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JAPAN TAKES SEMICONDUCTOR EQUIPMENT LEADERSHIP

Worldwide, the market for semiconductor production equipment is approaching $10 billion annually. The firms that develop chipmaking gear are largely responsible for the unrelenting advances in process technology that continue to give state-of-the-art chips their economy, power, and speed. *Like the chip industry, the chipmaking equipment* industry grew up in the U.S.

This year, however, Japanese-owned producers of semiconductor equipment are about to outsell their American counterparts. In fact, some market researchers say Japan has already taken the lead. Equipment line by equipment line, Japanese firms are asserting leadership, not only of the market, but of the technology. Connecticut-based

Perkin-Elmer, for years the leading producer of chipmaking equipment, may soon be sold to a Japanese firm. Pressure is building in Washington against the sale, based on the argument that it would transfer another key technology to Japan. However, it is likely that President Bush would approve the purchase, if a Japanese buyer is found. Perkin-Elmer has fallen upon hard times precisely because its Japanese competitors already have much of the technology.

American high-tech leaders warn that Japanese hegemony in semiconductor equipment could make it impossible for U.S. chipmakers to remain competitive with Japanese semiconductor makers, However, it is more accurate to say that expansion of the Japanese chipmaking business made it possible for Japanese equipment makers to move ahead. After all, Japanese companies took over the commodity chip—primarily dynamic random access memory (DRAM) circuits—business while largely dependent upon American production technology.

In fact, Japanese equipment and device makers have contributed to each others' success, largely because they work much more closely together than their American counterparts. The long-term health of U.S.-based industry may depend upon the development of similar links. (For a detailed history of the semiconductor equipment industry and the rise of Japanese competition, see Jay Stowsky, "The Weakest Link: Semiconductor Production Equipment, Linkages, and the Limits to International Trade," Berkeley Roundtable on the International Economy [BRIE] Working Paper #27, August, 1987. Stowsky presents a much more elaborate version of the thesis presented in this brief article.)

A Diffuse Industry

In the 1950's, before the invention of the integrated circuit, semiconductor producers supplied their own production equipment. The demands of integrated circuit mass production, funded by NASA and the Air Force in the early 1960's, spurred the formation of specialist equipment producers.

Since the device-manufacturing businesses was divided among numerous, entrepreneurial firms, it was inevitable that independent, competitive suppliers would emerge. Since chipmaking consists of a large number of distinct steps, each requiring unique equipment and open to diverse technological approaches, the equipment-making sector fragmented vertically as well. In turn, the availability of key process technologies on the open market provided easy entry into the device business and stimulated competition—and fragmentation—in the chip industry.

Today, according the the **San Jose Business Journal** (September 25, 1989), "It takes roughly 200 steps to create a chip product. At each level of the chipmaking process there are at least six companies making the equipment."

Most of those companies have historically maintained an arms length relationship with their customers, fearing that favoritism would hurt their relationship with competing customers. As a result, chipmakers sometimes have belatedly reaped the benefits of new production technologies, while equipment-producers often have been hurt financially when they developed equipment not suited for the next round of chipmaking expansion.

(In addition, the separation of device and equipment firms has also hampered the development of environmentally sound production

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techniques, for the companies that develop new process technology are generally not the ones who are held responsible for pollution.)

On the other hand, the competitive, independent nature of the industry has promoted the introduction of new technologies and encouraged the formation of new firms. Measured by either its market growth or technological development, the American semiconductor equipment industry has been enormously successful, and it has played a key role in the rise of the chip as an epochal innovation in the global economy.

About a decade ago, two factors arose that are still changing the face of the chipmaking equipment industry. First, computer memory chips emerged as commodity products, for which improvements in production technology would prove more significant than new designs. DRAM's are by no means the only important segment of the semiconductor business, but as the devices manufactured in highest volume, the DRAM business tends to shape investment in new generations of production equipment. In fact, firms that make DRAM's use them as "technology drivers," breaking in new equipment and refining production techniques in volume production before applying them to shorter-run product lines.

