, and after 1982 in the United States and other markets. Nikon's world market share for stepping aligners (not wafer exposure equipment as a whole) reached 49 percent in 1988 and has declined slightly since then. Two later entrants to the wafer stepper market, Canon and ASM Lithography, are recognized as sharing the technological lead with Nikon.

The process by which GCA lost its technological and market leadership to Nikon illustrates several factors that may have been involved in other SEM product segments as well. While it has been widely reported within the U.S. SEM industry that reverse engineering of GCA's equipment by Nikon played a major role in this process, statements by persons familiar with events suggest that much of the shift was due to other factors: first, the technical problems of GCA equipment, and GCA's unresponsiveness to customer desires;[16] and, second, to Nikon's aggressive R&D efforts, backed by technical and financial support from the Japanese Government and Japanese customers,[17] and by Nikon's own strong technological capability in both optical systems and precision manufacturing.[18]

As a result of their decline, GCA and Perkin Elmer have been reorganized and are now receiving assistance from the U.S semiconductor industry in an effort to restore their competitiveness. GCA was acquired by General Signal Corp. and is now receiving financial support and technical assistance from SEMATECH to develop a new line of steppers. Perkin Elmer Corp. sold its step-and-scan aligner business to Silicon Valley Group (SVG), which is receiving support from IBM for a new effort to develop a marketable system. Perkin Elmer sold a related line of business, electron-beam lithography, to Etec Systems, Inc., a new venture owned equally by IBM and four U.S. partners.

Whether any of these ventures will succeed is not yet known. Some industry analysts doubt that either GCA or SVG Lithographic Systems can gain sufficient market share to become profitable, given the entrenched market position and improving technology

[16] A former official of GCA attributed the emergence of Nikon as a competitor largely to Japanese dissatisfaction with the performance of GCA's equipment and the unresponsiveness of GCA to their needs. A Sept. 8, 1988 memorandum given to USITC staff by ACT International reported that:

> By 1980, from the Japanese perspective, the GCA 4800 Stepper was becoming unreliable in its performance, had low throughput, was difficult to operate, and suffered large amounts of downtime. By 1980, . . . Japanese [customers] departed from the concept of purchasing systems based on acceptance criteria established by U.S. semiconductor manufacturers. [They] began to demand systems based on performance criteria established by Japanese manufacturers. This was a very important change in attitude. GCA was made aware of this change but was not responsive to these demands. It believed systems acceptable to U.S. manufacturers should continue to be acceptable to Japanese manufacturers . . . . Further, it was noted by [Japanese] users that GCA was expending too much of its resources to treating reliability problems rather than solving them.

Support for the view that GCA equipment was unreliable, and that GCA failed to respond to customer complaints, was provided by semiconductor industry officials in both Europe and the United States. European officials particularly indicated that the ultraviolet light used in the equipment tended to degrade the quality of its lenses.

[17] As a result of Japanese dissatisfaction with GCA equipment, according to the memorandum quoted above, the Japanese Government (through MITI) and semiconductor manufacturers provided technical and financial support to Nikon to develop a better-performing alternative. In the process, Nikon imitated GCA's technology but added considerable improvements:

> So, solidly backed action was initiated in Japan to support Nikon in building wafer steppers in response to Japanese user needs. This work was supported financially by MITI and Japanese semiconductor houses. In particular, the effort was technically supported by Toshiba. Toshiba recognized the importance of steppers . . . . In retrospect, the technical development of the Nikon Stepper was funded by the VLSI program [a government-industry research consortium] by issuance

17—*Continued*

> of a purchase order wherein a system had to be delivered to a potential user (Toshiba) by 31 March 1981. Toshiba and Nikon worked on a very intimate basis to produce a reliable system. Nikon listened very carefully to Toshiba in building the first system. It incorporated all of the latest electronic technology to provide for great reliability . . . . Nikon did have a GCA system (apparently available from Toshiba), and did imitate it but with considerable improvements. After the first Nikon stepper was installed and operated, the best known comments from the user was 'it is the best built, best adjusted GCA stepper'. It was installed and running without difficulty.

At the USITC hearing on January 17, 1991, the president of SVG Lithographic Systems, Inc. presented a similar account of assistance Nikon received from its customers. The official indicated that,

> What [Nikon] did is . . . looked at what GCA was doing and took the machine, tore it apart, learned it . . . . Then they put their first prototype together and it was a very lousy machine. But the semiconductor manufacturers in Japan didn't say it was a lousy machine. They said, "let's see what we can do to help you make it better." So they put it in a semiconductor factory . . . right next to GCA and they started figuring out which one is good and which one is bad and what are the advantages and disadvantages. And they . . . [used] it over a three to four year period . . . . The machine in Japan became better than GCA . . . . They could not penetrate the U.S. market because the cost structure they had did not permit them to penetrate the U.S. market. GCA was much more competitive in the United States. And then they went back to the drawing board and figured how they were going to make it cheaper and . . . they did (transcript of proceedings, pp. 205-206).

[18] The chief operating officer of Nikon's U.S. subsidiary wrote to the USITC that, "In fact, the Nikon . . . Stepper was independently developed by Nikon Corporation in Japan. The genesis of the stepper was Nikon's own technology." He stated that Nikon's long experience in "ultra-precision and measuring technologies" was the basis of its development of the wafer stage and the alignment sub-system for its steppers, while Nikon's experience in reduction lenses provided its technology in optics.

of Nikon, Canon, and ASM Lithography. Etec Systems has little competition in its market niche, so its success depends chiefly on the growth of its market.

Diffusion and Oxidation Equipment

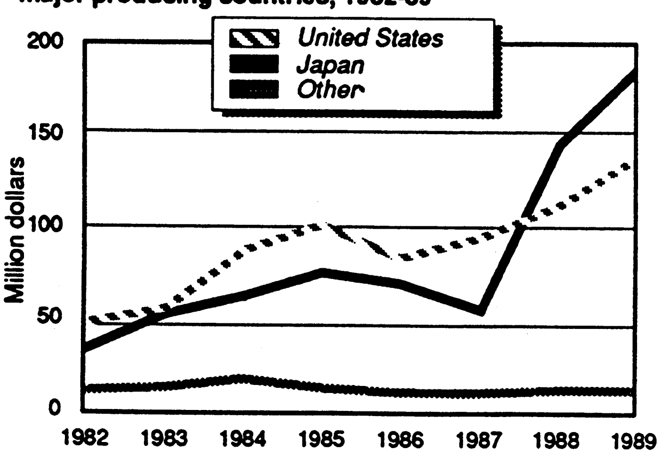
The diffusion and oxidation equipment market is dominated by sales of diffusion furnaces (table 4-4). In the early 1980s, U.S. suppliers of diffusion equipment, such as the Silicon Valley Group, Bruce, and Thermco, were leading producers of diffusion furnaces, but since 1987, Tokyo Electron and Kokusai of Japan emerged to dominate the market, as shown in the following tabulation and figure 4-4.[19] Although U.S. market share declined between 1982 and 1989, U.S. firms' sales rose from $53 million to $141 million

Diffusion & Oxidation Equipment

1982	*World Sales $ 106 million*
1. Tokyo Electron (J)	28.2%
2. Thermco (U.S.)	21.5%
3. Bruce (U.S.)[1]	17.0%
4. Kokusai (J)	7.3%
5. General Signal (U.S.)	4.4%
U.S. companies total	50.2%
Japanese companies total	36.6%
1989	*World Sales $ 343 million*
1. Tokyo Electron (J)	34.6%
2. Kokusai Electric (J)	14.4%
3. Silicon Valley Gr. (U.S.)[2]	14.3%
4. BTU International (U.S.)[2]	8.8%
5. Gasonics (U.S.)	4.3%
U.S. companies total	41.0%
Japanese companies total	54.9%

[1] Now part of BTU International.
[2] Thermco divisions purchased by these firms.

Figure 4-4
World sales of diffusion and oxidation equipment by major producing countries, 1982-89



Source: VLSI Research, Inc.

[19] The other product categories in this segment are high-pressure oxidation equipment and rapid thermal processing equipment. Both categories remain dominated by U.S. firms.

The market for diffusion and oxidation equipment has historically been a regionalized one, to the extent that even in the United States Thermco served the western region and Bruce the eastern region. Japan's increasing share of world semiconductor production has been one factor leading to increasing market share for Japanese suppliers. This regionalization lasted as long as suppliers in different regions had roughly equivalent technology, but in 1988 Tokyo Electron and Kokusai introduced lines of vertical furnaces that have proven superior in performance to horizontal furnaces. Vertical furnaces are easier to automate and provide more uniform results. As a consequence, the Japanese suppliers added a substantial portion of overseas markets to their strong sales in the Japanese market.

The U.S. producer Silicon Valley Group is currently developing vertical furnaces in cooperation with SEMATECH. The success or failure of this effort may be less consequential than the results of other SEMATECH programs, for diffusion and oxidation equipment is the smallest and slowest growing major segment within wafer-processing equipment (figure 4-2), and its role in wafer processing is increasing being replaced by ion implantation equipment, a segment dominated by U.S. suppliers.

Ion Implantation Equipment

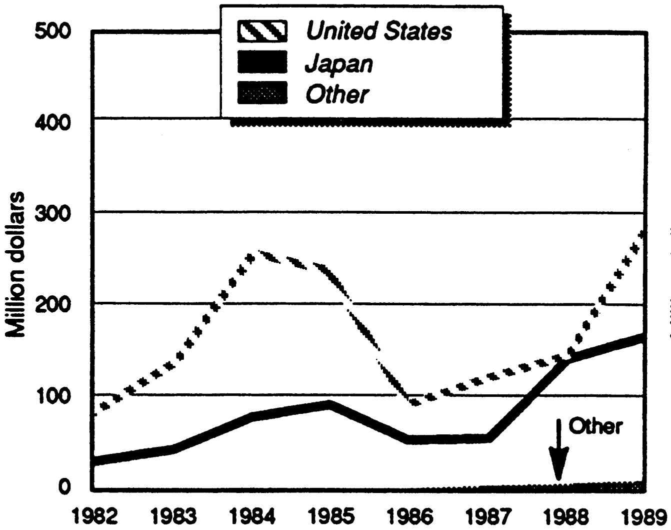
The world's leading suppliers of ion implantation equipment from the early 1970's to the present are the U.S. firms Varian and Eaton, which developed the basic technology used in 80 percent of this category of equipment. During the 1980's Varian and Eaton lost market share chiefly to the two Japanese suppliers with whom they formed joint ventures, Tokyo Electron Limited and Sumitomo, respectively. In 1989 these four firms together controlled 71 percent of world sales, as shown in the following tabulation and figure 4-5. U.S. firms' sales rose from $89 million in 1982 to $290 million in 1989.

Ion Implantation Equipment

1982	*World Sales $ 123 million*
1. Varian (U.S.)	40.7%
2. Eaton (U.S.)	24.9%
3. Ulvac (J)[1]	13.5%
4. Tokyo Electron (J/U.S.)[2]	12.9%
5. Applied Materials (U.S)	5.8%
U.S. companies total	72.3%
Japanese companies total	27.7%
1989	*World Sales $ 471 million*
1. Varian (U.S.)	24.1%
2. Eaton (U.S.)	21.8%
3. Tokyo Electron (J/U.S.)[2]	16.2%
4. Applied Materials (U.S.)	11.1%
5. Eaton Sumitomo (J/U.S.)[2]	8.5%
U.S. companies total	61.5%
Japanese companies total	36.6%

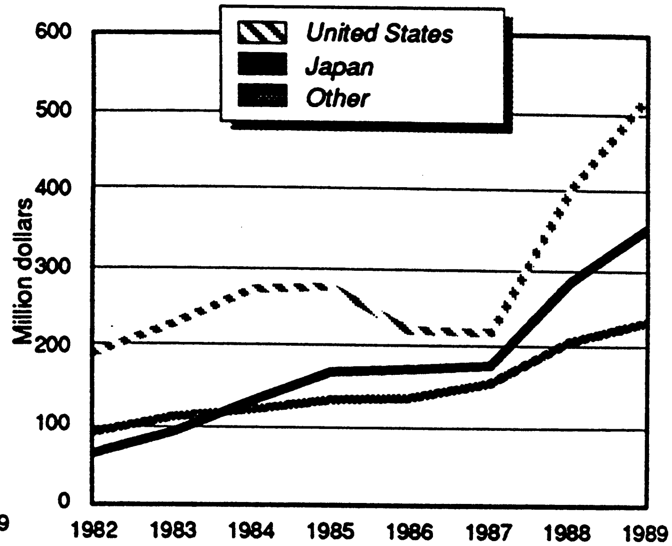
[1] Also a minor supplier in 1989.
[2] Joint ventures located in Japan

Figure 4-5
World sales of ion implantation equipment by major producing countries, 1982-89



Source: VLSI Research, Inc.

Figure 4-6
World sales of deposition equipment by major producing countries, 1982-89



Source: VLSI Research, Inc.

According to industry sources, Varian and Eaton have maintained their competitiveness by keeping a technological lead and pricing aggressively. They have lost market share to Japanese suppliers (a process that reversed briefly in 1989, as shown in figure 4-5, before continuing in 1990, according to preliminary figures) due largely to the technology transfer involved in their joint ventures and the shift of semiconductor production, and demand for equipment, to Japan and other Asian markets.

Deposition Equipment

Another SEM segment in which U.S. suppliers have maintained their lead is deposition equipment, as shown in the following tabulation and figure 4-6. U.S. firms' sales rose from $198 million in 1982 to $545 million in 1989.

Deposition Equipment

1982	*World Sales $ 364 million*
1. Applied Materials (U.S.)	13.0%
2. Varian (U.S.)	8.1%
3. ASM (N)	9.6%
4. MRC (U.S.)	7.4%
5. Balzers (Swiss)	6.9%
U.S. companies total	54.5%
Japanese companies total	19.2%
1989	*World Sales $ 1,135 million*
1. Applied Materials (U.S.)	14.9%
2. Varian (U.S.)	7.9%
3. ASM (N)	7.5%
4. ULVAC Corp. (J)	6.6%
5. MRC/Sony (J)	[1]6.3%
U.S. companies total	48.0%
Japanese companies total	31.4%

[1] MRC purchased by Sony in 1988.

Deposition equipment uses three technologies: chemical vapor deposition (CVD), representing approximately 55 percent of sales in the segment; physical vapor deposition (PVD), representing 30 percent; and epitaxy, 15 percent. In CVD, U.S. suppliers have recently made substantial gains on foreign competitors. In 1989, Applied Materials replaced ASM (of the Netherlands) as the CVD market leader, rising from a 16.3 percent share to 25.6 percent, while recent market entrant Novellus (U.S.) more than doubled its share to 7.2 percent, advancing past the Japanese firms, Tokyo Electron and Kokusai Electric, to take fourth place. Genus, another U.S. firm, retained its position in third place.

According to a customer survey by VLSI Research Inc.,[20] Applied Materials and Novellus both rate high in equipment performance, while Novellus and Genus provide good service after sales. Novellus is also noted in this survey for its "commitment to the industry." Industry analysts credit Novellus with excellence in both engineering and management, enabling it to offer the "best cost/performance system available in the market"[21] while still generating gross profit margins of 60 percent. As Novellus continues to gain market share and introduce a broader product line it is proving to be one of the most successful entrants to the SEM industry in recent years.

The market leader in PVD, with a 24.9 percent share in 1989, is Materials Research Corporation (MRC), a U.S.-based firm recently purchased by Sony of Japan. MRC's greatest strength relative to

[20] VLSI Research Inc., Manufacturing Outlook, 1990, p. 4.6.2 4.

[21] Ibid.

competitors, according to users surveyed by VLSI Research,[22] is its support of customers' production process. One industry analyst suggests that MRC's new relationship with Sony will both improve its financial strength and give it better access to the Japanese market, potentially threatening the major Japanese competitors.[23]

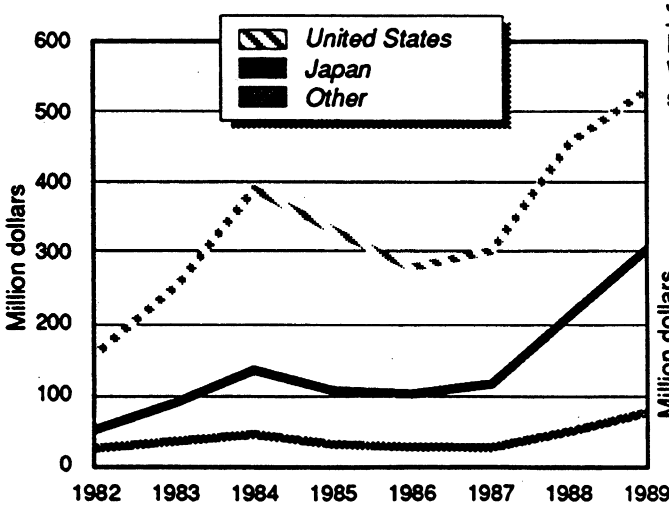
Etching and Cleaning Equipment

U.S. firms' sales in etching and cleaning equipment rose from $165 million in 1982 to $509 million in 1989, while their market share declined from 70 percent to 55 percent. (See the following tabulation and figure 4-7).

Etching & Cleaning

1982	*World Sales $ 236 million*
1. Applied Materials (U.S.)	12.7%
2. Tokyo Ohka (J)	10.6%
3. Integrated Air (U.S.)	8.4%
4. Tegal (U.S.)	7.4%
5. FSI (U.S.)	7.2%
U.S. companies total	69.9%
Japanese companies total	24.4%
1989	*World Sales $ 920 million*
1. Applied Materials (U.S.)	20.8%
2. Tokyo Electron (J)	10.1%
3. Lam Research (U.S.)	9.8%
4. Hitachi (J)	6.3%
5. Tegal (U.S.)	5.4%
U.S. companies total	55.3%
Japanese companies total	31.3%

Figure 4-7
World sales of etching and cleaning equipment by major producing countries, 1982-89



Source: VLSI Research, Inc.

Applied Materials, the market leader in the segment, enjoys its position as a result of "the breadth of its process technology and the strength of its worldwide service network."[24] Until recently the second leading producer was Lam Research, another U.S. company, but in 1989 it was surpassed by Tokyo Electron, which entered the market through a joint venture with Lam and bought out Lam's share of that venture in about 1986. Tokyo Electron's success is attributed to its improvements on Lam's technology.[25]

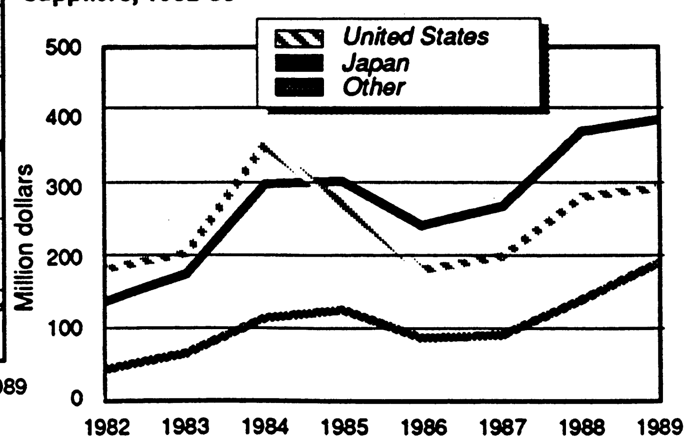
Assembly Equipment

More than 130 firms serve the assembly equipment market, which had sales of $708 million in 1989 and an estimated $1.0 billion in 1990. Nearly all these firms specialize in a single segment of this market, and even the top five firms each produce in only one or two segments. The following tabulation lists the largest suppliers in 1982, when U.S. firms had sales of $137 million, and 1989 when U.S. firms had sales of $239 million. Also see figure 4-8.

Assembly Equipment

1982	*World Sales $ 352 million*
1. Kulicke & Soffa (U.S.)	13.7%
2. Shinkawa (J)	7.2%
3. General Signal (U.S.)	6.8%
4. Yamada (J)	3.8%
5. Disco Abrasive (J)	3.6%
U.S. companies total	38.9%
Japanese companies total	26.3%
1989	*World Sales $ 708 million*
1. Shinkawa (J)	12.9%
2. Kulicke & Soffa (U.S.)	9.1%
3. ASM (N)	7.2%
4. Towa Elec. Co. Ltd. (J)	6.6%
5. Yamada (J)	6.3%
U.S. companies total	33.7%
Japanese companies total	44.3%

Figure 4-8
World sales of assembly equipment by major suppliers, 1982-83



Source: VLSI Research, Inc.

[22] Ibid. p.4.6.2 7
[23] Ibid.

[24] Ibid., p.4.7.2 2
[25] Ibid.

U.S. producers led in sales in world markets for assembly equipment from the late 1950s until 1972, when Shinkawa of Japan introduced the first automatic wire bonding machines.[26] U.S. companies soon responded with their own automatic wire bonding equipment, but by 1977, Japanese companies almost caught up to U.S. companies in worldwide sales. These inroads were shortlived; by 1980, U.S. companies such as Kulicke & Soffa and Jade Corp. had introduced bonding equipment so technologically superior to their foreign competitors that U.S. suppliers established a nearly 60-percent share of worldwide assembly equipment sales. Japanese suppliers managed only a 30-percent share of the world total in 1980. The major development that spurred this reversal was Kulicke and Soffa's digitally controlled wire bonding head, which allowed equipment users to change semiconductor products and die types by making a simple program change. Not only did this advancement increase user flexibility, but it also improved assembly yields while providing flexible, low cost bonding on a larger scale.