Second, the Japanese Ministry of International Trade and Industry (MITI) established the VLSI (Very Large Scale Integrated circuit) project. (Admittedly, MITI had sponsored earlier semiconductor programs, but the VLSI project reached new heights of effectiveness.) The Japanese government financed research and development in chip design and production, but more important, it consciously shaped the structure of both the Japanese semiconductor device and equipment industries. First, both sectors would be characterized by a high level of concentration, with little room for independent start-ups. And second, if not linked directly by ownership, Japanese-owned chipmakers and the Japanese-owned companies that supplied production equipment would cooperate closely.

In contrast, most of the American firms that at the time supplied Japanese device-makers with the bulk of their production equipment worked through Japanese partners, primarily trading companies.

As Japanese-owned firms took over the global production of memory chips, they looked more and more to Japanese equipment suppliers. Those suppliers, working closely with chipmakers on high-volume, state-of-the-art production lines soon caught up and in many cases surpassed American-owned firms in the design and marketing of new equipment. Nikon, for example, became the leader in wafer steppers. Canon moved forward in projection aligners. Advantest and Ando soon led the automatic test equipment segment of the market.

The New Reality

Today, Japanese equipment-makers are firmly entrenched, although Japanese chipmakers still rely upon some U.S.-based companies. (Applied Materials, which actually does much of its development in the United Kingdom, has prospered because it has stayed on top technically while maintaining a major subsidiary in Japan.) They not only dominate the Japanese market, but they have followed Japanese device-makers overseas, including to the United States. U.S.-owned chipmakers increasingly buy equipment from Japanese suppliers, as well.

A recent survey of U.S.-based device-makers illustrated the continuing rise of Japanese-owned equipment makers. Twenty-four U.S.-owned, U.S.-based chip manufacturers, accounting for over 75% of the total value of American semiconductors, responded to a Semiconductor Equipment and Materials International (SEMI) 1989 survey. SEMI found ten key categories of manufacturing equipment where American respondents said they expect to buy a substantially smaller share of their production equipment from U.S. suppliers in 1990 than in 1985-1987.

Specifically, SEMI identified the following categories either because the U.S. share of *all*

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responding firms' purchases is expected to drop 10% over that period, or because the U.S. share of *large* U.S. firms is expected to decline 10%. Large firms, as defined in the survey, are those with chip sales (or shipments, in the case of captive firms) over $625 million in 1988. The U.S.-equipment producers' share of large firm business are shown in brackets. (SEMI and Quick, Finan, & Associates, "Results of the 1989 Semiconductor Equipment and Materials Procurement Survey," October, 1989.

Equipment Categories	U.S. Market Share	
	(1985-1987)	(1990)
Optical Lithography	72	44
	[64]	[39]
Deposition	94	81
Sputtering	90	73
	[82]	[70]
Scriber Dicing	71	59
Die Attach	[71]	[56]
Wire Bonding	69	60
Seal/Mold/Packaging	68	53
	[48]	[36]
Test Handlers	[89]	[74]
Memory Test	88	77
	[90]	[70]
Analog Test	[89]	[76]

Industrial Policy

The relative decline of the U.S. equipment industry could make it difficult for American chipmakers to strengthen their manufacturing prowess, but just as Japanese device-makers gave Japan-based equipment-makers a boost, so American chip producers could help advance U.S. equipment companies. But Sematech, the most prominent effort by American firms to regain manufacturing parity with Japan, has treated equipment firms as second-class citizens—as suppliers, not equal partners.

Meanwhile, largely in response to its market and financial troubles, the U.S.-owned semiconductor equipment industry is consolidating. Existing firms are merging. It is harder for start-ups to find financing. However, there is little evidence that the equipment industry is establishing closer links to U.S. merchant chip producers. That cooperation, rather than government subsidies, is the key requirement for growth.

Perhaps the U.S. government, like MITI, should promote close relations between equipment and device-makers. We have always been hesitant to recommend such industrial policy on behalf of chipmakers, since they have historically demonstrated little loyalty to their consumers or employees in the U.S.

However, the manufacturers of production equipment, like other producers of industrial and scientific instruments, tend to be less footloose than component, computer, and consumer electronics manufacturers. Their relatively short production runs often require skilled workers, and they tend to locate even their more labor-intensive work within the United States. Thus, support for this industry is likely to help American workers. And providing skilled, decent-paying jobs in the U.S. is a worthy goal for U.S. industrial policy.