During the early 1980s, European companies made a strong entry into the worldwide assembly business, particularly in the area of die bonding equipment. Likewise, Japanese suppliers began to make steady inroads into the market share of U.S. suppliers. This reemergence was led by technological advances in packaging equipment and dicing saws.

Semiconductor Testing and Measuring Equipment

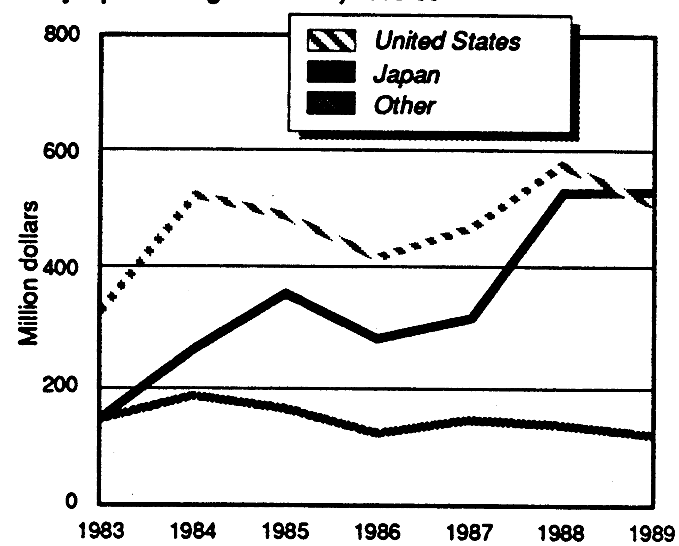
Semiconductor testing and measuring equipment includes test equipment, wafer measuring and inspection equipment, burn-in equipment, and a variety of other product categories (see table 4-4 above).[27] Test equipment represents approximately half the value of sales in the segment, and nearly all test equipment is now automated. U.S. market share in automated test

Automated Test Equipment

1983	*World Sales $ 648 million*
1. Schlumberger (French)	23.3%
2. Teradyne (U.S.)	16.8%
3. Advantest (J)	12.1%
4. LTX (U.S.)	9.4%
5. Ando (J)	8.6%
U.S. companies total	52.6%
Japanese companies total	23.9%
1989	*World Sales $ 1,190 million*
1. Advantest (J)	26.5%
2. Teradyne (U.S.)	16.8%
3. Ando (J)	10.9%
4. LTX (U.S.)	10.5%
5. Schlumberger (French)	9.9%
U.S. companies total	43.9%
Japanese companies total	44.5%

equipment declined from 53 percent on sales of $341 million in 1983 to 44 percent on sales of $523 million in 1989 (see the following tabulation and figure 4-9). This decline reflects changes in the location of semiconductor production rather than a shift of market share within separate regional markets.

Figure 4-9
World sales of automated test equipment by major producing countries, 1983-89



Source: Prime Data.

The particular types of test equipment produced in the U.S. and Japan reflect the structure of each country's semiconductor industry, as the United States accounts for 55 percent of world sales of testers for logic devices while Japan produces 65 percent of

[26] Automation of assembly operations has since proven advantageous for a number of reasons, including the reduction of labor costs and the improvement of yields through the reduction of human error. The cost disadvantage of assembling onshore, versus in low-wage markets offshore, has fallen from 75 percent using manual techniques, to just 9 percent when assembly is performed by automated equipment (VLSI Research Inc., 1989, pp. 5.1.2 16). Additionally, there are cost advantages that result from installing automated assembly equipment in line with wafer-processing equipment, reducing idle inventories of semi-finished semiconductor devices in transit, and avoiding air freight charges.

[27] Testing equipment is used to perform tests on semiconductor devices while they are still part of the wafer (wafer-probing equipment) and for final testing after the chips have been assembled and packaged. Burn-in test equipment is used to subject the packaged devices to controlled stresses by using electronic signals and elevated temperatures to force the failure of weak or potentially defective devices. Measuring equipment consists of machines that are capable of measuring the critical layer thickness and junction depths of semiconductor devices and detecting contamination from previous processes. Measuring

27—*Continued*

and inspection equipment is also used to manage the reticles or masks during their use to determine when replacements are necessary. Laser repair equipment is used to salvage defective devices by connecting new elements to the defective circuits.

memory testers. It was principally the growth of Japanese production in memory devices, therefore, that led to its increasing market share in testers.

U.S. suppliers accounted for 67 percent of global sales of wafer measuring and inspection equipment in 1989, while Japanese suppliers accounted for 20 percent.

Semiconductor Materials

Japan is the world's leading producer of semiconductor materials, supplying approximately 64 percent of $5.0 billion market for wafer processing materials and 85 percent of the $4.3 billion market for packaging materials in 1990[28]. The United States, by contrast, supplied 17 percent of wafer processing materials and 8 percent of packaging materials. Japan accounts for at least two-thirds of world production in 9 of the 14 categories of semiconductor materials noted in table 4-5, including the two largest categories of wafer processing materials and the five largest categories of packaging materials. U.S.-owned suppliers had substantial sales only in photomasks and the three categories of chemicals used in wafer processing: photoresists, wet chemicals, and gases. European suppliers produce primarily silicon wafers, sputtering targets, and various chemicals.

Historically, Japanese-owned suppliers' share of the world materials market rose from 21 percent in 1980[29] to 73 percent in 1990. U.S. suppliers' share declined correspondingly.

Much more than semiconductor equipment, the semiconductor materials industry involves offshore production (table 4-5). One reason for this is

[28] Percentages are based on partial information presented in table 4-5.

[29] Rose Associates, presentation to SEMI Information Services Seminar, 1981.

Table 4-5
World market shares of semiconductor materials, 1990

Product category	1990 World sales ($ millions)	By ownership[1] Japan	U.S.	Europe	By production Japan	U.S.	Europe
		Percent					
Processing materials:[2]							
Silicon wafers	2,010	70	0	30	58	29	11
Photomasks	1,100	69	29	1	63	32	1
Photomask blanks	143	99	1	0	99	1	0
Photoresists	242	46	42	12	49	43	7
Wet chemicals	427	42	46	12	48	41	11
Gases	580	40	32	28	42	38	14
Sputtering targets	200	78	3	19	40	52	8
Total processing	[3 4]4,702	64	17	18	56	33	8
Packaging materials:[5]							
Ceramic packages	1,110	100	0	0	92	7	1
Cerdip	197	92	8	0	61	29	0
Leadframes	1,203	74	10	16	65	7	10
Molding compound	459	83	17	0	74	5	1
Bonding wire	372	84	13	3	75	16	7
Die attachment	86	24	40	37	34	65	1
Headers	60	44	0	24	43	10	23
Total packaging	[4]3,487	85	8	7	74	10	5
Total materials	[4]8,189	73	13	14	64	23	7

[1] These percentages were computed by using data provided by SEMI/SEMATECH as purchased from Rose Associates. Ownership calculations are based on 92 percent of total production because 8 percent of total production, or $686 million, could not be identified by company and nationality of ownership.

[2] These data on processing materials, available from SEMI/SEMATECH (except for photomasks, from Rose Associates), represent 93 percent of total world sales of processing materials as published by Rose Associates. Non-silicon substrates are omitted ($245 million), as are deposition materials other than sputtering targets ($60 million). Photomask blanks ($143 million) have been added to the Rose Associates' data.

[3] Total of processing materials includes double-counting of photomask blanks used in production of photomasks.

[4] Omitted categories sum to $305 million for processing materials, $860 million for packaging materials, and $1,165 million total.

[5] These data on packaging materials, available from SEMI/SEMATECH, represent 80 percent of total world sales of packaging materials as published by Rose Associates. Thick film pastes are omitted ($220 million), as are seal lids ($260 million), cans ($45 million), hybrid substrates ($80 million), hybrid packages ($65 million), and miscellaneous packaging materials ($190 million).

Source: Prepared by the staff of the U.S. International Trade Commission; based on data provided by SEMI/SEMATECH (as purchased from Rose Associates) and by Rose Associates for photomasks.

trans-national purchases of supplying firms, particularly U.S. suppliers purchased by Japanese and, to a lesser extent, European firms. Another is that suppliers locate their production facilities near the markets they serve. For example, Shin-Etsu, the world's largest producer of silicon wafers, established production in the United States in the early 1980s in order, according to company officials, to improve service to U.S. customers.

World production of processing and packaging materials is concentrated in silicon wafers, photomasks, ceramic packages, and leadframes (table 4-5 and the following tabulation).

Major Wafer Processing Materials

Photomasks *1990*	*World Sales* *$ 1,110 million*
1. Dai Nippon Printing (J)	15.9%
2. Toppan Printing (J)	14.8%
3. DuPont Photomasks (U.S.)	9.6%
4. Hoya (J)	4.8%
5. Photronics (U.S.)	3.4%
U.S. companies total	28.5%
Japanese companies total	67.9%

Silicon Wafers *1990*	*World Sales* *$ 2,010 million*
1. Shin-Etsu Handotai (J)	28.1%
2. Huels (G)	14.2%
3. Wacker (G)	13.2%
4. Jasil-Siltec (J)	11.7%
5. Osaka Titanium (J)	11.2%
U.S. companies total	0.0%
Japanese companies total	65.0%

Major Packaging Materials

Leadframes *1990*	*World Sales* *$ 1,203 million*
1. Mitsui High-Tech (J)	16.7%
2. Shinko Electric (J)	16.2%
3. Sumitomo (J)	9.8%
4. Dynacraft (U.S.)	8.4%
5. Enomoto (J	8.1%

Ceramic packages *1990*	*World Sales* *$ 1,110 million*
1. Kyocera (J)	56.8%
2. NTK (J)	27.0%
3. Shinko (J)	8.1%
4. NGK Insulator (J)	2.7%
5. Narumi (J)	0.9%

U.S.-owned firms produce negligible quantities in two of these categories and only 8 percent in a third, but in each category foreign firms have production facilities in the United States. Silicon wafer production is dominated by five Japanese firms, three of which have production facilities in the United States, and two German firms, both of which also produce in the United States. The world's leading producer of ceramic packages, Kyocera, locates approximately 10 percent of its production in the United States. In leadframes, the only significant U.S.-owned producer, Dynacraft, with 8 percent of the world market, undertakes 70 percent of its production in Malaysia, but three foreign firms (one Japanese and two European) produce in the United States.

A 1987 industry survey by Semiconductor Research Corp. found that product performance, due to technology, was an important factor in the rise in Japan and decline of the United States in semiconductor materials.[30] The respondents reported that, although U.S. suppliers had been world technological leaders in 1981 in all materials except ceramic packages, by 1986 Japanese suppliers had taken the lead in silicon wafers, mask blanks, and ceramic packages. Furthermore, Japanese suppliers had achieved technological parity in chemicals: photoresists, wet chemicals, gases, and molding compounds.

These survey results by product category correlate strongly with the 1990 data on market shares in table 4-5. U.S. suppliers had virtually no sales in the categories identified by the survey as areas of Japanese technological advantage, while U.S. suppliers had approximately the same market share as Japanese suppliers in three of the four categories identified as areas of technological parity. It appears likely, therefore, that a relative decline in technology was instrumental in the decline of U.S. market share in materials.

The reason for the relative decline in technology, however, remains to be explained. It seems clear that, in several categories of semiconductor materials, U.S. suppliers did not undertake the R&D expenditures required to match product improvements by Japanese competitors. It is not clear, however, whether this has usually been due to the small size of many U.S. materials firms, or other factors. According to one industry source,[31] several U.S. manufacturers of high-end leadframes exited that line of business between 1982 and 1986 because they could not "afford" R&D expenditures, which suggests that size may have been a factor in this case.

Geographic location appears to have been an important factor in the case of several packaging materials. The location of U.S. assembly plants in the Far East gives Japanese suppliers the advantage of relative nearness.

Another factor in the loss of materials segments is the loss of equipment segments. According to one U.S. supplier of photoresists,[32] Japanese manufacturers of photolithographic equipment guarantee their products only when used in conjunction with Japanese photoresists. A U.S. semiconductor manufacturer

[30] Electronic Business, *Why Japan has the Corner on the IC Materials Market*, Aug. 15, 1987, p. 40.

[31] Staff interview with President of Dyna-Craft, Inc., Mar. 28, 1991.

[32] ITC staff interview, March 28, 1991.

confirms that its switch to Japanese photolithographic equipment is leading it to use Japanese photoresists designed to work with that equipment.[33]

Competitive Strengths and Weaknesses of the U.S. SEM Industry

This section applies the analytical framework introduced in chapter 2 to assess the current competitive strengths and weaknesses of the U.S. SEM industry, with a view to understanding whether the declining trends identified in the previous sections are likely to continue. The main part of the analytical framework is repeated in figure 4-10 with some added detail. This section considers, in turn, the six factors identified as direct determinants of competitiveness and then the determinants of product performance.

Product Performance

U.S. SEM suppliers show both relative strengths and relative weaknesses in product performance. As the previous section illustrated, the relative sales performance of particular firms in both the U.S. and world markets has depended strongly on product performance. Although U.S. firms have maintained a substantial lead in the performance of products in several categories, the Japanese industry has introduced certain products that exhibit higher performance. Whereas U.S. firms have often excelled in developing innovative equipment designs, they have often trailed the Japanese industry in incremental improvement through precision engineering that enhances both the technical capabilities of equipment and facets of quality such as throughput and reliability.[34] [35] It appears from statements of industry sources, however,[36] that the U.S. industry is improving in the latter area, in part due to the work of SEMATECH and leading customers such as IBM and Motorola.

[33] Letter from U.S. semiconductor manufacturer, July 25, 1991.

[34] Industry sources suggest that the most important facets of quality for equipment, identified in figure 4-10, are throughput (productivity or speed of operation), reliability (uptime or mean time between failures), yield (the number of functional chips that emerge from a processing step), flexibility (ease of switching to different device designs), automation (reduces labor costs and increases reliability and yield), and serviceability (improves ease of maintenance and reduces downtime). For materials, the most important facets are purity and absence of defects. According to a 1989 SEMATECH survey of member semiconductor companies, their U.S. suppliers rated "poor" in equipment uptime and "fair" in material purity, while Japanese suppliers rated "excellent" in both categories.

[35] Some industry sources suggest that differences between U.S. and Japanese firms in these areas are rooted in the engineering cultures of each country: the U.S. culture emphasizes development of innovative designs, while the Japanese culture emphasizes production process engineering and continuous improvement. Views presented in chapter 2, as well as the case of photolithographic equipment reviewed in the previous section, suggest that the differences may also reflect qualitative differences in the demands of U.S. and Japanese customers.

[36] See the discussion of industry views in chapter 2.

Services to Users

Services to users has been an area of relative weakness for U.S. SEM suppliers. SEM suppliers and users in both the United States and Japan agree that Japanese suppliers often provide more extensive marketing services, better training of equipment operators, and more reliable equipment maintenance services than U.S. suppliers. Providing high-quality service is an important element in Japanese business practices and gives Japanese SEM suppliers an advantage in the Japanese market over U.S. firms, which are unaccustomed to giving service top priority. In addition, the high cost of maintaining foreign employees and of establishing an extensive service network hinders U.S. firms (particularly small firms with limited capital) from establishing a service network that is comparable to networks established by Japanese competitors.[37]

Cooperative Relationships with Users

Cooperative relationships between SEM suppliers and users are another area of generally acknowledged competitive weakness for U.S. suppliers. Because SEM users gain detailed practical knowledge about SEM products under actual working conditions (a situation commonly known as "learning by using"[38]), feedback from users to suppliers can improve product performance.[39] Similarly, SEM users can benefit from the direct involvement of suppliers in improving their process control, and they increasingly choose suppliers on the basis of their willingness to be involved in this way.[40] Another potential benefit of such relationships is that users can assist key suppliers in obtaining access to capital.[41] Industry sources in the United States

[37] According to one estimate, it costs approximately one million dollars annually to establish a minimal service operation in Japan consisting of one foreigner, one Japanese sales representative, and a bilingual secretary, with moderate entertainment and participation in two trade shows a year. (Interview in Japan with John Stern, Vice President of Asian Operations, American Electronic Association, May 14, 1991.)

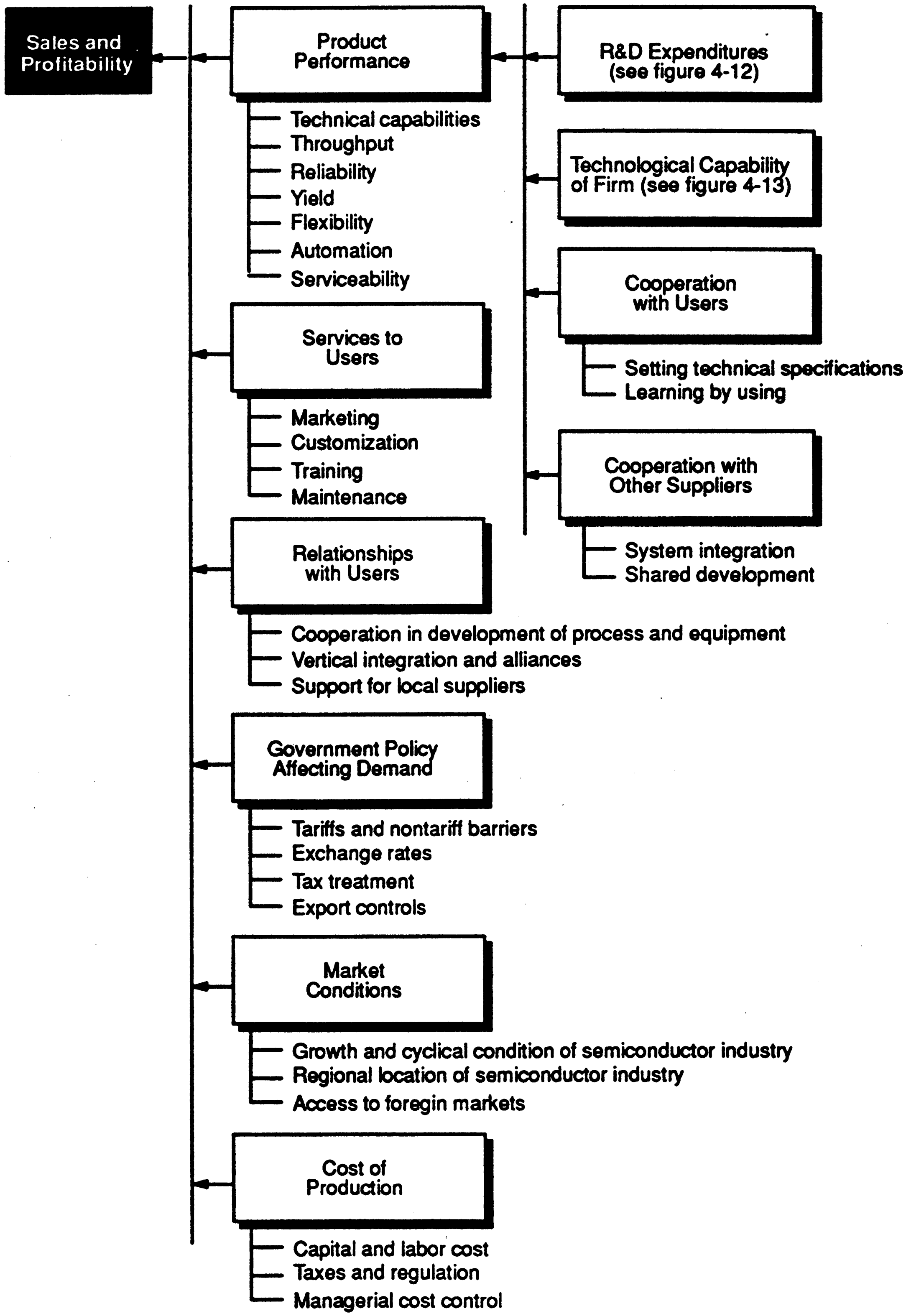
[38] "Learning by using" refers to the acquisition by product users of practical knowledge about its operating characteristics. It should be distinguished from "learning by doing," which refers to improvements in productivity in a production process as a result of cumulative experience. In semiconductor production, the manufacturer's "learning by doing" also involves "learning by using" about the equipment and materials used. For a general discussion, see Nathan Rosenberg, "Learning by Using," in ***Inside the Black Box: Technology and Economics*** (Cambridge University Press, 1982), pp. 120-140.

[39] The working of this process in the origin and development of Nikon's wafer steppers was examined in the previous section.

[40] One U.S. semiconductor industry executive informed USITC staff that his firm chooses suppliers 40 percent on the basis of product performance and 60 percent on the basis of readiness to cooperate in this way (telephone interview, May 10, 1991).

[41] The written submission of SEMI to the USITC hearing suggests (p. 39) that partnerships may include sharing the costs and risks of R&D. Japanese SEM

Figure 4-10
Analytical framework for competitiveness in the SEM industry



and Japan agree that such relationships have been a part of the Japanese way of doing business since the beginning of the industry and have been a substantial competitive advantage for Japanese suppliers. Relationships among U.S. suppliers and users, on the other hand, have been characterized as "project specific, cost-driven, and litigious,"[42] so that U.S. suppliers have developed their products in relative isolation from customer feedback and good information about customer desires for future products.[43] U.S. industry sources indicate that U.S. suppliers and users are consciously seeking to follow the Japanese example in this regard, with leadership from SEMATECH, IBM, Motorola, and other users.

Industry Structure and Support for Local Suppliers

Many U.S. and European SEM industry participants and other observers have suggested that Japanese industrial structure and a strong domestic preference on the part of Japanese customers are major competitive disadvantages for U.S. suppliers in the Japanese market. The evidence on the matter, however, is not conclusive. It is sometimes suggested that vertical integration between SEM suppliers and users, cross-holdings of firm ownership, and membership in the industrial groupings called *keiretsus*[44] affect the purchasing patterns of Japanese customers. Japanese SEM suppliers presented data to the effect that vertical integration, at least, does not prevent SEM users from buying from sources other than their captive suppliers in order to get good products.[45] Moreover, according to these sources, captive suppliers tend to be avoided by competitors of the parent firm.

Empirically, as table 4-1 above indicates, SEM users in the United States and third-country markets, as well as Japan, all tend to buy more from domestic suppliers than from overseas suppliers. Part of the reason for this, in addition to the simple advantage of locality, appears to be that suppliers in each regional market have learned to respond to the particular desires of their local customer base; thus Japanese suppliers, for example, learned to provide the service and cooperative relationships wanted by their customers. Another factor appears to be cultural barriers, particularly in language and business practices. Some U.S. and European SEM suppliers reported, for example, that their sales in Japan were greatly enhanced by their adoption of Japanese cultural practices.[46] A third reason for the observed pattern of national preference appears to be the desire of semiconductor manufacturers to support their local supplier base. While SEM and semiconductor company officials in both the United States and Europe acknowledge that this desire is a factor in both of those markets, they assert that it is a more important factor in Japan.

According to several U.S. and (especially) European SEM suppliers, as noted in chapter 2, Japanese semiconductor firms buy from foreign suppliers only if the foreign products are substantially different from or superior to Japanese products, irrespective of relative prices. Furthermore, according to these sources, Japanese equipment users systematically nurture local suppliers for every item of equipment or materials used in a standard production process, eventually leaving only smaller "niche" markets to foreign suppliers.

Japanese semiconductor firm officials themselves indicate that they are not so much interested in having Japanese suppliers as they are in having suppliers that demonstrate a strong commitment to meeting the desires of Japanese customers. Generally, according to these officials, this requires not only the establishment of a service network in Japan, but R&D facilities as well. Production in Japan, furthermore, is preferred.[47]

41—*Continued*

customers report assisting suppliers primarily by carrying loans on their books for suppliers, which particularly assists small suppliers that would otherwise be bad credit risks, and by allowing space in their facilities for supplier R&D work in partnership with the customer.

42 *SEMATECH 1990: A Report to Congress by the Advisory Council on Federal Participation in SEMATECH* (May 1990).

43 The U.S. SEM industry, reportedly, has long had antagonistic relationships with the U.S. semiconductor industry. Negotiations over sales have tended to involve hard bargaining over prices and other conditions of sale, and suppliers and users have treated their specialized information about SEM products and product needs as strategic bargaining tools rather than as a basis for mutual gain. Semiconductor manufacturers have been reluctant to inform their suppliers about their future needs, because they have feared that suppliers could deduce their plans for new semiconductor products and pass that information on to competing semiconductor manufacturers. Similarly, SEM suppliers have feared that information about their future products could be leaked to their competitors. Distrust has been engendered by a history of failures on both sides: frequent cancelled orders on the part of SEM users; and late deliveries, extravagant promises about new equipment followed by its failure to perform as promised, and inattention to customers, except when initially seeking orders, on the part of SEM suppliers.

According to a 1989 survey of U.S. SEM suppliers conducted by SEMATECH, these suppliers have better relations with their Japanese customers than with their U.S. customers. Japanese customers are concerned more with their suppliers' commitment to customers and goals for future products, while U.S. customers are concerned more with the price and present features of products.

44 See the discussion of antitrust issues in chapter 3. Robert Z. Lawrence has found a statistical relationship

44-*Continued*

between the extent of *keiretsu* organization and degree of resistence to import penetration in Japanese industries, (*Efficient of Exclusionist? The Import Behavior of Japanese Corporate Groups,* Brookings Institution, 1991.

45 USITC staff interviews with SEM industry officials in Japan, May 1991.

46 USITC staff interviews with U.S. and European SEM industry officials, April 1991.

47 USITC staff interviews with Japanese semiconductor industry officials, May 1991.

Foreign (i.e., U.S. and European) suppliers and Japanese customers agree on the historical point that Japanese customers have tended to switch from foreign to domestic suppliers, in product category after product category, when Japanese suppliers emerged with products that performed comparably to foreign products. Foreign suppliers attribute this in large part to a closed market; Japanese customers attribute this to the superior commitment of Japanese suppliers to customer satisfaction. In terms of practical results, there may not be much difference between these interpretations, for the cost of establishing a presence in the Japanese market sufficient to satisfy Japanese customers may be beyond the means of many U.S. and European suppliers, particularly as this cost must be paid up front, before there is any assurance of sales.

Foreign suppliers currently in Japan sell products primarily in areas where Japanese technology is weak. Applied Materials, the largest U.S. supplier to Japan, for example, sells equipment that embodies advanced chemical engineering, an area of relative Japanese weakness.[48] Applied Materials has reportedly made a concerted effort to satisfy Japanese standards of commitment to the market.[49]

Some U.S. and European semiconductor officials suggest that their own recently developed interest in supporting their local supplier bases is a defensive response to their increasing reliance on Japanese suppliers for the most advanced SEM products. These officials state that their Japanese competitors generally have first access to advanced Japanese SEM products, and they express concern that the inability of their local suppliers to offer comparable products puts them (the semiconductor firms) at an increasing competitive disadvantage.[50] Furthermore, they expect that a stronger local SEM industry would provide them with a better pool of potential partners in developing their production process.[51]

Nevertheless, according to some of these semiconductor company officials, they are sometimes caught in the dilemma of being unable to support local suppliers with orders, which suppliers need in order to remain in business and develop improved products for the future, because they (the users) need the most advanced Japanese SEM products of the present day in order to maintain their own competitive position. Indeed, a common complaint of SEM firms in both the United States and Europe is that their local customers buy Japanese products instead of supporting their local supplier bases and thus safeguarding the future success of both the supplying and using industries.

The Effect of Government Policy on Demand

As discussed in chapter 3, government policy affecting demand is an area of competitive weakness for the U.S. SEM industry. Tariffs and nontariff barriers are not an important factor for the U.S. industry,[52] and exchange rates have been relatively favorable since the decline of the dollar over the period 1985-87. International differences in tax laws related to investment and, especially, depreciation, however, tend to increase the size of the Japanese equipment market relative to the U.S. market, and thus favor Japanese SEM suppliers over U.S. suppliers. Export control regulations tended to hinder U.S. sales in the foreign markets in the past, but improved processing of export licenses reduced this problem in recent years, and the recent decontrol of many SEM products is expected to reduce it still further.

Market Conditions

The highly cyclical nature of demand for SEM products (equipment especially) has negative impacts on suppliers in all regions, but it is uncertain whether these effects are worse for U.S. suppliers or foreign suppliers. The discussion of profitability early in this chapter noted that many U.S. suppliers suffered losses during the last (before late 1990) industry recession in 1986-87. It is not known how Japanese and other foreign firms performed during that period. Some industry analysts assert that Japanese suppliers experience less cyclicity of demand than others because Japanese users maintain a more even pace of investment over the business cycle. The data presented in table 4-2 above, however, suggest that Japanese worldwide equipment sales, valued in constant yen, fell 32 percent from 1985 to 1986, while the value of U.S. equipment sales, valued in constant dollars, fell 19 percent. In the same terms, the value of Japanese sales rose 48 percent from 1987 to 1988, while the value of U.S. sales rose 27 percent.

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[48] USITC staff telephone interview with U.S.-based industry analyst, June 1990.

[49] James C. Morgan and J. Jeffrey Morgan, *Cracking the Japanese Market* (Free Press, 1991).

[50] One particular concern expressed by some U.S. and European semiconductor manufacturers is that any equipment or materials supplied only by Japanese firms may be withheld from foreign semiconductor producers, placing them at a competitive disadvantage relative to Japanese producers. According to a just-released report of the U.S. General Accounting Office, 22 out of 52 U.S. companies that have recently purchased state-of-the-art SEM products from Japanese suppliers "provided specific examples of instances in which Japanese suppliers had rejected their offers to buy advanced equipment, parts, or technologies or had delayed their delivery by more than 6 months" (U.S. General Accounting Office, *International Trade: U.S. Business Access to Certain Foreign State-of-the-Art Technology*, Washington, D.C., September 1991).

[51] These same motivations might explain the actions of Japanese SEM customers as well.

[52] According to European SEM suppliers interviewed during April 1991, nontariff barriers are applied in certain East Asian countries against Japanese SEM suppliers. These barriers, taking the form of administrative guidance by government officials to semiconductor firms, are designed to reduce dependence on Japan. U.S. and European firms reportedly increase their sales as a result.

Trends in the regional location of the SEM market are a major competitive weakness for the U.S. SEM industry. As tables 4-1 and 4-2 above illustrate, the U.S. market, where U.S. suppliers have their greatest advantage, is the slowest growing of the three regional markets. Moreover, the market for the technologically most advanced products has shifted much more dramatically, which may have important implications for the future competitiveness of the U.S. industry. High-density DRAMs use the smallest linewidths of any semiconductor device, and so they require the most advanced equipment and materials. Approximately 70 percent of DRAM production now takes place in Japan, and only about 10 percent in the United States. Japanese suppliers are therefore in a relatively strong position to develop the most advanced products, giving them a competitive advantage for products used in all types of devices.

As the market for SEM products moves overseas, a presence in foreign markets becomes increasingly important for U.S. suppliers. This presence is important not only for sales, but also in order to establish cooperative relationships with the most technologically advanced customers. Whether it is possible for U.S. SEM firms to establish such cooperation with foreign customers, however, has not yet been widely demonstrated.

Cost of Production

Cost of production does not appear to be a strong source of competitive strength or weakness for the U.S. SEM industry as a whole. International differences in the cost of production are cited primarily by European firms to explain their decisions to develop and produce equipment in the United States rather than Europe. The most important advantages the United States offers for European producers includes lower labor costs (particularly wage taxes that go for social benefits), freedom to lay off workers without major severance payments, and the ease of leasing rather than purchasing facilities in the United States.

For some firms, managerial control over costs has been an important competitive weakness. Many SEM suppliers in both the United States and Europe are entrepeneurial ventures founded by engineers with little experience in business management. Often their technical skills have generated innovative products leading to strong sales and profitability even with inefficient business practices. As stronger, well managed competitors have emerged in their product segments, however, the lack of managerial control has become an increasing problem.

Determinants of Product Performance

Product performance depends, in the analytical framework in figure 4-10, on R&D spending, the firm's technological capability, cooperation with users, and cooperation with other SEM suppliers. Cooperation with users was treated above, as it is a direct determinant of sales and profit as well as a determinant of product performance. The remaining factors are treated here.

R&D Expenditures

The level of R&D expenditures appears to be an area of competitive weakness for some U.S. SEM suppliers, due their inability to raise capital for the purpose. The SEM industry is highly R&D-intensive compared to other industries. As figure 4-11 illustrates, in the years since 1980 U.S. semiconductor equipment suppliers have spent, by one estimate, from 10 to 18 percent of sales on R&D, averaging about 16 percent since 1984. This compares to an average of 9 percent for the U.S. semiconductor industry, 5 percent for the U.S. electronics industry, and 3 to 4 percent for U.S. manufacturing industries as a whole in 1989.[53] Comparable data on R&D spending in Japan and other supplying countries are not available.

Figure 4-12 identifies several factors that industry participants, analysts, and simple economic theory identify as determinants of R&D expenditures: the cost of new-product development and the supplier's expectations about potential sales, the availability of capital, and the cost of capital.

In some segments of the SEM industry the expenditures required to develop new products have increased dramatically over the past decade, and even over the past five years. According to a recent industry survey,[54] the cost of developing new equipment for optical photolithography (wafer exposure) was fully 10 times as large in 1990 as in 1985, while costs for developing chemical vapor deposition and diffusion/oxidation equipment were 8.3 times and 5.6 times larger, respectively. Ion implantation equipment costs 5 times as much to develop, and physical vapor deposition equipment 4.4 times. Development costs in other product categories have risen by smaller factors, just 1.4 times in wafer inspection equipment and 1.2 times in test equipment, for example.

One apparent result of this increase in development cost is to raise the minimum market share required to remain competitive in the long term. A supplier must be able to spread large development costs over a large volume of sales. According to some suppliers, the minimum market share now required to remain competitive in the market for wafer-exposure equipment, which has the largest and fastest growing development costs, is about 25 percent.[55] If this is

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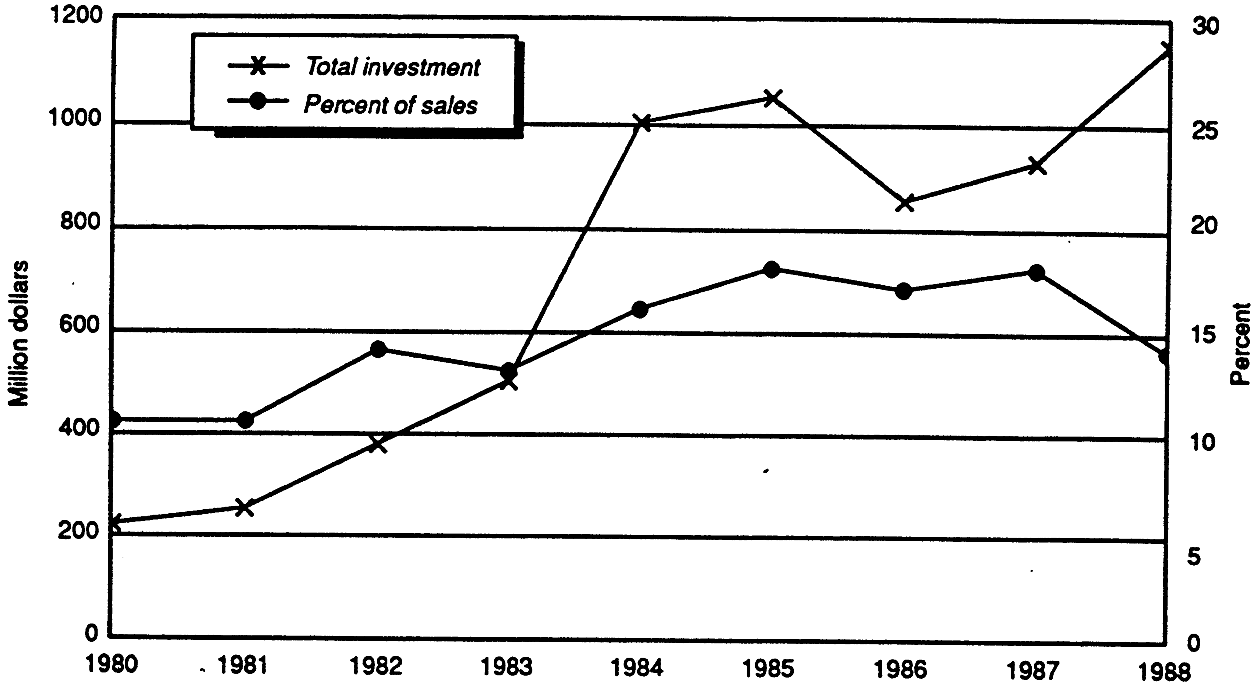
[53] *Business Week*, "R&D Scoreboard," June 15, 1989, p. 204.

[54] Survey by SEMI/SEMATECH and Technecon, May 1991.

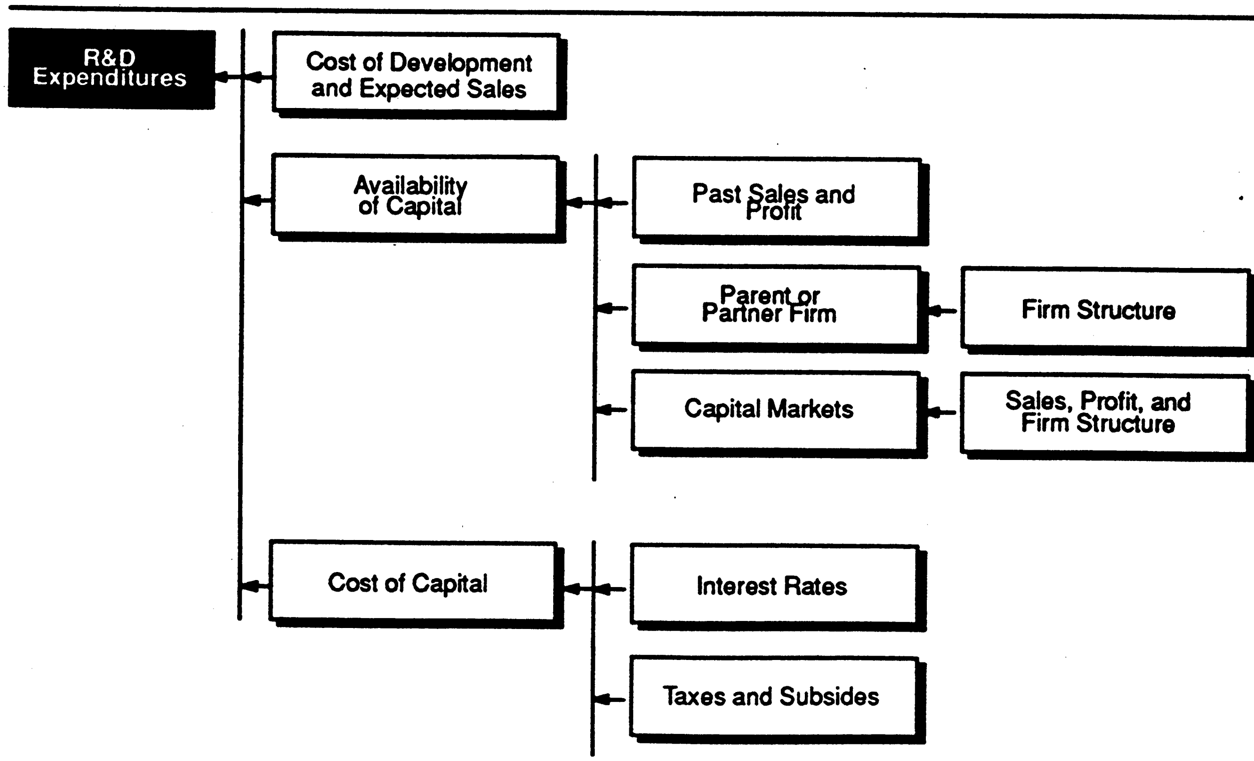
[55] USITC staff interview with a European supplier of wafer-exposure equipment, April 15, 1991. A Japanese source indicates that the minimum viable sales level is 100 units, which is closer to 10 percent of the market (USITC staff interview, May 6, 1991).

Figure 4-11
U.S. semiconductor manufacturing equipment industry R & D expenditures, total and as a perentage of sales, 1980-88



Source: VLSI Research, Inc.

Figure 4-12
Determinants of R&D expenditures



true, then not all the current suppliers can remain in the business. Industry observers predict that rising development costs will lead to shake-outs, and the elimination of financially and technologically weak suppliers, in both this segment and other industry segments.

A firm's R&D spending may be limited by financial constraints, particularly when the firm is under severe competitive pressure. A firm must finance its R&D efforts either from its retained earnings, the resources of a parent corporation, assistance from customers (generally in connection with a cooperative relationship in which the customer receives first access to new products), or capital markets. Firms that rely on internal financing face the dilemma that if they fail to compete successfully in one product generation, or if an industry recession restricts their sales, they may lack the means to develop technology for the next generation. Similarly, lack of competitive success makes suppliers poor risks for outside sources of capital. Vertically integrated suppliers, and those assisted by their customers, may lack this constraint.

The problem of financing needed R&D expenditures appears to be particularly acute for smaller U.S. SEM firms facing Japanese competition, as these firms are most vulnerable to fluctuations in earnings, and suppliers of capital regard such firms as particularly poor risks.[56] Japanese suppliers do not face a similar problem, both because there is less of a competitive threat from foreign suppliers, and because the great majority are involved in cooperative relationships with customers willing to supply R&D capital if needed, often by endorsing loans for the suppliers.[57]

Throughout the 1980s, U.S. SEM suppliers that were able to borrow in financial markets were at a competitive disadvantage in that interest rates were lower in Japan. Since 1990, however, there has been little difference in interest rates. R&D tax credits, another aspect of the cost of R&D capital, is not an area in which the U.S. industry is at a competitive disadvantage compared to Japan, as chapter 3 explains.

Technological Capability

Technological capability is an area of both competitive strengths and weaknesses for U.S. SEM suppliers. The success of a firm's R&D efforts depends not only on the amount of spending but also on the firm's ability to develop the technology to enable SEM products to perform as desired.[58] While U.S. firms have often introduced major product innovations, as discussed in the segment analysis, Japanese suppliers often developed improved versions that became competitive successes. As the case of Nikon's wafer stepper illustrates, they did so by applying their own capabilities in the relevant technologies (in this case, optics and precision engineering) to the designs developed in the United States.