DOMESTIC ASSEMBLY

U.S.-based semiconductor producers have always done the bulk of their assembly—that is, the packaging and connecting of diced wafers—overseas, and the SEMI survey described above suggests that the situation is unlikely to change. In particular, few large chipmakers expect to increase or decrease their domestic assembly operations. More small firms, however, expect to add to rather than reduce domestic assembly.

About half of all survey firms plan to keep domestic assembly at the same level; 30% expect an increase; and 20% expect a decrease. When only the responses of the larger (over $625 million sales in 1988) companies are counted, slightly more than 70% plan to keep the same level of U.S. assembly. Of the rest, about half plan to increase while the others expect to reduce U.S. assembly.

One small Silicon Valley-based chipmaker, Atmel, is already investing $10 million in the expansion of its Colorado Springs assembly operation. Earlier this year it spent $15 million on upgrading its wafer fab operations there, so the firm expects to operate a fully integrated domestic plant. The Colorado Springs operation was acquired from Honeywell. (**San Jose Business Journal**, September 18, 1989)

SILICON VALLEY ETHNIC HIERARCHY

Non-Hispanic whites still dominate top jobs in Silicon Valley, and although some Asian ethnic groups hold key professional positions, Asians and Hispanic workers dominate low-level jobs. Citing data from the U.S. Equal Employment Opportunity Commission (EEOC), the **San Jose Mercury**

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News reports (October 1, 1989), "Anglos still dominate white-collar jobs; 82 percent in 1979, 75 percent in 1987… Hispanics and Asians fill a disproportionate number of blue-collar jobs. They represent 35 percent of the population, but 51 percent of these jobs."

The EEOC data has a major limitation, it covers all industrial sectors in Silicon Valley, not just high-tech. Consequently, the professional category include teachers and nurses; the craft workers category including construction workers; and service employees are employed in diverse work, including restaurant operation, beauty care, and building maintenance.

Non-whites have established statistical dominance in one category that is largely confined to the electronics industry, semiskilled labor. Only about a third of Santa Clara County's machine operators are Anglo, down from 54 percent in 1979, largely due to an increase in Asian—that is Southeast Asian—assemblers and operatives.

And the highly visible Asian and Asian-American professionals—primarily ethnic Chinese, Japanese, and Indian—say that they have a difficult time moving into top management or corporate boards of directors. But there is one route: starting one's own company, often with the aid of investment from Asia. Bill Sun, president of the Chinese Institute of Engineers, told the **Far Eastern Economic Review** (October 19, 1989) that "there are around 200 (mainly small) companies run by Chinese-Americans in the Valley."

The table below, taken from the **Mercury News** EEOC data, shows 1979 percentages in parentheses.

1987 Share of Santa Clara County Workforce by Job Category

Type of Job	Anglo	Asian	Black	Hispanic
Managers	84(88)	9(4)	3(2)	5(5)
Professionals	78(85)	15(9)	3(2)	4(3)
Technicians	62(75)	22(11)	5(5)	11(10)
Sales	77(82)	6(4)	5(4)	13(10)
Clerical	70(77)	10(6)	7(6)	13(11)
Craft	60(72)	15(5)	5(4)	20(18)
Machine Operators	34(54)	34(13)	6(7)	25(26)
Laborers	38(45)	13(7)	6(5)	42(42)
Service	50(63)	14(6)	9(9)	26(22)

TANDEM LAWSUIT

We always watch for reports about computer-maker Tandem, which touts itself as one of Silicon Valley's most enlightened employers. (See, for example, **Global Electronics** Issue No. 97.) Quickly viewing a headline in the **San Jose Mercury News** (November 30, 1989), we tentatively concluded that the firm had slipped up. It appeared to be the target of a sexual harassment lawsuit.

Reading more carefully, however, we found that Tandem was trying to clamp down on sexual harassment. The litigant is a former marketing manager who had been fired—he claims without a chance to respond—following accusations from female employees that he had harassed them!

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