A major focus of interest in this regard is the transfer of technology from U.S. firms to Japanese firms through licensing, joint ventures, distributorship agreements, sales of U.S. firms, reverse engineering of products, and disclosure of technology in patent filings. This transfer has apparently had a substantial impact on the growth of the Japanese SEM industry.

According to industry sources, U.S. firms have been willing to license their technology to Japanese firms, or enter into joint ventures with production in Japan, for two reasons: the difficulty and expense of establishing their own independent presence in the Japanese market, and their undercapitalization and need of cash in order to remain viable even in the U.S. market.[59] Furthermore, some U.S. firms found the use of Japanese distributors to be a relatively easy way to enter the Japanese market, with the result in several cases, however, that the distributors gained the technology of the products and later emerged as competitors in the same line of business.[60] U.S. firms have sold partial or total ownership interests both due to their need of cash infusions and because they have sometimes received substantially more than the firm was worth on the U.S. market.[61] Japanese suppliers have not sold ownership interests to foreign firms. Some Japanese firms are beginning to show interest in establishing

[56] According to a U.S.-based industry analyst, officials of lending institutions have confirmed to him on numerous occasions that they regard small U.S. firms facing Japanese competition as poor risks, even if those firms are currently profitable. (USITC staff interview, Sept. 2, 1991). One official of a U.S. SEM company reported that a bank would not extend a loan to his firm when he indicated its line of business. When he later visited another bank and indicated that his firm made scientific instruments, he had no difficulty procuring a loan.

[57] Interviews with U.S. based industry analyst, September 2, 1991.

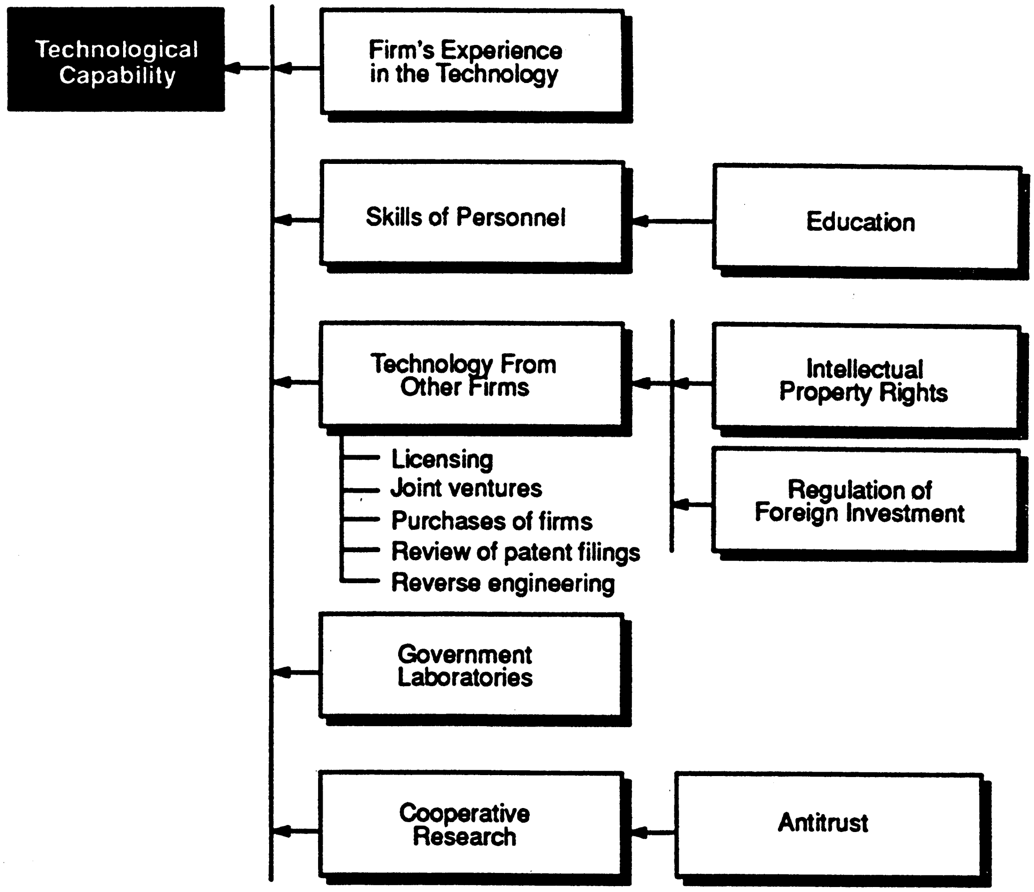
[58] As figure 4-13 illustrates, a SEM firm's technological capability appears to depend most importantly on two factors: the firm's experience in making previous generations of the product and other products that embody similar technologies, and the skills of its technical personnel. Nevertheless, a firm can also gain technology from several sources outside the firm. It can acquire it from other firms, both cooperatively through licensing, joint venture contracts, or the purchase of firms, and non-cooperatively through review of other firms' patent filings and the reverse-engineering of equipment on the market. The firm may also benefit from work done in government laboratories. Another mechanism which has been prominent in both the semiconductor industry and the semiconductor equipment industry, particularly in Japan, is cooperative research with other firms at a "pre-competitive" stage of development of technology.

[59] USITC staff interviews.

[60] For example, Tokyo Electron Limited (TEL), the world's largest SEM supplier, entered the industry as a distributor for U.S. SEM suppliers in Japan. TEL later entered several joint production ventures as well.

[61] Such firms may be worth substantially more to Japanese owners than to U.S. owners precisely because Japanese owners can more easily gain access to the Japanese market.

Figure 4-13
Determinants of technological capability



joint production ventures with U.S. firms in the United States.[62]

Japanese firms have also acquired U.S. technology through reverse engineering[63] (a common and accepted practice in other producing regions as well) and reviews of patent filings. As chapter 3 suggests, the Japanese patent system reportedly gives Japanese suppliers an advantage by requiring the transfer of information while offering little effective protection.

Cooperation with Other SEM Suppliers

Cooperation among suppliers appears to be an area of growing competitive strength for U.S. firms. One focus of such cooperation is to develop integrated systems of equipment that simplify semiconductor production process. The setting of interface standards by the industry as a whole facilitates this, as does cooperation among particular firms in the development of cluster tools, which provide an automated environment in which wafers are passed from one processing step to another without human handling and with minimal exposure to possible contamination. U.S. firms are pioneering in the development of cluster tools. Another focus of cooperation is to combine the technological capabilities of different firms in order to develop products that none could develop alone. The CEO of Novellus Systems, for example, attributes his firm's strong success to this practice.[64] However, U.S. firms identify antitrust restrictions on joint production as a major impediment to pursuing this strategy more fully.[65]

[62] TEL recently established a U.S.-based joint venture with Varian to produce vertical diffusion furnaces in this country (Varian Annual Report, 1989). This follows a long standing joint venture between the two firms in Japan for the production of ion implantation equipment.

[63] Reverse engineering may be more effective for learning about design concepts, the aspect of innovation in which U.S. firms have a relative advantage, than precision manufacturing, an area of Japanese expertise. If so, then Japanese suppliers have a competitive advantage due simply to the nature of the expertise of each national industry.

[64] *Electronic Business*, May 20, 1991, p. 40.

[65] USITC staff interview with president of SEMI/SEMATECH, July 1991.

Inter-Industry Linkages and the Self-Reinforcing Nature of Competitiveness

In two of the factors where U.S. SEM suppliers show competitive weakness, R&D finance and market location, competitiveness appears to be self-reinforcing over time. In R&D finance, this is because the current competitive success and profitability of firms often appears to put a limit on their level of funding for the development of future products, particularly in the case of smaller U.S. firms. In market location, this is due to the sales and technology linkages between the SEM and semiconductor industries. The relative decline of the U.S. semiconductor industry both reduces the sales of U.S. SEM firms (which in turn reduces R&D funds) and limits the opportunity of U.S. SEM firms to develop their technology through cooperative relationships with the most advanced customers. Similarly, the relative decline of the U.S. SEM industry (particularly in key technologies such as photolithography) both reduces the access of U.S. semiconductor firms to the most advanced SEM products and also limits the opportunity of semiconductor firms to improve their production process through cooperative relationships with advanced suppliers.

An important premise of this analysis is that the linkages between the SEM and semiconductor industries operate primarily locally rather than trans-nationally. If the U.S. SEM industry could both sell its products and establish cooperative relationships in foreign markets as easily as in the domestic market, then the relative decline of the U.S. semiconductor industry would matter little to the U.S. SEM industry. Similarly, if the leading foreign SEM suppliers served U.S. semiconductor firms as well as they served their domestic customers, then the relative decline of the U.S. SEM industry would be of little consequence to the U.S. semiconductor industry.[66] As neither of these conditions appears to hold at present, the competitiveness of each U.S. industry appears to depend on the competitiveness of the other.[67] It is recognition of this process that motivates semiconductor manufacturers in all major markets to support their local suppliers.[68]

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[66] This should not be taken to imply that all foreign SEM firms serve their domestic customers better than their foreign customers. Some Japanese- and European-owned suppliers have excellent sales, service, and

66—Continued

customer-oriented research operations in the United States and appear to provide new products to U.S. customers as soon as to their domestic customers. The actions taken by both U.S. and European semiconductor firms to support their domestic supplier bases, however, indicates their belief that some leading Japanese suppliers do not act in this way. The U.S. General Accounting Office's just-released study of Japanese SEM supplier behavior lends considerable support to this view (U.S. General Accounting Office, *International Trade: U.S. Business Access to Certain Foreign State-of-the-Art Technology*, Washington, D.C., September 1991).

[67] For similar reasons, as noted both in chapter 1 and in the studies of the National Advisory Committee on Semiconductors cited in chapter 2, the competitiveness of both depends partly on that of U.S. electronics industries as well.

[68] In technical terms, this analysis suggests that competitiveness in the SEM industry is generated by a dynamic process involving endogenous (i.e., internal) positive feedbacks. Exogenous (i.e., external) factors, therefore, do not lead to the sort of stable market-sharing equilibrium that is analyzed in static economic models of supply and demand. Economists are giving increasing attention to self-reinforcing processes such as this both in general theoretical terms and in the economics of international trade in particular. It is generally recognized that, where different industries are mutually supporting in these ways, greater activity in each industry improves the performance of the others, and that there is a minimum level of activity needed in each of the supporting industries in order to sustain the whole system. Recent academic literature in this area includes Joseph Francois, "Optimal Commercial Policy with International Returns to Scale," *Canadian Journal of Economics*, in press; Gene M. Grossman and Elhanan Helpman, "Quality Ladders in the Theory of Growth," *Review of Economic Studies*, vol. 58 (January 1991), pp. 43-61; Gene M. Grossman and Elhanan Helpman, "Quality Ladders and Product Cycles," *Quarterly Journal of Economics*, in press; and Paul S. Segerstrom, "Innovation, Imitation, and Economic Growth," *Journal of Political Economy*, vol. 99 (August 1991), pp. 807-27. For a discussion of general issues see W. Brian Arthur, "Positive Feedbacks in the Economy," *Scientific American*, February 1990, pp. 92-99.

CHAPTER 5
FINDINGS

The Decline of U.S. Market Leadership

During the 1980s, the U.S. semiconductor equipment and materials industry lost a significant share of the world market for its products to Japanese suppliers. In 1980, the United States dominated every segment of the industry except assembly equipment, while Japan shared the technological and market lead with the United States in assembly equipment and some types of materials. By 1990 the United States led Japan slightly in sales of equipment, but trailed Japan substantially in sales of materials. Throughout this period Europe remained a relatively minor party, with a market share fluctuating near 10 percent.

While the U.S. SEM industry lost market share in every segment of both equipment and materials, it retains world leadership in several segments of equipment, most notably ion implantation and chemical vapor deposition. The industry has fallen substantially behind its Japanese counterpart in photolithographic (wafer exposure) equipment, diffusion furnaces, assembly equipment, and most product categories within materials. The loss of photolithography is probably the most significant, as this is the single most important technology used in semiconductor manufacturing, and this technology has the most important links to other technologies used in wafer processing. The increasing costs of product development for photolithographic equipment, and the entrenched positions of Nikon and Canon, will make it difficult for U.S. firms to regain a leading role in this segment. The loss of sales in diffusion furnaces is less important, both because ion implantation is replacing the role of this equipment and because there does not appear to be a large technological barrier preventing U.S. firms from developing product performance to equal that of Japanese competitors.

Japanese suppliers now have a substantial position in all major segments and nearly all product categories in the SEM industry. At present, leading semiconductor manufacturing facilities throughout the world still require both some Japanese SEM products and some U.S. products, but the dependence of Japanese semiconductor manufacturers on U.S. SEM products appears to be decreasing, while the dependence of U.S. manufacturers on Japanese products appears to be increasing.

The decline in the competitiveness of the U.S. SEM industry during the 1980s resulted primarily from both the decline in the performance of U.S. SEM products relative to Japanese products and the continuing shift of the market for SEM products from the United States to Japan and other foreign markets. The relative decline in U.S. product performance was in turn the result of (1) Japanese SEM industry efforts to improve technology invented in the United States, (2) the superior access of Japanese SEM suppliers to financing for R&D, and (3) more effective technical cooperation between Japanese SEM suppliers and users than between U.S. firms.

Technology, Product Performance, and Competitiveness

The Japanese SEM industry gained its competitive position in world markets largely by improving on technology originally developed in the United States. While U.S. SEM suppliers have proven innovative in design, Japanese suppliers have often excelled in incremental innovations that greatly improved the performance of designs.

Japanese SEM suppliers gained some of their technology through distributing products for U.S. firms and entering joint ventures with U.S. firms. Tokyo Electron Limited, the world's largest SEM firm, entered many of its product lines in these ways. Japan's own technological base also contributed substantially to the performance of Japanese SEM products. The success of Nikon and Canon in photolithographic equipment, for example, owes much to these firms' capabilities in optics and precision manufacturing. Japanese SEM suppliers' skills in precision manufacturing have helped in other industry segments as well, while Japanese firms' relative weakness in chemical engineering and other technologies have inhibited Japanese firms' success in some segments.

R&D Finance, Cooperation with Users, and Product Performance

Two important sources of relative disadvantage for the U.S. SEM industry in its improvement of product performance are access to financing for R&D and relationships with users of SEM products. It is widely accepted that SEM customers in Japan frequently assure access to financing for their local suppliers, so that SEM suppliers' internal financing constraints have been much less important there than in the United States. The small size and undercapitalized structure of many U.S. SEM suppliers have often constrained their development of new technology and products, leading in numerous cases to the exit of U.S. suppliers from the industry. As product development costs continue to increase, the minimum market share needed to sustain internal financing of R&D is expected to increase as well, leading to further exits or consolidations.

The Japanese SEM industry has gained an advantage over the U.S. industry by developing close working relationships with customers. Such relationships appear to have led to substantial product improvement on the basis of the customers' experience. U.S. SEM suppliers, by contrast, in many instances maintained arms-length and occasionally antagonistic relationships with users. Current efforts by SEMATECH and leading U.S. SEM customers appear to be improving this situation.

The Changing Location of the Market

Another factor in the decline of U.S. SEM suppliers is the relative shift of semiconductor production from the United States, where U.S. suppliers have a larger market share, to Japan and other overseas markets. This shift affects not only the quantity but also the quality of demand, as a substantial majority of the world's most advanced semiconductor manufacturing plants are now being built in Japan and elsewhere in Asia. Long-run viability for U.S. SEM suppliers will increasingly require that they compete successfully in these markets. Access to the Japanese market remains difficult, however, due to high entry costs and an apparent preference by Japanese SEM users to buy from local suppliers.

As the number of leading-edge customers in the United States declines, U.S. SEM suppliers also find it increasingly important to form cooperative relationships with Japanese semiconductor manufacturers in order to develop leading-edge SEM products. However, the workability of such relationships has not yet been widely demonstrated

Conclusion

The future competitive success or decline of the U.S. SEM industry is uncertain, but it appears to depend chiefly on (1) the development of stable sources of financing for R&D, (2) the success of cooperative relationships with domestic or foreign customers, and (3) the growth of the domestic market for SEM products and the ability of U.S. firms to establish a presence in foreign markets. While all of these factors depend in part upon actions of the firms themselves, they also depend upon government policy and the structure of domestic and foreign markets.

APPENDIX A
LETTERS FROM THE COMMITTEE ON FINANCE, UNITED STATES SENATE REQUESTING THE INVESTIGATION

United States Senate

COMMITTEE ON FINANCE
WASHINGTON, DC 20510

RECEIVED
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OFFICE OF THE ...

September 27, 1990

The Honorable
Anne Brunsdale
Acting Chairman
United States International
Trade Commission
500 E Street, S.W.
Washington, D.C. 20436

Dear Madam Chairman:

The Committee on Finance has received the Commission's report identifying U.S. advanced technology manufacturing industries for monitoring and possible comprehensive study. We understand that the Commission proposes to conduct comprehensive studies of the following three industries: communications technology and equipment, pharmaceuticals, and semiconductor manufacturing and testing equipment.

The Committee hereby approves the Commission's recommendations. As indicated in our letter of June 21, 1990, the Commission should complete the study of these three industries within 12 months.

Sincerely,

Lloyd Bentsen

United States Senate

COMMITTEE ON FINANCE
WASHINGTON, DC 20510-6200

June 21, 1990

DOCKET

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The Honorable
Anne Brunsdale
Chairman
United States International
Trade Commission
500 "E" Street, S.W.
Washington, D.C. 20436

Dear Madam Chairman:

As part of its policymaking process, the Senate Committee on Finance anticipates a need for impartial and detailed information on the competitiveness of advanced technology manufacturing industries in the United States. As an independent Federal agency with the authority to investigate the impact of international trade upon domestic industry, it would be a logical extension of the Commission's responsibility to expand and enhance its capacity to provide information on an ongoing basis concerning the relative global competitiveness of American industry.

Accordingly, the Committee hereby requests the Commission to expand its collection of, and ability to analyze, information on the competitiveness of such industries pursuant to sections 332(b), 332(d), and 332(g) of the Tariff Act of 1930.

While the Committee wants the Commission to develop a long-term capacity on a broad range of industries, it recognizes that this expertise must evolve in stages. Thus, the Committee requests initially a two-step investigation. Within three months of the receipt of this letter, the Commission is requested to provide to the Committee a list of industries about which the Commission will develop and maintain up-to-date information. In identifying these industries, the Commission should consider the following criteria, as well as any other criteria it may choose to establish:

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U.S. INT'L TRADE COMMISSION

-- Those industries producing a product that:

(1) involves use or development of new or advanced technology, involves high value-added, involves research and development expenditures that, as a percentage of sales, are substantially above the national average, and is expected to experience above-average growth of demand in both domestic and international markets; and

(2) benefits in foreign markets from coordinated -- though not necessarily sector-specific -- policies that include, but are not limited to, protection of the home market, tax policies, export promotion policies, antitrust exemptions, regulatory policies, patent and other intellectual property policies, assistance in developing technology and bringing it to market, technical or extension services, performance requirements that mandate either certain levels of investment or exports or transfers of technology in order to gain access to that country's market, and other forms of Government assistance.

At the time the Commission provides this list of industries, the Commission is requested to recommend to the Committee three industries for comprehensive study. In selecting these industries, the Commission should consider, among any other factors it considers relevant, the importance of the industries producing these products to future U.S. global competitiveness; and the extent of foreign government benefits to industries producing competing products.

The Commission's report on these three industries should include, but is not limited to, the following information:

-- Existing or proposed foreign government policies that assist or encourage these industries to remain or to become globally competitive, existing or proposed U.S. Government policies that assist or encourage these industries to remain or become globally competitive, and impediments in the U.S. economy that inhibit increased competitiveness of these U.S. industries.

The Commission should complete the study of these three industries within 12 months of the Committee's approval of the list of recommended industries.

It would be the Committee's intention to review the report carefully in order to determine how to expand, extend, or otherwise modify this request, if necessary, to ensure that future reports continue to yield worthwhile results.

Sincerely,

Lloyd Bentsen
Chairman

APPENDIX B
THE COMMISSION'S NOTICE OF INVESTIGATION

programs for these subspecies held in captivity.

PRT-753821

Applicant: California State University, Haycoard, CA.

The applicant requests a permit to trap, mark, transport, implant with mirco telemetry transitors, and release Santa Cruz long-toed salamanders (*Ambystoma macrodactylum croceum*) in Valencia and Ellicott Ponds of Santa Cruz County, California for population censusing and monitoring of the species.

PRT-752415

Applicant: John M. Rife, Jr., Winter Park, FL.

The applicant requests a permit to import the sport-hunted trophy of one male bontebok (*Damaliscus dorcas dorcas*), culled from the captive herd maintained by M.J. D'Alton, P.O. Box 400, Bredasdorp, 7280 Republic of South Africa, for the purpose of enhancement of survival of the species.

PRT-752731

Applicant: The Planning Center, Newport Beach, CA.

The applicant requests a permit to live-trap and release Stephen's kangaroo-rats (*Dipodomys stephensi*) on the southeast quarter of section 34, T4S, R6W of Lake Mathews Quad (Riverside county), California, for preliminary biological survey purposes.

Documents and other information submitted with these applications are available to the public during normal business hours (7:45 am to 4:15 pm) room 430, 4401 N. Fairfax Dr., Arlington, VA 22203, or by writing to the Director, U.S. Office of Management Authority, 4401 N. Fairfax Drive, room 432, Arlington, VA 22203.

Interested persons may comment on any of these applications within 30 days of the date of this publication by submitting written views, arguments, or data to the Director at the above address. Please refer to the appropriate PRT number when submitting comments.

Dated: November 9, 1990.

Karen Wilson,

Acting Chief, Branch of Permits, U.S. Office of Management Authority.

[FR Doc. 90-26942 Filed 11-14-90; 8:45 am]

BILLING CODE 4310-55-M

INTERNATIONAL TRADE COMMISSION

Global Competitiveness of U.S. Advanced-Technology Manufacturing Industries

In the matter of Investigation No. 332-301, Global Competitiveness of U.S. Advanced-Technology Manufacturing Industries: Communications Technology and Equipment; Investigation No. 332-302, Global Competitiveness of U.S. Advanced-Technology Manufacturing Industries: Pharmaceuticals; Investigation No. 332-303, Global Competitiveness of U.S. Advanced-Technology Manufacturing Industries: Semiconductor Manufacturing and Testing Equipment.

AGENCY: United States International Trade Commission.

ACTION: Institution of investigations and scheduling of a single public hearing.

EFFECTIVE DATE: November 8, 1990.

FOR FURTHER INFORMATION CONTACT: General inquiries regarding the three names investigations may be directed to Mr. Aaron Chesser, Office of Industries (202-252-1380). Industry-specific information regarding the three investigations may be obtained from the following staff members, also located in the Office of Industries, U.S. International Trade Commission, 500 E Street SW., Washington, DC 20436:

Inv. No. 332-301 (Communications Technology and Equipment), Ms. Sylvia McDonough (202-252-1393);
Inv. No. 332-302 (Pharmaceuticals), Mr. Edmund Cappuccilli (202-252-1368); and
Inv. No. 332-303 (Semiconductor Manufacturing and Testing Equipment), Mr. Nelson Hogge (202-252-1395).

For information on legal aspects of these investigations contact Mr. William Gearhart of the Commission's Office of General Counsel (202-252-1091).

BACKGROUND: On July 20, 1990, at the request of the Senate Committee on Finance, and in accordance with section 332(g) of the Tariff Act of 1930 (19 U.S.C. 1332(g)), the U.S. International Trade Commission instituted investigation No. 332-294, Identification of U.S. Advanced-Technology Manufacturing Industries for Monitoring and Possible Comprehensive Study. The Committee requested the Commission to expand its collection of, and ability to analyze, information on the competitiveness of advanced-technology manufacturing industries in the United States, pursuant to sections 332(b), 332(d), and 332(g) of the Tariff Act of 1930.

Specifically, the Committee requested that the Commission, under a two-stage investigation, (1) within 3 months of receipt of the letter, identify for the purpose of monitoring, using criteria provided by the Committee and any additional criteria of the Commission's choosing, U.S. advanced-technology manufacturing industries, and recommend three of those industries as subjects for comprehensive Commission studies; and (2) within 12 months of the receipt of the Committee's approval (or modification) of the Commission's recommendations, submit its report on three industries the subject of comprehensive studies.

Notice of the Commission's investigation was posted in the Office of the Secretary, U.S. International Trade Commission, Washington, DC, and published in the Federal Register (55 FR 30830) of July 28, 1990. All persons were afforded the opportunity to submit written views concerning the industries to be included on the list and that may be the subject of a comprehensive study.

The Commission's report on investigation No. 332-294 (USITC Publication 2319, September 1990) was transmitted to the Senate Committe on Finance on September 21, 1990. In its report, the Commission identified ten advanced-technology industries and recommended the following three for comprehensive study: communications technology and equipment; pharmaceuticals; and semiconductor manufacturing and testing equipment.

By letter of September 27, 1990, the Senate Committee on Finance acknowledged receipt of the Commission's report on investigation No. 332-294 and approved the Commission's recommendation concerning the three industries for comprehensive study; the Committee further indicated its desire that the Commission complete its study of the three industries within 12 months.

In identifying the industries to be monitored, the Committee requested that the Commission consider the following criteria as well as any other criteria it may choose—

(1) Industries producing a product that involves use or development of new or advanced technology, involves high value-added, involves research and development expenditures that, as a percentage of sales, are substantially above the national average, and is expected to experience above-average growth of demand in both domestic and international markets; and

(2) benefits in foreign markets from coordinated—though not necessarily sector specific—policies that include, but are not limited to, protection of the home market, tax policies, export promotion policies, antitrust exemptions, regulatory policies, patent and other intellectual property policies, assistance in developing technology and bringing it to market, technical or extension services, performance requirements that mandate either certain levels of investment or exports or transfers of technology in order to

gain access to that country's market, and other forms of Government assistance.

The Committee requested that the report on the three industries to be selected include at least the following information—

Existing or proposed foreign government policies that assist or encourage these industries to remain or to become globally competitive, existing or proposed U.S. Government policies that assist or encourage these industries to remain or become globally competitive, and impediments in the U.S. economy that inhibit increased competitiveness of these U.S. industries.

As requested by the Committee, the Commission will attempt to include the aforementioned information in its reports.

PUBLIC HEARING: A consolidated public hearing in connection with the three investigations will be held in the Commission Hearing Room, 500 E Street SW., Washington, DC 20436, beginning at 9:30 a.m. on January 17, 1991, and continuing as required on January 18, 1991. All persons shall have the right to appear by counsel or in person, to present information, and to be heard. Persons wishing to appear at the public hearing should file requests to appear and should file prehearing briefs (original and 14 copies) with the Secretary, United States International Trade Commission, 500 E St., SW., Washington, DC 20436, not later than the close of business on January 3, 1991. Posthearing briefs must be filed by January 31, 1991.

WRITTEN SUBMISSIONS: In lieu of or in addition to appearances at the public hearing, interested persons are invited to submit written statements concerning the investigations. Written statements are encourage early in the investigative process, but should be received no later than the close of business on June 7, 1991. Commercial or financial information which a submitter desires the Commission to treat as confidential must be submitted on separate sheets of paper, each clearly marked "Confidential Business Information" at the top. All submissions requesting confidential treatment must conform with the requirements of § 201.6 of the Commission's *Rules of Practice and Procedure* (19 CFR 201.6). All written submissions, except for confidential business information, will be made available for inspection by interested persons. All submissions should be addressed to the Office of the Secretary of the Commission in Washington, DC.

Hearing-impaired individuals are advised that information on this matter can be obtained by contacting the Commisison's TDD terminal on (202) 252-1810.

By order of the Commission.

Issued: November 8, 1990.

Kenneth R. Mason,

Secretary.

[FR Doc. 90-26923 Filed 11-14-90; 8:45 am]

BILLING CODE 7020-02-M

[Inv. No. 337-TA-311]

Certain Air Impact Wrenches; Commission Decision Not to Review an Initial Determination Designating the Investigation More Complicated

AGENCY: U.S. International Trade Commission.

ACTION: Notice.

SUMMARY: Notice is hereby given that the U.S. International Trade Commission has determined not to review an initial determination (ID) issued by the presiding administrative law judge (ALJ) designating the above-captioned investigation more complicated and extending the administrative deadline for filing the final ID by three months. The Commission has also extended the deadline for completion of the investigation by three months, *i.e.*, until August 8, 1991.

ADDRESSES: Copies of the ID and all other nonconfidential documents filed in connection with this investigation are available for inspection during official business hours (8:45 a.m. to 5:15 p.m.) in the Office of the Secretary, U.S. International Trade Commission, 500 E Street, SW., Washington, DC 20436, telephone 202-252-1000.

Hearing-impaired individuals are advised that information on this matter can be obtained by contacting the Commission's TDD terminal on 202-252-1810.

SUPPLEMENTARY INFORMATION: On October 3, 1990, the presiding ALJ issued an ID designating the investigation more complicated and extending the administrative deadline for filing the ALJ's final ID by three months. No petitions for review or agency comments were received. The investigation was designated more complicated because of the serious illness of the president of respondent Astro Pneumatic Tool Co. (Astro) that temporarily jeopardizes the ability of Astro and respondent Kuan-I Gear Co. to defend themselves in the investigation.

Authority for the Commission action is found in section 337(b)(1) of the Tariff Act of 1930 (19 U.S.C. 1337(b)(1)) and in Commission interim rule 210.59 (19 CFR 210.59).

By order of the Commission.

Issued: November 7, 1990.

Kenneth R. Mason,

Secretary.

[FR Doc. 90-26926 Filed 11-14-90; 8:45 am]

BILLING CODE 7020-02-M

[Investigation No. 731-TA-455 (Final)]

Certain Laser Light-Scattering Instruments and Parts Thereof From Japan

Determination

On the basis of the record [1] developed in the subject investigation, the Commission determines,[2] pursuant to section 735(b) of the Tariff Act of 1930 (19 U.S.C. 1673d(b)) (the act), that an industry in the United States is threatened with material injury [3] by reason of imports from Japan of certain laser light-scattering instruments (LLSIs) and parts thereof,[4] provided for in subheadings 9027.30.40 and 9027.90.40 of the Harmonized Tariff Schedule of the United States, that have been found by the Department of Commerce to be sold in the United States at less than their fair value (LTFV).

Background

The Commission instituted this investigation effective July 6, 1990, following a preliminary determination by the Department of Commerce that imports of LLSIs and parts thereof from Japan were being sold at LTFV within the meaning of section 733(a) of the act (19 U.S.C. 1673b(a)). Notice of the institution of the Commission's investigation and of a public hearing to be held in connection therewith was

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[1] The record is defined in sec. 207.2(h) of the Commission's Rules of Practice and Procedure (19 CFR 207.2(h)).

[2] Acting Chairman Brunsdale and Commissioner Lodwick dissenting.

[3] Commissioners Rohr and Newquist further determine that, pursuant to section 735(b)(4)(B), they would not have found material injury by reason of the imports subject to the investigation but for the suspension of liquidation of the entries of the subject merchandise.

[4] The products covered by this investigation are laser light-scattering instruments and parts thereof from Japan that have classical measurement capabilities, whether or not also capable of dynamic measurements. The following parts are included in the scope of the investigation when they are manufactured according to specifications and operational requirements for use only in such an LLSI: Scanning photomultiplier assemblies, immersion baths, sample-containing structures, electronic signal-processing boards, molecular characterization software, preamplifier/discriminator circuitry, and optical benches.

APPENDIX C
CALENDAR OF WITNESSES APPEARING AT THE PUBLIC HEARING

As of 1/16/91, Rev. 2

TENTATIVE CALENDAR OF PUBLIC HEARING

Those listed below are scheduled to appear as witnesses at the United States International Trade Commission's hearing:

Subject	:	GLOBAL COMPETITIVENESS OF U.S. ADVANCED TECHNOLOGY MANUFACTURING INDUSTRIES: COMMUNICATIONS TECHNOLOGY AND EQUIPMENT; PHARMACEUTICALS; AND SEMICONDUCTOR MANUFACTURING AND TESTING EQUIPMENT
Inv. Nos.	:	332-301 through 303
Date and Time:	:	January 17 (& 18), 1991

Sessions will be held in connection with the investigation in the Main Hearing Room 101, United States International Trade Commission, 500 E Street, S.W., in Washington, D.C.

WITNESS AND ORGANIZATION:	INV. NO.	TIME CONSTRAINTS
Pharmaceutical Manufacturers Association Washington, D.C. Gerald J. Mossinghoff, President	332-302	10 Minutes
Industrial Biotechnology Association Washington, D.C. Richard D. Godown, President Lisa Raines, Director of Government Relations	332-302	10 Minutes
North American Telecommunications Association, Washington, D.C. Eric Nelson, Director of Government Relations	332-301	10 Minutes

- more -

Government Witness:

Robert Scace, National Institute of Standards and Technology, U.S. Department of Commerce (332-303)

WITNESS AND ORGANIZATION:	INV. NO.	TIME CONSTRAINTS
United States Advanced Ceramics Association Washington, D.C. Grover Coors, Chairman and CEO, Coors Electronics Package Co. Steven B. Hellem, Executive Director	332-303	10 Minutes
Semi/Sematech Austin, Texas Peggy Haggerty, Vice Presdient of Public Policy (representing over 130 U.S. Semiconductor Equipment and Materials Suppliers)	332-303	10 Minutes
SVG Lithography Systems, Inc. Wilton, Connecticut Vahe Sarkissian, President	332-303	10 Minutes

- more -

WITNESS AND ORGANIZATION:	INV. NO.	TIME CONSTRAINTS
Semiconductor Equipment and Materials International (SEMI) Washington, D.C. Joel Elftmann, Chairman, SEMI Board of Directors and Chairman, FSI International, Inc. Michael Ciesinski, Director, North American Operations Victoria Hadfield, Manager, Government Relations	332-303	10 Minutes
ETEC Systems, Inc. Hayward, CA Charles E. Minihan, Chairman and Chief Executive Officer	332-303	10 Minutes

- end -

APPENDIX D
COMPANIES AND ORGANIZATIONS INTERVIEWED FOR STUDY

Companies Interviewed for Study

	Country[1]	Organization	Product/Activity
1.	U.S.	ACT International	industry consultant
2.	Japan	Advantest Corporation	test equipment
3.	U.S.	Air Products and Chemicals, Inc.	various gases and chemicals including bulk gases, silicon-precursors, dopants, etchants, and deposition products
4.	U.S. (in Japan)	American Electronics Association	industry association
5.	Japan	Ando Electric Co., Ltd.	testing equipment
6.	Netherlands	ASM International, n.v.	furnaces, assembly equipment
7.	Netherlands	ASM Lithography	photolithography
8.	Germany	Baasel Lasertechnik GmbH	vapor deposition, alignment and exposure, die separation, marking machines
9.	U.S.	J.T. Baker, Inc.	photoresists, developers, rinses, thinners, strippers, and cleaners
10.	Liechtenstein	Balzers AG	wafer processing equipment
11.	Japan	Canon Inc.	semiconductor processing equipment including mask aligners and steppers
12.	Germany	Convac GmbH	photoreist application, photomasks, test equipment
13.	U.S.	The Dexter Corporation, Electronic Materials Division	encapsulating resins
14.	U.S.	Du Pont Company, Du Pont Electronics	photomasks, gases, chemicals, and polymides
15.	U.S.	Dyna-Craft, Inc.	leadframes
16.	Switzerland	ESEC SA	die separation, die and wire bonding
17.	U.S.	GCA Division of General Signal Corp.	alignment and exposure
18.	Germany	German Machinery and Plant Manufacturers Association (VDMA)	industry association
19.	U.S.	Hewlett-Packard Corp.	automated test equipment and semiconductors
20.	Japan	Hitachi, Ltd.	a wide range of semiconductor equipment and materials including steppers, ion implanters, and dry etchers
21.	U.S.	Hughes Aircraft Company, Industrial Products Division	assembly and test products
22.	Korea	Hyundai Group	semiconductors and finished products

See footnotes at end of table.

	Country[1]	*Organization*	*Product/Activity*
23.	U.S.	Intel Corporation	semiconductors and finished products
24.	Japan Market	Japan Economic Institute (JEI)	economic analysis
25.	European Community	Joint European Submicron Silicon Initiative (JESSI) Office	cooperative research
26.	U.S.	KLA Instruments	measurement equipment
27.	Germany	Kontron Elektronik GmbH	alignment and exposure, test and measurement, die separation machines
87.	Korea	Korea Semiconductor Equipment Association	industry association
29.	U.S.	KTI Chemicals, Inc.	photoresists, developers, primers, acids, etchants, solvents, and strippers
30.	Japan (in U.S.)	Kyocera Corporation	various products including semiconductor parts such as layer packaging, cerdips, advanced packages, ceramic modules, and metallized products
31.	Japan	Kyocera International, Inc.	various products including semiconductor parts such as layer packages, cerdips, advanced packages, ceramic modules, and metallized products
32.	U.S.	Lanxide Electronic Components, L.P.	electronic packaging substrate and support structures
33.	Germany	Lauffer Pressen GmbH	packing and molding presses
34.	Germany	Leica Mikroskopie und Systeme GmbH	alignment and exposure, photomasks, test and measurement equipment
35.	U.S.	LSI Logic Corporation	semiconductors
36.	U.S.	LTX Corporation	test systems
37.	U.S.	Micron Technology	seminconductors
38.	Japan	Ministry of International Trade and Industry (MITI)	government agency
39.	Korea	Ministry of Trade and Industry,	government agency
40.	Germany	Multitest Elektronische Systeme, GmbH	testing equipment
41.	Japan	Nikon Corporation	steppers and other equipment for repair, cleaning, mounting, inspection, and analysis
42.	Philippines (in Japan)	Pacific Semiconductors, Inc.	assembly house packaging
43.	Netherlands	Philips International	semiconductor materials
44.	Germany	Pokorny Kunstoff-Apparatebau	chemical equipment

See footnotes at end of table.

	Country[1]	*Organization*	*Product/Activity*
45.	U.S.	Promextrix	measurement and inspection equipment
46.	U.S.	Rose Associates, Inc.	industry consultant
47.	Korea	Samsung Group	semiconductors and finished products
48.	Germany	Schunk Kohlenstofftechnik GmbH	deposition and sealing equipment
49.	U.S.	SEMATECH	cooperative research
50.	Japan	Semiconductor Equipment Association of Japan (SEAJ)	industry association
51.	U.S.	Semiconductor Equipment and Materials International (SEMI)	industry association
52.	U.S.	Semiconductor Industry Association (SIA)	industry association
53.	U.S.	SEMI/SEMATECH	cooperative research
54.	Japan	Shin-Etsu Chemical	wafer processing materials
55.	Japan	Shin-Etsu Handotai Co., Ltd.	silicon wafers
56.	Japan	Shinkawa, Ltd.	assembly equipment
57.	Korea	Shin Young Hi-Tech Co., Ltd.	vacuum furnaces, magnetrons, sputtering, plasma, and deposition equipment
58.	Germany	Siemens AG	semiconductors
59.	U.S.	Silicon Valley Group, Lithography Division	alignment and exposure equipment
60.	Japan (in U.S.)	Siltec Corporation	silicon wafers
61.	Germany	Karl Suss KG GmbH & Co.	alignment and exposure, test and measurement equipment, die separation machines
62.	Germany	SZ Testsysteme	mixed signal testers
63.	U.S.	Teradyne	test equipment, factory automation systems
64.	U.S. (in Korea)	Texas Instruments	semiconductors and finished products
65.	Japan	Tokyo Electron Limited (TEL)	wide range of semiconductor processing, inspection, and testing equipment
66.	U.S.	Ultratech Stepper Division of General Signal Corp.	alignment and exposure
67.	Korea	U.S. Embassy, Seoul	
68.	Korea	Varian Korea, Ltd.	ion implanters and sputters
69.	U.S.	Veeco Instruments Inc.	deposition, photomasks, testing and measurement equipment

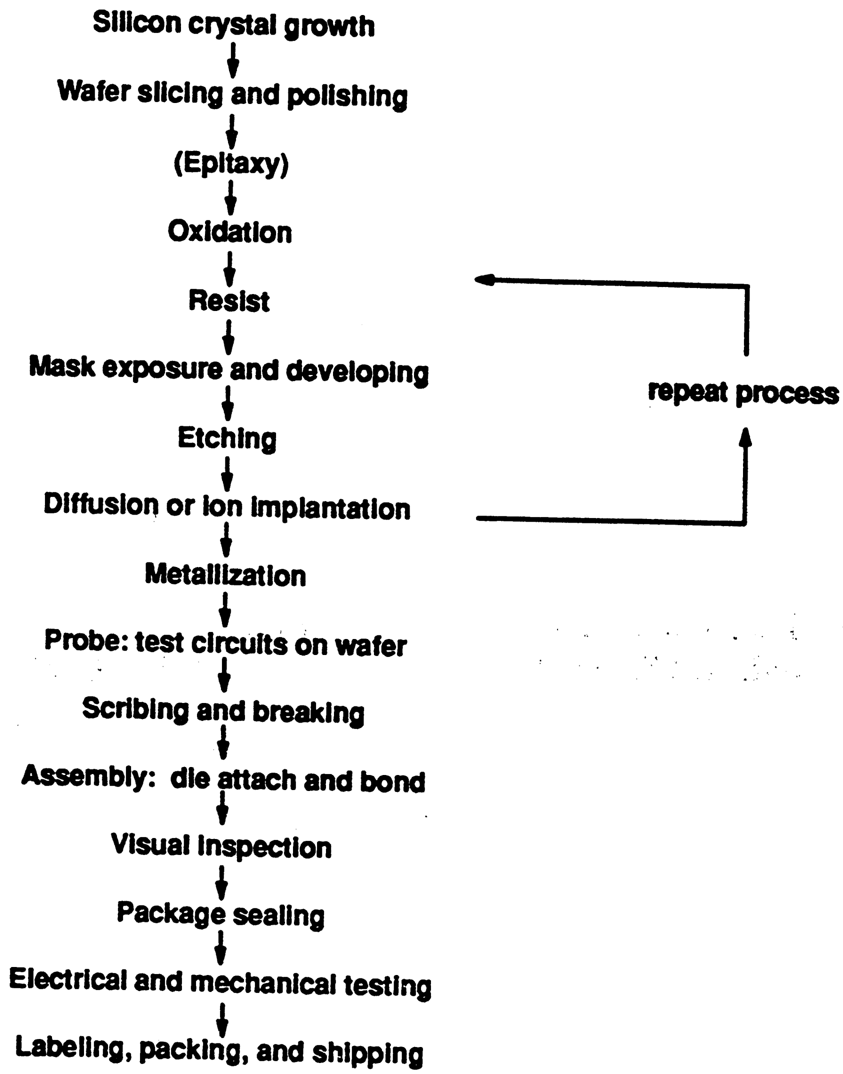
See footnotes at end of table.

	Country[1]	*Organization*	*Product/Activity*
70.	U.S.	VLSI Research Inc.	industry consultant
71.	Germany	Wacker-Chemitronic GmbH	semiconductor process materials
72.	Germany	Carl Zeiss	alignment and exposure, photomasks, test equipment

[1] Country of ownership.

APPENDIX E
SEMICONDUCTOR MANUFACTURING AND TESTING EQUIPMENT AND MATERIALS: PRODUCT AND PROCESS DESCRIPTION

Figure 1
The Stages of Integrated Circuit Fabrication



Source: Congress of the United States, Congressional Budget Office, *Using R&D Consortia for Commercial Innovation: SEMATECH, X-ray Lithography, and High-Resolution Systems,* July 1990, p. 21.

Semiconductor Manufacturing and Testing Equipment and Materials: Product and Process Description

Wafer-Fabrication Equipment[1]

Silicon wafers are produced from polysilicon, which is obtained from raw materials by first manufacturing an intermediate compound, such as silicon tetrachloride or trichlorosilane. These compounds are subsequently reduced with hydrogen at high temperatures to produce ultra-pure polycrystalline silicon metal. The polysilicon is crushed, melted, and drawn into single crystal ingots in a vacuum chamber under elevated temperatures. After the ingots are drawn, a saw using a specially designed blade is used to cut thin cross-sections from the ingots. These thin slices, measuring about one millimeter in thickness, are polished and lapped to create wafers that are essentially flat and defect free. A majority of the ingots currently produced measure slightly more than 150 millimeters in diameter, or about 6 inches in diameter. Equipment used in the production of silicon wafers include furnaces, vacuum chambers, crystal pullers, saws, polishers, and lappers.

Wafer-Processing Equipment

Wafer-processing equipment usually consists of the following types of process equipment: (1) mask-fabrication equipment; (2) photolithographic equipment; (3) diffusion and oxidation equipment; (4) ion implantation equipment; (5) deposition equipment; and (6) etching and cleaning equipment.

Mask-Fabrication Equipment

These are either optical or electron (E-beam) machines that represent the leading technological edge of photolithography equipment. The tolerances of an integrated circuit cannot exceed the precision of its original masks, and the equipment selected to produce the masks depends upon the design geometries of the device. Optical equipment is used to produce line widths of one micron and larger, but E-beam equipment can be used to produce both large and small line widths because superior accuracy and registration between the mask steps can be obtained with this type of equipment. Ten to twenty masks are usually required to produce a given type of semiconductor device.

Photolithographic Equipment

This equipment creates the layered circuit patterns of the integrated circuit through the use of masks and photosensitive emulsions (photoresists). The wafer is first coated with a thin layer of photoresist and the circuit pattern is projected through the mask onto the coated surface of the wafer, exposing the resist and "curing" selective patterns on the wafer. The emulsion is then developed and the unexposed sections of the resist are removed, leaving hundreds of images of the original mask exposed in the surrounding resist. The exposed surfaces of the images on the wafer (areas not covered by the resist) may be etched away, ions implanted, or metal conductors or insulating materials deposited, leaving the areas of the wafer protected by the resist unaffected. The resist coating, exposure, developing, etching, and other operations are subsequently repeated using different masks.

The majority of the machines used to project the images of the masks onto the coated wafers are called "optical aligners". Optical exposure can be accomplished by using X-rays or electron and heavy ion beams, but exposure using an ultraviolet light source is by far the dominant process. The use of X-ray lithography has been touted since 1979, but to date, this lithography technology has gained little or no market acceptance. The three basic types of optical aligners are scanning projection aligners, stepping aligners, and step and scan aligners.

Scanning projection aligners are designed for use with masks that contain the same number of duplicative image patterns as the number of semiconductor devices or chips to be created on the wafer. The patterns are scanned across the surface of the wafer by moving the mask and wafer in exact synchronism through the path of the optical system. This type of equipment was in dominant use from 1973 through the early 1980s. Stepping aligners (steppers) are designed to use masks that contain only a few of the images to be reproduced on the wafer. The mask (or reticle) is fixed in an optical path and the wafer is moved (or "stepped") in an X-Y coordinate to create the desired number of chips on the wafer.

[1] Information on wafer fabrication was obtained from *Free-World Microelectronic Manufacturing Equipment*, J.S. Kilby, et. al., Science Applications International Corp., Dec. 1988.

Step and scan aligners[2], which are the most advanced photolithographic machines, combine features of the scanning aligners and steppers. These aligners use a slit scanning system similar to that used in ultra high speed photography, and unlike a stepper in which a complete image is exposed during each mask step, step and scan aligners expose the photoresist through a slit in the optical system. The wafer and the reticle are synchronized in a continuous motion and the precision lens in the equipment serves to produce finer line widths. This type of system, which requires special types of photoresists, operates at shorter wavelengths of light and has a higher throughput than other types of aligners.

Unlike aligners, direct-write use electron beams to expose the photoresist directly without the use of lenses. These systems, which can produce very fine line widths and excellent registration, are used principally for mask making, rather than for wafer processing because of their slow speed and software and hardware complexity. However, considerable research is being undertaken to improve the throughput of these machines and to make them more cost effective to use because of their accuracy.

Diffusion and Oxidation Equipment

Diffusion and oxidation equipment are machines used to change or modify the electrical characteristics of silicon wafers or crystal substrates. The creation of diodes and transistors (the fundamental building blocks of integrated circuits) within crystal wafers is accomplished by the introduction of foreign atoms (dopants) through thermal diffusion or ion implantation. The same equipment that creates diffusion in the substrate can also be used to create good insulators through oxidation processes.

The diffusion process takes place when the temperature of a wafer is elevated in the presence of a dopant gas that is diffused through the areas of the wafer left exposed in the photoresist. Oxidation, or the creation of insulators, occurs when the wafer is exposed to oxygen at elevated temperatures. Furnaces required in the diffusion and oxidation processes are produced in both horizontal and vertical configurations. Horizontal furnaces are the most common type of furnaces in use, but producers of vertical furnaces contend that the performance of these type of equipment is superior.

Ion Implantation Equipment

These machines provide an alternate means of introducing dopants into the areas of a wafer that are unexposed in the photoresist. In this process, the wafer is bombarded by a beam of high energy dopant ions. In cases where low levels of doping, precise control of the doping profile, depth of doping, and the doping gradient are required, these operations can be more precisely controlled through ion implantation than thermal diffusion. In the production of certain types of semiconductors, ion implantation equipment has completely replaced thermal diffusion furnaces.

Deposition Equipment

These are machines used to create thin-film layers on the surface of a wafer. The deposited layers may become part of the semiconducting structures of the transistors and diodes, insulators separating the individual transistors, or they become metal conductors needed to connect the transistors and diodes to create an electrical circuit. The two principal types of deposition machines are physical vapor deposition (PVD) equipment and chemical vapor deposition (CVD) equipment. In PVD equipment, metal ions are evaporated or sputtered through the bombardment of the source materials in a high vacuum chamber and deposited on the exposed surfaces of the wafer. CVD equipment uses chemical reactions of gases.

Etching and Cleaning Equipment

Etching and cleaning equipment is used to remove material from the exposed regions of the wafer in preparation for the next process step in the fabrication of integrated circuits. The removal of materials is needed in preparation for metalization of contacts, or the removal of unwanted materials, which were byproducts of a previous process.

Semiconductor Assembly Equipment

Equipment used to assemble integrated circuits can be divided into five basic categories of machines, as follows: (1) wafer-dicing and die-separation equipment; (2) die-bonding equipment; (3) wire-bonding equipment; (4) molding and sealing (encapsulation) equipment; and (5) finishing and marking machines.

Wafer-dicing and die-separation equipment are machines that employ diamond tipped cut-

[2] USITC staff conference on December 19, 1990, with representatives of Silicon Valley Group, Lithography Division.

ters (or similar scribing devices) or lasers to cut channels (grooves) around each of the dice (semiconductor devices) that have been formed on the silicon wafer. After scoring, the dice are separated through the application of light mechanical pressure, and each die is secured to a lead frame through the use of a die bonder. After the dice are secured to the lead frames, wire bonders are used to attach hairline wires from the pads on the dice to corresponding pads on the lead frames. A typical automatic wire bonder can attach wire leads at speeds ranging from 100 to 250 milliseconds.

Molding and sealing equipment is used to encapsulate the dice that have been connected to the lead frames into packages that shield the devices from the surrounding environment. This type of equipment include molding presses, molding dies, curing ovens, belt furnaces, other thermal reflow furnaces, and weld sealers. Finishing and marking machines include equipment used for lead straightening and forming, lead trimming, and package trimming. These operations are principally performed on plastic integrated circuit packages because they typically emerge from the forming operations on a common lead frame strip on which the individual packages are still interconnected. Finishing equipment is used to cut and trim the leads on the lead frames and to form them into their final shape. Marking machines, which are used to identify the semiconductor devices, their date of manufacture, and names of the manufacturer, represent the last operation in the production of the device. The final marking of the devices takes place after the devices have been inspected and electrically tested.

Test and Measuring Equipment

Test and measuring equipment is used throughout the smiconductor manufacturing cycle. Measuring (metrology) equipment ensures that design dimensions of the semiconductor devices are achieved and maintained during the various manufacturing steps. In metrology, the most important requirement is the ability to inspect at high magnification the resist patterns and the overlay relationships between new resist layers and previous circuit layers. High magnification was accomplished in the 1980s through the use of optical brightfield microscopes, but increasingly the industry is using low-voltage scanning electron microscopes because these machines are capable of measuring line widths of less than 0.5 micron. Line widths and overlay dimensions can also be measured electrically by creating special test structures on the wafers. Electrical measuring equipment, such as automated die probe testers, are used to identify defective chips after the wafer-processing operations have been completed.

Test equipment includes a variety of testers with various capabilities, sophistication, and price ranges. These machines are identified by the type of semiconductor devices or process that they are designed to test or perform, such as digital integrated circuit testers (logic testers), memory testers, linear or analog testers (mixed-signal testers), microprocessor testers, discrete semiconductor (transistors and diodes) testers, and burn-in equipment. Because undiscovered defects affect the yields, circuit performance, and reliability of semiconductor devices, a number of tests, measurements, and inspections are required to produce integrated circuits and other semiconductor devices.

Materials

The principal materials used in wafer processing include silicon wafers, photoresists, photomasks, wet chemicals, gases, and deposition materials. The principal materials used in the assembly of semiconductors include ceramic packages, leadframes, encapsulation resins, bonding wire, thick film pastes, and hybrid packages.

APPENDIX F
U.S. FOREIGN INVESTMENT AND ACQUISITION

U.S. Foreign Investment and Acquisition

Under the Exon-Florio provision, information on pending foreign investments and acquisitions is reported to CFIUS on a voluntary basis by the parties involved because CFIUS is not empowered to compel firms to report such activities. CFIUS was created in May 1975 by President Ford to monitor trends in foreign investment in the United States and make policy recommendations regarding the effects of foreign investments on national security. CFIUS members include the Secretaries of State, Defense, and Commerce, the Attorney General, the Director of the Office of Management and Budget, the Chairman of the Council of Economic Advisers, the United States Trade Representative and is chaired by the Secretary of the Treasury. The Department of Energy and NASA are also included when issues arise within their areas of interest.[1]

The Defense Science Board Task Force recommended in June 1990, the U.S. Government should take steps to strengthen the role of CFIUS in shaping the direction of foreign investment. Among others, these steps would include efforts by the U.S. Department of Defense to provide incentives for other U.S. firms to purchase targeted companies, or when a U.S. buyer cannot be found, the Department of Defense should have the authority to impose performance requirements on the foreign purchaser as a condition of approval. These would include a requirement that the foreign firm (1) license critical technologies to a U.S. firm, or conduct certain specialized R&D in the United States using a high proportion of U.S. technical personnel, or (2) maintain a certain level of U.S. production using a high proportion of U.S. technical personnel.

On June 12, 1991, a draft of The Technology Preservation Act of 1991, which largely followed the recommendations of the Defense Science Board Task Force, was introduced in the Congress.[2] The pending bill would make the following changes to the Exon-Florio provision:

1. Give the President authority to place conditions on foreign investment when needed to protect the erosion of the U.S. technology and industrial base.
2. Allow a foreign takeover to be stopped to permit a thorough investigation under Exon-Florio.
3. Replace the Secretary of the Treasury with the Secretary of Commerce, as Chairman of the CFIUS.
4. Require that investigations be conducted into the takeover of any U.S. firm that involves a "critical technology".[3]
5. Allow national security to be defined more broadly than it is currently.[4]

U.S. trading partners employ various procedures, regulations, and business practices to control the types of foreign investments permitted in their countries. In some countries, foreign investment in general discouraged, but

[1] Exon-Florio authority ceased to exist on October 20, 1990 with the expiration of the Defense Production Act. After consultation with interested U.S. Government authorities, the Department of the Treasury announced, effective Nov. 6, 1990, that CFIUS would continue to operate under an informal agreement in accordance with Exon-Florio criteria.

[2] The bill was introduced by Congresswoman Cardiss Collins (D-IL) and was supported by the House Majority Leader, Congressman Richard A. Gephart (D-MO).

[3] The National Critical Technologies Panel was appointed in 1990, in accordance with the Defense Authorization Act for Fiscal Year 1990, to identify technologies that had long-term implications for U.S. security and economic well being. Of the 22 critical technologies chosen by the Panel, five technologies related to semiconductors, semiconductor equipment, and materials. These semiconductors and related equipment and materials included electronic and photonic materials, ceramics, micro-and nanofabrication, software, and microelectronics and optoelectronics.

[4] In support of the draft bill, Professor Theodore H. Moran of Georgetown University recommended that the Congress consider an empirical approach from antitrust studies to guide its foreign-investment policy. Professor Moran suggested that the adoption of a "four-four-fifty" rule regarding the concentration of foreign investment would strengthen the Exon-Florio Provision. Under this rule, if a foreign acquisition is proposed in any U.S. industry where foreign concentration is higher than four countries, or four companies supplying fifty percent of the global market, the U.S. Government should impose performance requirements to ensure the retention of production and R&D facilities in the United States. If the acquisition is proposed in any U.S. industry where the foreign concentration is lower than four firms or four countries, then the acquisition should be approved without conditions. Professor Theodore H. Moran is the Karl F. Landegger Professor and Director, Program in International Business Diplomacy, School of Foreign Service, Georgetown University, and Senior Associate, Business Executives for National Security.

actually encouraged in those instances where an economic or technology benefit is provided. In most U.S. trading partners monitor foreign investment.[5] Table F-1 lists Japanese investments in U.S. semiconductor equipment firms during 1983-91.

[5] In May 1991, Congressman Mel Levine (D-CA) released a report entitled, *Foreign Ownership and Control of U.S. Industry*, prepared in June 1990 by the Defense Science Board Task Force. The Task Force indicated on pages 73 and 74 of the report that "(1) most U.S. trading partners (including the governments of Japan, Taiwan, Korea, Australia, Mexico, Canada, and France) require government notification or at least screening of high-value investments. Most governments screen all investments; (2) a number of U.S. trading partners (such as South Korea and Mexico, although both are changing) have prohibited foreigners from acquiring domestic firms. Where governments do expressly prohibit such acquisitions e.g. in Japan, Switzerland, the Netherlands, and West Germany, the firms themselves or other firms use business practices to fend off unwanted foreign buyers; (3) many foreign governments have the power to restrict any foreign investment that simply runs counter to their national economic interests. In Japan, for example, a proposed foreign purchase must not "harm national security, disturb public order, or hamper public safety.' Moreover, a foreign investment cannot 'adversely and seriously affect' Japanese companies in a similar line of business or 'adversely affect the smooth operation of the national economy.' In making its decision about whether to permit a foreign investment, the Japanese government can consider whether reciprocity exists between Japan and the foreign competitor's home country and whether the foreign investment attempts to evade restrictions on capital control." The Task Force also indicated that, "In some countries, governments lure investment for sectors that have been targeted for growth, either because those sectors are lagging or because external technologies will help the country promote those sectors' world market position. Enticements generally take the form of government loans, tax benefits, or other financial support."

Table F-1
Acquisitions of or investments in U.S. semiconductor manufacturing equipment makers by Japanese companies

U.S. Company	*Headquarters*	*Japanese Company*	*Share*	*Product line*	*Year*
Matheson Gas Products, Inc	Secaucus, NJ	Nippon Sanso K.K.	50%	Gas-handling equipment	1983
Matheson Gas Products, Inc	Secaucus, NJ	Nippon Sanso K.K.	50	Specialty gases	1983
Hemlock Semiconductor Corp	Hemlock, MI	Shin-Etsu Handotai Co., Ltd. Mitsubishi Materials Corp.	24.5 12.25	Polysilicon1984	
Koltran Corp	Sunnyvale, CA	Nippon Mining Co., Ltd.	36.7	IC leadframes	1985
NBK Corp./Kawasaki Wafer Technology, Inc	Santa Clara, CA	Kawasaki Steel Corp.	100	Silicon/epitaxial wafers	1985
Siltec Corp., Cybeq/	Menlo Park, CA	Mitsubishi Materials Corp.	90	Wafer production/handling equipment	1986
Cybeq Systems Inc.		Mitsubishi Corp.	10		
Siltec Corp., Siltec	Menlo Park, CA	Mitsubishi Materials Corp.	90	Silicon/epitaxial wafers	1986
Silicon		Mitsubishi Corp.	10		
U.S. Semiconductor Corp	Fremont, CA	Osaka Titanium Co., Ltd.	100	Epitaxial wafers	1986
Aegis Inc	New Bedford, MA	Asahi Glass Co., Ltd.	49	Metal IC packages1987	
Novellus Systems Inc	Santa Clara, CA	Seki & Co., Ltd.	n.a.	Deposition equipment	1988
Varian Associates, Inc.'s specialty metals division/ Tosoh SMD, Inc	Grove City, OH	Tosoh Corp.	100	Sputtering targets	1988
AG Associates	Sunnyvale, CA	Canon Sales Co., Inc.	30	Rapid thermal	1989
Cincinnati Milacron Semiconductor Materials Inc./ Cincinnati Semiconductor Inc.	Maineville, OH	Osaka Titanium Co.,	100	Silicon/epitaxial wafers	1989
General Ceramics, Inc.	Haskell, NJ	Tokuyama Soda Co., Ltd.	100	Ceramic IC pacakages	1989
Lam Research Corp.	San Mateo, CA	Sumitomo Metal Industries, Ltd.	4.5	Plasma etching/deposition equipment	1989
Materials Research Corp	Orangeburg, NY	Sony Corp.	100	Sputtering/etching equipment processing equipment	1989
Materials Research Corp	Orangeburg, NY	Sony Corp.	100	Sputtering targets	1989
Matheson Gas Products, Inc	Secaucus, NJ	Nippon Sanso K.K.	100	Gas-handling equipment	1989

Table F-1—Continued
Acquisitions of or Investments in U.S. semiconductor manufacturing equipment makers by Japanese companies

U.S. Company	*Headquarters*	*Japanese Company*	*Share*	*Product line*	*Year*
Matheson Gas Products, Inc	Secaucus, NJ	Nippon Sanso K.K.	100	Specialty gases	1989
Micro Mask, Inc	Sunnyvale, CA	Hoya Corp.	100	Photomasks	1989
Lepton, Inc	Murray Hill, NJ	Canon, Inc.	10	Electron-beam lithography equipment	1990
LTX Corp	Westwood, MA	Sumitomo Metal Industries, Ltd.	15	Linear, digital/ mixed-signal test equipment	1990
Prometrix Corp	Santa Clara, CA	Sumitomo Corp.	3	Metrology equipment	1990
Texas Instruments Inc.'s photomask business/ Toppan Printronics (USA) Inc	Dallas, TX	Toppan Printing Co., Ltd.	85	Photomasks	1990
Union Carbide Corp.'s polysilicon business/ Advanced Silicon Materials Inc	Moses Lake, WA	Komatsu Electronics Metals Co., Ltd.	100	Polysilicon	1990
U.S. Chrome Corp	Stratford, CT	Japan Metals &	100	Chrome for metallizing	1990
Chemicals Co., Ltd.					
Mattson Technology Inc	Sunnyvale, CA	Marubeni Hytech Corp.	20	Photoresist striping equipment	1991
Semi-Gas Systems Inc	San Jose, CA	Nippon Sanso K.K.	100	Gas-handling equipment	1991

Source: Japan Economic Institute.

APPENDIX G
THE U.S. EXPORT CONTROL REGIME

The U.S. Export Control Regime

Since World War II, the United States has continuously maintained a system of strategic export controls. U.S. export controls are generally imposed to restrict exports of goods and technology that would make a significant contribution to the military potential of the Soviet Bloc or the People's Republic of China. The United States currently controls the exports of such goods and technology under the Export Administration Act of 1979 (EAA) for national security and foreign policy reasons.[1] The United States also seeks to control reexports of U.S. goods, and exports of foreign goods that incorporate U.S. goods or technology.[2]

Export controls are particularly difficult to devise and administer in a dynamic, geopolitical environment with shifting strategic and security interests and with constantly evolving technological developments. Reasonable disagreements may arise frequently about the appropriate scope of controls, the actual effectiveness of controls, and about which commercial products may in fact make a significant contribution to the military potential of controlled destinations. Also, there are the questions of whether the controlled technology is state-of-the-art and whether it is available from non-U.S. sources.

To some extent, there is an inherent tension between the notion of fundamental national military security and the notion of national economic security.[3] If U.S. controls impede the sale of U.S. high technology to all markets, or even to certain markets, and such technology is readily available in those markets from suppliers in other countries, then America's national military security would not be effectively safeguarded by the imposition of U.S. controls, and our national economic security may be affected unnecessarily.

The EAA provides that there is no right to export under the Act.[4] However, "[i]t is the policy of the United States . . . to encourage trade with all countries with which the United States has diplomatic or trading relations."[5] Moreover, "[i]t is the policy of the United States that export trade . . . be given a high priority and not be controlled except when such controls (A) are necessary to further fundamental national security, foreign policy, or short supply objectives, (B) will clearly further such objectives, and (C) are administered consistent with basic standards of due process."[6]

In order to facilitate some flexibility in the administration of U.S. export controls, the Administration has considerable discretion under the EAA. The Secretary of Commerce may require a general license, a validated license, or any other type of license that may assist in the effective and efficient implementation of export controls. A general license permits exports without application by the exporter to the Department of Commerce (DOC). Exporters of goods that do not qualify for a general license must apply for a validated license. An individual validated license authorizes a specific export and a bulk validated license authorizes multiple shipments under specified circumstances. Consistent with the strategic policy of export controls, license requirements depend on the nature of the exported good and the country of destination. U.S. export controls also apply to reexports of U.S. goods and technology.[7]

The Export Administration Regulations (EAR) implement the EAA.[8] The EAR contain the Commodity Control List (CCL), which describes all commodities subject to control by the DOC.[9] Semiconductor manufacturing equipment is controlled under export commodity control number (ECCN) 1355A and semiconductor materials are controlled under ECCN 1757A.[10] The

[1] 50 U.S.C. App. 2401 et seq.

[2] The extraterritorial application of U.S. export controls has been a concern of U.S. companies and of our trading partners.

[3] See, e.g., R. Kuttner, *Export Controls: Industrial Policy in Reverse*. Mr. Kuttner writes that "the focus on one narrow conception of security—denial of high-tech exports—undermines security in a broader sense by harming the nation's commercial technology base." See Kuttner, p. 1.

[4] Section 4(d) of the EAA. By contrast, it is interesting to note that, in Japan, the right of an individual to export is a

4—Continued

constitutional right. In one reported case, a Japanese exporter challenged the application of the Japanese export control law, and the Tokyo District Court held that, as applied in that particular case, the controls were unconstitutional. See M. Matsushita, *Japan and the Implementation of the Tokyo Round Results* (1984), as reprinted in J. Jackson and W. Davey, *Legal Problems of International Economic Relations* (1986), pp. 234-235.

[5] Section 3(1) of the EAA.

[6] Section 3(10) of the EAA.

[7] 15 CFR 774.1.

[8] 15 CFR 768 et. seq.

[9] 15 CFR 799.1 et. seq.

[10] The Central Intelligence Agency, in its STARBASE study, has estimated that over 90 percent of semiconductor manufacturing equipment and materials were controlled for national security purposes under either ECCN 1355A or ECCN 1757A. See White Paper, p. 4.

EAR provide that, with certain exceptions, the export from the United States of all commodities and all technical data is prohibited unless and until a general license authorizing such export is established or a validated license or other authorization is granted.[11] In periodically reviewing the scope of the CCL, the DOC considers such matters as a commodity's essential physical and technical characteristics, its civilian and military uses, its end-use pattern in the United States, its availability abroad, and whether it is the latest, state-of-the-art technology.[12]

Multilateral Controls

Multilateral agreements seek to ensure that our allies maintain comparable export controls and that controlled articles are not reexported to controlled destinations. The multilateral export control regime is administered through the Coordinating Committee on Multilateral Export Controls (COCOM). The United States participates in the work of COCOM which administers control lists on munitions, nuclear energy, and dual-use technologies. COCOM imposes various levels of controls ranging from a strict "general embargo" control (which requires unanimous COCOM approval), to a "favorable consideration" control, to a flexible "national discretion" control (which only requires post-export notification), again depending on the level of the technology that is sought to be exported and the country of destination. The multilateral COCOM controls are set forth in the so-called International List.

COCOM operates on the basis of the unanimous consent of the member nations, but the actual implementation of the controls rests with the individual members.[13] Each member nation has committed itself to enforcing the multilateral controls provided for on the International List.[14] In principle, all COCOM countries license exports of dual-use goods and technology to controlled destinations (i.e., East-West trade) and, until very recently, have licensed exports to COCOM and third-country destinations (i.e., West-West trade). In practice, varying practices have evolved, and members interpret, administer and enforce the multilateral export controls differently. For example, unlike many of our trading partners, the United States seeks to impose its control regime extraterritorially and, until very recently, has maintained relatively rigorous pre- and post-license oversight for exports to other COCOM countries.

There is a widely-held view in the United States that multilateral controls are enforced more comprehensively in the United States than in other COCOM countries. At the same time, however, it is interesting to note that European and Asian companies reportedly believe that the United States has used national security export controls to promote U.S. economic interests.[15]

In addition to the items that all COCOM members have agreed to control, the United States has consistently imposed additional controls unilaterally. In the years following World War II, unilateral U.S. controls tended to be effective because the United States was often the sole source of a great deal of high technology equipment. In more recent years, sophisticated, high-technology equipment has been available from a variety of COCOM and non-COCOM sources, making unilateral controls relatively less effective.

General Industry Concerns

The high technology business community has long been concerned about the impact of the U.S. export control regime.[16] It has argued that the U.S. regime is complex, inefficient, and cumbersome; that its administration is relatively

[11] 15 CFR 770.3(a).

[12] 15 CFR 770.1(b)(3).

[13] COCOM includes all the NATO countries (except Iceland) and Japan and Australia.

[14] The basic export control laws of some other COCOM members are as follows. In Japan, export controls are administered by the Ministry of International Trade and Industry (MITI) pursuant to the Foreign Exchange and Foreign Trade Control Law, and the Japanese control list is contained in Annex 1 to the Export Trade Control Order. In the United Kingdom, export controls are administered by the Department of Trade and Industry (DTI) pursuant to the Import, Export and Customs Powers (Defense) Act of 1939 and the Customs and Excise Management Act of 1979, and the control list is set forth in the Export of Goods (Control) Order.

14—*Continued*

The Order incorporates the International List as well as additional national controls.

In Germany, export controls are administered by the Federal Office of Economics in the Ministry of Economics pursuant to the Foreign Trade and Payments Act, and the COCOM lists are incorporated in part I of the Export List, which is an Annex to the law. In France, the Director-General of Customs and Indirect Taxes enforces export controls pursuant to a Decree of November 30, 1944, and a Ministerial Order of January 30, 1967.

[15] See, e.g., S. Macdonald, *Strategic Export Controls: Hurting the East or Weakening the West?* (May 1990), p. 11, and National Academy of Sciences, *Balancing the National Interest: U.S. National Security Export Controls and Global Economic Competition* (1987), p. 19.

more rigorous and stringent than those of our major competitors (e.g., licenses take longer to be approved and there are more documentation requirements); that the United States imposes unilateral controls on certain goods; that the United States imposes reexport controls; and that the United States interprets the multilateral controls more broadly and enforces them more stringently than our competitors. Also, there has been concern about the increasing reliance on foreign policy controls, which are unilateral and, hence, may have a disparate impact on U.S. competitiveness. Moreover, the nonproliferation initiative,[17] which is aimed at controlling exports of chemical and biological weapons to developing countries, may have the effect of recontrolling certain technologies.[18]

A report of the President's Commission on Industrial Competitiveness concluded that the U.S. export control regime is unduly rigorous and cumbersome and that unilateral foreign policy controls are often ineffective.[19] The Department of Commerce has noted that "[s]ome enforcement problems are common to all foreign policy controls."[20] Moreover, when "no violation of the laws of the third country exists, it is difficult to secure third country cooperation in enforcement efforts."[21]

U.S. business tends to get the reputation as an unreliable supplier when such controls are applied to preexisting contracts and to foreign affiliates of U.S. firms. The burden of unilateral and reexport controls may tend to create an environment in which foreign companies seek alternative non-U.S. suppliers when possible to avoid the extraterritorial application of U.S. export controls. This is often referred to as the "design out" problem because foreign companies may "design out" U.S. components and technology. The President's Commission urged a streamlining of the licensing procedure and greater multilateral coordination and enforcement of controls. It also called for greater balance in the formulation of export control policy between export competitiveness and national security and foreign policy considerations.[22]

A report by the National Academy of Sciences (NAS) on the U.S. export control regime.[23] The NAS Report "determined that reliable quantitative data regarding the effectiveness of controls—and the impact of controls on economic development and trade—continue to be very difficult to obtain."[24] Nevertheless, the Report concluded that "export controls are not a leading cause of the recent decline in U.S. high-technology performance, [but] they may contribute to lost sales and to an environment that discourages export activities by U.S. firms."[25]

The NAS Report recommended the establishment of "a community of common controls" based on improved enforcement of more effective multilateral controls covering truly strategic goods and technology. After referring to the NAS Report, the conferees on the 1988 Trade Act noted that "higher fences around fewer goods will be more effective in protecting U.S. national security and strengthening America's economic competitiveness."[26]

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[16] See, e.g., the 1991 Agenda of the Industry Coalition on Technology Transfer (ICOTT), a coalition whose principal purpose is to reflect the concerns of high technology industries about U.S. export controls.

[17] On Dec. 13, 1990, President Bush announced the Enhanced Proliferation Control Initiative.

[18] Conversations with SEM industry sources in May 1991 indicate that one of the main concerns is with nonproliferation controls on cluster tools. Also, see F. Schuchat, *The Evolution of U.S. Export Controls: From East-West to North-South*, International Law News (Spring 1991), p. 1.

[19] The President's Commission on Industrial Competitiveness, *Global Competition: The New Reality* [New Reality], p. 39 (1985). This 1985 report estimated that foreign policy controls cost the U.S. economy $4.7 billion annually and that national security controls cost $7.6 billion in lost sales. It also reported that license processing took much longer for U.S. firms than for our trading partners. New Reality, pp. 40-42.

[20] Department of Commerce/Bureau of Export Administration, *1991 Annual Foreign Policy Report to the Congress* [Foreign Policy Report], p. 3. In formally commenting to the Department on existing foreign policy controls, manufacturers and exporters have "noted that unilateral controls disadvantage U.S. suppliers relative to foreign competitors that do not have controls, are generally ineffective because the controlled items are available from foreign sources, and affect future trade because the United States is perceived as an unreliable supplier." Foreign Policy Report, p. 69.

[21] Foreign Policy Report, p. 3.

[22] New Reality, p. 43.

[23] National Academy of Sciences, *Balancing the National Interest: U.S. National Security Export Controls and Global Economic Competition* [NAS Report] (1987).

[24] NAS Report, p. vii.

[25] NAS Report, p. 7.

[26] Conference Report on the Omnibus Trade and Competitiveness Act of 1988, House Report 100-576 (April 20, 1988) [Conference Report], p. 814.

Recent Developments

As part of its continuing review responsibility, COCOM has been reviewing the multilateral control list in light of political, military and economic changes in the Soviet Union and the East Bloc, as well as changes in the state of technology. In May 1990, the White House announced that "[t]he President has concluded that a complete overhaul of the [COCOM] control list is warranted.... [O]ur proposals will build 'higher fences around fewer goods'."[27] In June 1990, COCOM agreed to review and replace the Industrial List with a greatly shortened "core list" in order to facilitate certain exports to the Soviet Union and Eastern Europe.[28] The U.S. Commodity Control List is currently undergoing a similar review.[29]

In January 1991, the National Academy of Sciences released its second report on U.S. export controls.[30] Among numerous recommendations, the report recommends that COCOM members "change the basis of their technology transfer and trade relationships with the Soviet Union and the East European countries from the 'denial regime' ... to an 'approval regime' based on multilaterally agreed upon and verifiable end-use conditions."[31] Also, it recommends better coordination of U.S. policy and greater industry participation because "economic security must be institutionalized in a national security framework".[32]

Concerns of the SEM Industry

The stringency of the U.S. export control regime has created problems for the U.S. semiconductor equipment manufacturing (SEM) industry.[33] In some cases, export sales are lost due to the cumbersome approval process, even when the prospective sale is to a COCOM member, or because an export license is not granted at all.[34] However, certain SEM firms may be more affected by export controls than others, depending on their respective markets and product lines.

Despite the strengthening of statutory provisions on foreign availability, some SEM suppliers have had particular difficulty in seeking the decontrol of equipment that is available to controlled destinations from non-U.S. suppliers. In fact, the first decontrol action that was based on the foreign availability provisions of the U.S. export control law involved an SEM company.[35] Silicon Technology Corporation (STC) had been selling wafer saws under a validated export license to the Soviet Union and Eastern Europe during the 1970s. Beginning in 1980, STC's license applications were denied on national security grounds, notwithstanding the fact that comparable wafering saws were available in those controlled markets from Switzerland.

[27] White House Press Release, May 2, 1990. The initial U.S. proposal included certain goals: (1) replacement of the International List with a shortened "core list" that would be written from scratch; (2) immediate decontrol of at least 30 control categories; (3) approximate decontrol to the so-called China Green Line (i.e., a control level that grants certain preferential access to the Peoples Republic of China); (4) significant decontrol in three priority sectors (i.e., computers, telecommunications and machine tools); and, (5) strengthened multilateral enforcement. The proposal also indicated that decontrol efforts for exports to Eastern Europe would go a bit further than for exports to the Soviet Union.

[28] At the June 6-7 COCOM High Level Meeting, COCOM countries agreed to overhaul and replace the International List with a "core list" based on strategically critical items. COCOM members agreed to eliminate about one-third of the control list right away. Also, the members agreed prepare a "positive" list such that only named items are controlled, and they agreed to take into account whether an item is available from a non-COCOM source.

[29] A new, revised Commodity Control List, which is based on the new COCOM "core list", has been issued in draft form. Controls on semiconductor manufacturing equipment are provided for in category 3B. See 56 *Federal Register* 30798, July 5, 1991.

[30] National Academy of Sciences, *Finding Common Ground: U.S. Export Controls in a Changed Global Environment* [Finding Common Ground] (National Academy Press 1991).

[31] Finding Common Ground, p. 2. On December 13, 1990, the President decided that certain items on the core list would carry a presumption of approval for export to Eastern Europe and the Soviet Union.

[32] Finding Common Ground, p. 153.

[33] See, e.g., White Paper, p. 1. See also, statement of Mr. Edward Braun, President, Veeco Instruments, Inc., on behalf of the Semiconductor Equipment and Materials Industry before the Subcommittee on Commerce, Consumer Protection, and Competitiveness of the House Energy and Commerce Committee, Serial No. 101-149, May 9, 1990, p. 66, and U.S. Department of Commerce, *A Competitive Assessment of the U.S. Semiconductor Manufacturing Equipment Industry*, p. 102 (1985).

[34] Based on conversation with representatives of Semiconductor Equipment and Materials International (SEMI) on November 27, 1990.

[35] Based on conversation with Mr. George S. Kachajian, President, Silicon Technology Corporation, Oakland, NJ, in May 1991. Also, see L. Rhodes, *Kachajian's Rebellion*, Inc. Magazine (Oct. 1986), p. 92, and L. Rhodes, *Update: Export Controls—Kachajian's Revenge*, Inc. Magazine (Aug. 1987), p. 13.

Although it took about seven years, eventually the controls were lifted pursuant to a positive foreign availability determination. During that time, STC's Swiss competitors were reportedly able to increase considerably their market share and profits on sales of wafer saws to the controlled destinations. This enabled the Swiss company to greatly reduce its U.S. prices, thereby increasing its U.S. market share as well.[36]

Semiconductor manufacturing equipment has been the subject of other foreign availability assessments. Positive foreign availability determinations were made with regard to stored program controlled wire bonders, magnetically enhanced sputter deposition systems and prepreg production equipment. In each case, however, the President issued a national security override (NSO) pursuant to an interagency recommendation, deciding to maintain controls pending the outcome of negotiations to eliminate such foreign availability. The wire bonders were initially decontrolled to Western destinations and, after negotiations failed, they were decontrolled to the Soviet Union and the East Bloc as well. Some sputter deposition equipment was decontrolled pursuant to the foreign availability finding, whereas controls on prepreg equipment has been maintained under foreign policy controls despite the foreign availability findings. Thus, while there has been mixed success in applying the foreign availability criteria to remove ineffective controls, it appears that delays in the decontrol process are common.

In testimony before the Commission, Ms. Peggy Haggerty, Vice President of Public Policy, SEMI/SEMATECH, stated that "export controls have been a detriment in general to the [semiconductor manufacturing] equipment industry and to the materials industry as well, mainly because of the unilateral controls that the United States has imposed."[37] At the same hearing, Ms. Victoria Hadfield, Government Relations Manager, Semiconductor Equipment and Materials International (SEMI), stated that COCOM controls "have posed a substantial burden on [SEMI] members", and noted that, unlike many of our trading partners, the United States has imposed controls on exports to COCOM destinations. For example, Ms. Hadfield noted that, until very recently, semiconductor manufacturing equipment exports to Japan were subject to U.S. licensing requirements, "despite the fact that there were many sources of competitive products in Japan."[38]

Ms. Haggerty of SEMI/SEMATECH also gave an illustration of how other COCOM countries interpret the multilateral controls more narrowly than does the United States. A group of executives, on a visit to see a number of semiconductor plants in China, saw that Japanese fabrication lines had been installed in a lot of the facilities. Ms. Haggerty said that this was possible "[b]ecause the Japanese interpreted the export control rules on each piece of equipment. There was nothing there that said that you could not ship the fabline [in its entirety]."[39] At the same hearing, Ms. Victoria Hadfield of SEMI stated that "the U.S. Government has interpreted the COCOM controls much more strictly than other members of COCOM in many cases."[40]

As relatively small companies, semiconductor equipment manufacturers are not suited to deal with the complexities and costs of the export licensing system. Moreover, as small companies with a relatively small number of transactions it is difficult to obtain a distribution license authorizing a repeated number of exportations under set conditions, SEM manufacturers usually must apply for an individual validated license for each transaction.

The COCOM agreement on the "core list" was finally reached in May 1991. The agreement will result in a 50-percent reduction in existing multilateral export controls, which is in addition to the 33-percent reduction achieved in June 1990.[41] The agreement will decontrol semiconductor manufacturing equipment for 1.5-microns integrated circuits (see pp. G-20-G-23). Among the decontrolled items are diffusion and oxidation equipment, sputtering equipment, certain etch, ion implantation and chemical vapor deposition equipment, assembly and inspection equipment, and all testing equipment with a pattern rate below 40 megahertz. SEMI's principal criticism of the decontrolled list was related to "cluster tools," which are tools capable of performing more than one process in the same piece of equipment. Cluster tools are likely to come into greater use within the semiconductor industry, but are also used in the production of other sensitive products.

[36] Ibid.

[37] Hearing transcript, p. 177.

[38] Hearing transcript, pp. 237-238.

[39] Hearing transcript. p. 178.

[40] Hearing transcript, p. 237.

[41] White House Press Release, May 24, 1991.

Conclusion

Although the impact of export controls during the 1980s has undoubtedly been significant, the multilateral decontrol effort in COCOM should go a long way toward improving the export trading environment for semiconductor equipment manufacturers in the 1990s. Also, greater multilateral coordination and cooperation, as reflected by the COCOM initiative to establish a "common standard level of effective protection," should help ensure that the COCOM controls are enforced fairly evenly by high technology exporting nations.

DEPARTMENT OF COMMERCE

Bureau of Export Administration

[Docket No. 910668–1158]

Notice of Upcoming Changes in U.S. National Security Controls

AGENCY: Bureau of Export Administration, Commerce.

ACTION: Notice.

SUMMARY: The United States has been participating with its COCOM allies in developing a "Core List" of dual-use items that must be subject to continued export controls in support of national security objectives. The resulting list contains only the most critical goods and technologies that are essential to maintaining military superiority, while recognizing that broad diffusion of certain other items has made continued control impracticable.

The "Core List" will become the new International Industrial List, and will form the basis for a completely new Commerce Control List (CCL) (Supplement No. 1 to 15 CFR 799.1). The new CCL will be published later this summer, and will include not only the COCOM agreed national security list, but also controls based on nuclear nonproliferation, foreign policy, and short supply. The United States expects that the dual-use commodities and technologies listed below will be controlled for national security purposes effective September 1, 1991. However, when this notice was submitted for publication, drafting groups in COCOM continued to examine wording for propulsion systems 9E03.e and telecommunications and information security category 5. The reader may expect changes in wording in those areas. Readers are cautioned that some of the listed items may be controlled under the International Traffic in Arms Regulations (ITAR), administered by the Department of State.

This is an advisory notice only—it does not change the export controls currently in effect, and does not represent the CCL as it will appear after September 1, 1991.

FOR FURTHER INFORMATION CONTACT: For questions of a technical nature, the following persons in the Office of Technology and Policy Analysis are available:

Category 1: Jeff Tripp—(202) 377–1309
Category 2: Surendra Dhir—(202) 377–5695
Category 3: Jerald Beiter—(202) 377–1641
Category 4: Randolf Williams—(202) 377–0708
Category 5: Joseph Westlake—(202) 377–0731
Category 6: Joseph Chuchla—(202) 377–1641
Categories 7 and 9: Bruce Webb—(202) 377–3806
Category 8: Steve Clagett—(202) 377–8550

SUPPLEMENTARY INFORMATION:

Background

On May 23, 1991, the United States and 16 Western allies agreed in Paris to implement a new system of export controls for dual-use goods and technologies with significant military applications. The agreement follows a major review by member states of the Coordinating Committee for Multilateral Export Controls (COCOM). COCOM comprises the NATO countries (except Iceland), Australia, and Japan. COCOM controls are aimed at keeping militarily significant items from such countries as the Soviet Union, the former members of the Warsaw Pact, and the People's Republic of China. The agreement continues the trend toward reducing controls on items destined for Poland, Hungary, and Czechoslovakia, reflecting agreements by these countries to prevent diversion of Western technology.

The list provided here represents the U.S. dual-use export controls that would be imposed for national security reasons as a result of COCOM agreement on a new International Industrial List. The United States does not maintain national security controls unless there is a multilateral commitment to impose such controls. The list is presented in the modified outline form agreed to by the seventeen COCOM governments, except that the first three places in the outline are compressed here into new entry numbers (Export Control Classification Numbers—ECCNs) that will be used in the new CCL. Use of these four-character ECCNs will facilitate computerization and uniform submission of export license applications. Exporters are encouraged to identify where their products are located on the list to aid in an orderly conversion to the new system.

The list provided here is divided into nine categories, as follows:

1. Advanced materials
2. Material processing
3. Electronics
4. Computers
5. Telecommunications and information security
6. Sensors and lasers
7. Navigation and avionics
8. Marine
9. Propulsion.

For the first time, the CCL will include all software and technical data. Each category in the list below is structured to provide controls for the following five subcategories:

A. Equipment, assemblies, and components
B. Production and test equipment
C. Materials
D. Software
E. Technology.

The list is published below. Users are cautioned that it represents only items under national security controls and is not the complete CCL, that it is subject to changes, and that it is not an official control list. Parties wishing to export should continue to consult the existing CCL at 15 CFR 799.1 until the new CCL that will be published later this summer takes effect.

Authority

Authority: Pub. L. 96–72, 93 Stat. 503 (50 U.S.C. app. 2401 *et seq.*), as amended; Pub. L. 95–242, 92 Stat. 120 (22 U.S.C. 3201 *et seq.*); E.O. 12532 of September 9, 1985 (50 FR 36861, September 10, 1985) as affected by notice of September 4, 1986 (51 FR 31925, September 8, 1986); Pub. L. 99–440 of October 2, 1986 (22 U.S.C. 5001 *et seq.*); and E.O. 12571 of October 27, 1986 (51 FR 39505, October 29, 1986); Pub. L. 95–223, 91 Stat. 1626 (50 U.S.C. 1701 *et seq.*); E.O. 12730 of September 30, 1990 (55 FR 40373, October 2, 1990).

NEW INTERNATIONAL INDUSTRIAL LIST

Category 1—Advanced Materials

A. Equipment, Assemblies and Components

1A01 Components made from fluorinated compounds.

a. Seals, gaskets, sealants or fuel bladders specially designed for aircraft or aerospace use made from more than 50% of any of the materials embargoed by 1C09.b or c;

b. Piezoelectric polymers and copolymers made from vinylidene fluoride:

1. In sheet or film form; and
2. With a thickness exceeding 200 micrometre;

c. Seals, gaskets, valve seats, bladders or diaphragms made from fluoroelastomers containing at least one vinylether monomer, specially designed for aircraft, aerospace or missile use;

1A02 "Composite" structures or laminates.

a. Having an organic "matrix" and made from materials embargoed by 1C10.c, d or e; or

b. Having a metal or carbon "matrix" and made from:

1. Carbon "fibrous and filamentary materials" with:

a. A "specific modulus" exceeding 10.15×10^6 m; and

b. An output voltage exceeding 500 kV; and

c. A pulse width of less than 0.2 microsecond;

f. Rotary input type shaft absolute position encoders having either of the following:

1. A resolution of better than 1 part in 265,000 (18 bit resolution) of full scale; or

2. An accuracy better than ±2.5 seconds of arc;

3A02 General purpose electronic equipment.

a. Recording equipment, as follows, and specially designed test tape therefor:

1. Analogue instrumentation magnetic tape recorders, including those permitting the recording of digital signals (e.g., using a high density digital recording (HDDR) module), having any of the following:

a. A bandwidth exceeding 4 MHz per electronic channel or track;

b. A bandwidth exceeding 2 MHz per electronic channel or track and having more than 42 tracks; or

c. A time displacement (base) error, measured in accordance with applicable IRIG or EIA documents, of less than ±0.1 microsecond;

2. Digital video magnetic tape recorders having a maximum digital interface transfer rate exceeding 180 Mbit/s, except those specially designed for television recording as standardized or recommended by the CCIR or the IEC for civil television applications;

3. Digital instrumentation magnetic tape data recorders having any of the following characteristics:

a. A maximum digital interface transfer rate exceeding 60 Mbit/s and employing helical scan techniques;

b. A maximum digital interface transfer rate exceeding 120 Mbit/s and employing fixed head techniques; or

c. "Space qualified";

Note: 3A02.a.3 does not embargo analogue magnetic tape recorders equipped with HDDR conversion electronics and configured to record only digital data.

4. Equipment, with a maximum digital interface transfer rate exceeding 60 Mbit/s, designed to convert digital video magnetic tape recorders for use as digital instrumentation data recorders;

b. "Frequency synthesizer" "assemblies" having a "frequency switching time" from one selected frequency to another of less than 1 ms;

c. "Signal analysers", as follows:

1. Capable of analysing frequencies exceeding 31 GHz;

2. "Dynamic signal analysers" with a "real-time bandwidth" exceeding 25.6 kHz, except those using only constant percentage bandwidth filters (also known as octave or fractional octave filters);

d. Frequency synthesised signal generators producing output frequencies the accuracy and short term and long term stability of which are controlled, derived from or disciplined by the internal master frequency, and having any of the following:

1. A maximum synthesised frequency exceeding 31 GHz;

2. A "frequency switching time" from one selected frequency to another of less than 1 ms; or

3. A single sideband (SSB) phase noise better than $(126+20 \log_{10}F-20 \log_{10}f)$ in dBc/Hz, where F is the off-set from the operating frequency in Hz and f is the operating frequency in MHz;

Note: 3A02.d does not embargo equipment in which the output frequency is either produced by the addition or subtraction of two or more crystal oscillator frequencies, or by an addition or subtraction followed by a multiplication of the result.

e. Network analysers with a maximum operating frequency exceeding 31 GHz;

Note: 3A02.e does not embargo "swept frequency network analysers" with a maximum operating frequency not exceeding 40 GHz and which cannot be remotely controlled (i.e., contain a data bus for interfacing).

f. Microwave test receivers with both of the following:

1. A maximum operating frequency exceeding 31 GHz; and

2. The capability of measuring amplitude and phase simultaneously;

g. Atomic frequency standards having either of the following characteristics:

1. Long term stability (aging) less (better) than 1×10^{-11}/month; or

2. "Space qualified";

Note: 3A02.g.1 does not embargo non-"space qualified" rubidium standards.

h. Emulators for microcircuits embargoed by 3A01.a.3 or 3A01.a.9;

Note: 3A02.h does not embargo emulators designed for a "family" which contains at least one device not embargoed by 3A01.a.3 or 3A01.a.9.

B. Test, Inspection and Production Equipment

Equipment for the manufacture or testing of semiconductor devices or materials, as follows, and specially designed components and accessories therefor.

3B01 "Stored programme controlled" equipment for epitaxial growth.

a. Capable of producing a layer thickness uniform to less than ±2.5% across a distance of 75 mm or more;

b. Metal organic chemical vapour deposition (MOCVD) reactors specially designed for compound semiconductor crystal growth by the chemical reaction between materials embargoed by 3C03 or 3C04;

c. Molecular beam epitaxial growth equipment using gas sources;

3B02 "Stored programme controlled" equipment designed for ion implantation, as follows.

a. With accelerating voltages exceeding 200 keV;

b. Specially designed and optimized to operate at accelerating voltages of less than 10 keV;

c. With direct write capability; or

d. Capable of high energy oxygen implant into a heated semiconductor material "substrate";

3B03 "Stored programme controlled" anisotropic plasma dry etching equipment.

a. With cassette-to-cassette operation and load-locks, and having either of the following:

1. Magnetic confinement; or

2. Electron cyclotron resonance (ECR);

b. Specially designed for equipment embargoed by 3B06 and having either of the following:

1. Magnetic confinement; or

2. Electron cyclotron resonance (ECR);

3B04 "Stored programme controlled" plasma enhanced CVD equipment, as follows.

a. With cassette-to-cassette operation and load-locks, and having either of the following:

1. Magnetic confinement; or

2. Electron cyclotron resonance (ECR);

b. Specially designed for equipment embargoed by 3B06 and having either of the following:

1. Magnetic confinement; or

2. Electron cyclotron resonance (ECR);

3B05 "Stored programme controlled" multifunctional focused ion beam systems specially designed for manufacturing, repairing, physical layout analysis and testing of masks or semiconductor devices, having either of the following.

a. Target-to-beam position feedback control precision of 0.25 micrometre or finer; or

b. Digital-to-analogue conversion resolution exceeding 12 bits;

3B06 "Stored programme controlled" automatic loading multi-chamber central wafer handling systems, having interfaces for wafer input and output, to which more than two pieces of semiconductor processing equipment are to be connected, to form an integrated system in a vacuum environment for sequential multiple wafer processing.

Note: 3B06 does not embargo automatic robotic wafer handling systems not designed to operate in a vacuum environment.

3B07 "Stored programme controlled" lithography equipment.

a. Align and expose step and repeat equipment for wafer processing using photo-optical or X-ray methods, having any of the following:

1. A light source wavelength shorter than 400 nm;

2. A numerical aperture more than 0.40; or

3. An overlay accuracy of ±0.20 micrometre (3 sigma) or better;

Note: 3B07.a does not embargo align and expose step and repeat equipment having all of the following:

1. A light source wavelength of 430 nm or more;

2. A numerical aperture 0.38 or less; and

3. An image size diameter 22 mm or less;

b. "Stored programme controlled" equipment specially designed for mask making or semiconductor device processing using deflected focussed electron beam, ion beam or "laser" beam, with any of the following:

1. A spot size smaller than 0.2 micrometre;

2. Capable of producing a pattern with a feature size of less than 1 micrometre; or

3. An overlay accuracy of better than ±0.20 micrometre (3 sigma);

3B08 Masks or reticles.

a. For integrated circuits embargoed by 3A01;

b. Multi-layer masks with a phase shift layer;

3B09 "Stored programme controlled" test equipment, specially designed for testing semiconductor devices and unencapsulated dice.

a. For testing S-parameters of transistor devices at frequencies exceeding 31 GHz;

b. For testing integrated circuits, and "assemblies" thereof, capable of performing functional (truth table) testing at a pattern rate of more than 40 MHz;

Note: 3B09.b does not embargo test equipment specially designed for testing:

1. "Assemblies" or a class of "assemblies" for home or entertainment applications;

2. Unembargoed electronic components, "assemblies" or integrated circuits.

c. For testing microwave integrated circuits at frequencies exceeding 3 GHz;

Note: 3B09.c does not embargo test equipment specially designed for testing microwave integrated circuits operating solely in the Standard Civil Telecommunication Bands at frequencies not exceeding 31 GHz.

d. Electron beam systems designed for operation at or below 3 keV, or "laser" beam systems, for the non-contactive probing of powered-up semiconductor devices, with both of the following:

1. Stroboscopic capability with either beam-blanking or detector strobing; and

2. An electron spectrometer for voltage measurement with a resolution of less than 0.5 V;

Note: 3B09.d does not embargo scanning electron microscopes, except when specially designed and instrumented for the non-contactive probing of powered-up semiconductor devices.

C. Materials

3C01 Hetero-epitaxial materials consisting of a "substrate" with stacked epitaxially grown multiple layers of:

a. Silicon;

b. Germanium; or

c. III/V compounds of gallium or indium;

Technical Note: III/V compounds are polycrystalline or binary or complex monocrystalline products consisting of elements of groups IIIA and VA of Mendeleyev's periodic classification table (gallium arsenide, gallium-aluminium arsenide, indium phosphide, etc.).

3C02 Resist materials, and "substrates" coated with embargoed resists.

a. Positive resists with a spectral response optimized for use below 370 nm;

b. All resists, for use with electron beams or ion beams, with a sensitivity of 0.01 microcoulomb/mm² or better;

c. All resists, for use with X-rays, with a sensitivity of 2.5 mJ/mm² or better;

d. All resists optimized for surface imaging technologies, including silyated resists;

Technical Note: Silyation techniques are defined as processes incorporating oxidation of the resist surface to enhance performance for both wet and dry developing.

3C03 Metal-organic compounds of aluminium, gallium or indium, having a purity (metal basis) better than 99.999%.

3C04 Hydrides of phosphorus, arsenic or antimony, having a purity better than 99.999%, even diluted in neutral gases.

Note: 3C04 does not embargo hydrides containing less than 20% molar of rare gases or hydrogen.

D. Software

3D01 "Software" specially designed for the "development" or "production" of equipment embargoed by 3A01.b to 3A02.h or 3B.

3D02 "Software" specially designed for the "use" of "stored programme controlled" equipment embargoed by 3B.

3D03 Computer-aided-design (CAD) "software" for semiconductor devices or integrated circuits, having any of the following:

a. Design rules or circuit verification rules;

b. Simulation of the physically laid out circuits; or

c. Lithographic processing simulators for design;

Technical Note: A lithographic processing simulator is a "software" package used in the design phase to define the sequence of lithographic, etching and deposition steps for translating masking patterns into specific topographical patterns in conductors, dielectrics or semiconductor material.

Note: 3D03 does not embargo "software" specially designed for schematic entry, logic simulation, placing and routing, layout verification or process generation tape;

N.B.: Libraries, design attributes or associated data for the design of semiconductor devices or integrated circuits are considered as technology.

E. Technology

3E01 Technology according to the General Technology Note for the "development" or "production" of equipment or materials embargoed by 3A, 3B or 3C.

3E02 Other technology for the "development" or "production" of the following.

a. Vacuum microelectronic devices;

b. Hetero-structure semiconductor devices such as high electron mobility transistors (HEMT), hetero-bipolar transistors (HBT), quantum well or super lattice devices;

c. Superconductor electronic devices;

Note: 3E01 does not embargo technology for the "development" or "production" of:

a. Microwave transistors operating at frequencies below 31 GHz;

b. Integrated circuits embargoed by 3A01.a.3 to 11, having both of the following characteristics:

1. Using technology of one micrometre or more, and

2. Not incorporating multi-layer structures.

N.B.: This Note does not preclude the export of multilayer technology for devices incorporating a maximum of two metal layers and two polysilicon layers.

Note for Category 3:

Governments may permit, as administrative exceptions, the shipment to the People's Republic of China of:

a. Epitaxial reactors embargoed by 3B01.a for use in silicon semiconductor manufacturing, except those specially designed for metal-organic deposition;

b. Instrument "frequency synthesisers" or synthesised signal generators embargoed by 3A02.b or 3A02.d.2, and specially designed components or accessories therefor, provided they have a synthesised output frequency of 2.6 GHz or less and the "frequency switching time" is 0.3 ms or more;

c. Analogue instrumentation magnetic tape recorders embargoed by 3A02.a.1, provided all of the following conditions are met:

1. Bandwidths do not exceed:

a. 4 MHz per track; or

b. 2 MHz per track and have up to 42 tracks;

2. Tape speed does not exceed 6.1 m/s;

3. They are not designed for underwater use;

4. They are not ruggedised for military use; and

5. Recording density does not exceed 653.2 magnetic flux sine waves per mm;

d. Positive resists not optimised for photolithography at a wavelength of less than 365 nm, provided they are not embargoed by 3C02.b to .d.

Category 4—Computers

Note: 1. Computers, related equipment or "software" performing telecommunications or "local area network" functions must also be evaluated against the performance characteristics of 5A.

N.B.: 1. Control units which directly interconnect the buses or channels of central processing units, "main storage" or disk controllers, are not regarded as telecommunications equipment described in 5A.

N.B.: 2. For the embargo status of "software" which provides routing or switching of "datagram" or "fast select" packets (i.e., packet by packet route selection) or for "software" specially designed for packet switching, see 5A.

Note: 2. Computers, related equipment or "software" performing cryptographic, cryptanalytic, certifiable multi-level security or certifiable user isolation functions, or which limit electromagnetic compatibility (EMC), must also be evaluated against the performance characteristics of 5B.

A. Equipment, Sub-Assemblies & Components

4A01 Electronic computers and related equipment, as follows, and "assemblies" and specially designed components therefor.

a. Specially designed to have either of the following characteristics:

1. Rated for operation at an ambient temperature below 228 K (−45 °C) or above 343 K (+70 °C);

Note: The temperature limits in 4A01.a.1. do not apply to computers specially designed for civil automobile and train engine applications.

2. Radiation-hardened to exceed any of the following specifications:

a. Total Dose, 5×10^5 Rads (Si)

b. Dose Rate Upset, 5×10^8 Rads (Si)/sec

c. Single Event Upset 1×10^{-7} Error/bit/day; or

Note: Equipment designed or rated for transient ionising radiation is embargoed by the ITAR.

b. Having characteristics or performing functions exceeding the limits in 5B;

4A02 "Hybrid computers", as follows, and "assemblies" and specially designed components therefor.

a. Containing "digital computers" embargoed by 4A03;

b. Containing analogue-to-digital or digital-to-analogue converters having both of the following characteristics:

1. 32 channels or more; and

2. A resolution of 14 bits (plus sign bit) or more with a conversion rate of 200,000 conversions/s or more;

4A03 "Digital computers", "assemblies", and related equipment therefor, as follows, and specially designed components therefor.

Note: 1. 4A03 includes vector processors, array processors, logic processors, and equipment for "image enhancement" or "signal processing".

Note: 2. The embargo status of the "digital computers" or related equipment described in 4A03 is governed by the embargo status of other equipment or systems provided:

a. The "digital computers" or related equipment are essential for the operation of the other equipment or systems;

b. The "digital computers" or related equipment are not a "principal element" of the other equipment or systems; *and*

N.B.: 1. The embargo status of "signal processing" or "image enhancement" equipment described in 4A03.f and specially designed for other equipment with functions limited to those required for the other equipment is determined by the embargo status of the other equipment even if it exceeds the "principal element" criterion.

N.B.: 2. For the embargo status of "digital computers" or related equipment for telecommunications equipment, see 5A.

c. The technology for the "digital computers" and related equipment is governed by 4E.

Note: 3. "Digital computers" or related equipment are not embargoed by 4A03 provided:

a. They are essential for medical applications;

b. The equipment is substantially restricted to medical applications by nature of its design and performance;

c. The equipment does not have "user-accessible programmability" other than that allowing for insertion of the original or modified "programmes" supplied by the original manufacturer;

d. The "composite theoretical performance" of any "digital computer" which is not designed or modified but essential for the medical application does not exceed 20 million composite theoretical operations per second (Mtops); and

e. The technology for the "digital computers" or related equipment is governed by 4E.

a. Designed for combined recognition, understanding and interpretation of image or continuous (connected) speech;

a. Designed or modified for "fault tolerance";

Note: For the purposes of 4A03.b, "digital computers" and related equipment are not considered to be designed or modified for "fault tolerance", if they use:

1. Error detection or correction algorithms in "main storage";

2. The interconnection of two "digital computers" so that, if the active central processing unit fails, an idling but mirroring central processing unit can continue the system's functioning;

3. The interconnection of two central processing units by data channels or by use of shared storage to permit one central processing unit to perform other work until the second central processing unit fails, at which time the first central processing unit takes over in order to continue the system's functioning; or

4. The synchronisation of two central processing units by "software" so that one central processing unit recognises when the other central processing unit fails and recovers tasks from the failing unit.

c. "Digital computers" having a "composite theoretical performance" exceeding 12.5 million composite theoretical operations per second (Mtops);

d. "Assemblies" specially designed or modified to enhance performance by aggregation of "computing elements", as follows:

Note: 1. 4A03.d applies only to "assemblies" and programmable interconnections not exceeding the limits in 4A03.c, when shipped as unintegrated "assemblies". It does not apply to "assemblies" inherently limited by nature of

APPENDIX H
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