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Policies to Restore the International Competitiveness of Japanese Semiconductor Industry

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Contents

Policies to Restore the International Competitiveness of Japanese Semiconductor Industry

Summary

1. As the global semiconductor market slows from double-digit to single-digit growth, keener competition among manufacturers is likely to produce clear winners and losers. The world's largest semiconductor market has shifted from Japan to the U.S. and then to Asia and the Pacific, making it increasingly important for Japanese manufacturers to introduce a global marketing strategy by focusing on the Asian and Western markets as well as its own market at home. An increase in semiconductor demand is expected for automobiles and consumer equipment, including consumer electronics, as well as for computers and communications. To create their own markets, therefore, semiconductor manufacturers must take the initiative in developing new uses.

2. Securing an overwhelming market share for a general-purpose product is the best way to ensure profitability in the semiconductor business. Likewise, successful operation in application-specific products depends on standardizing to allow sales to as many customers as possible, rather than clinging to a small number of specific clients. Despite their respectable position in microcontrollers and flash memory, Japanese manufacturers have not always been able to secure an advantage in general-purpose products such as processors, FPGAs/PLDs and analog semiconductors. It is true that since their exit from the DRAM market, Japanese manufacturers have been focusing on special purpose products and hold a certain edge in application-specific integrated circuits (ASICs). As regards application-specific standard products (ASSPs: a highly promising application-specific product), however, the largest market shares belong to overseas manufacturers – an indication that Japanese manufacturers are falling behind in the competition for standardization.

3. Four categories of major semiconductor manufacturers show high profitability both in Japan and overseas: (1) leading integrated device manufacturers (IDMs), (2) fabless companies (specializing in design), (3) foundries (manufacturers under contract) and (4) intellectual property (IP) providers. Foundries reportedly produce almost one quarter of the semiconductor products in the world, of which about 60% is accounted for by two Taiwanese firms, TSMC and UMC. The strengths of Taiwanese foundries include: (1) cost competitiveness, (2) quality services, (3) leading-edge technologies, (4) broad product lineups and (5) provision of IP libraries.

Low-cost production under contract has been the driving force behind the rapid growth of foundries so far. When it comes to nano-level systems-on-chips (SoCs: system LSIs), the complexity of design and the large amount of IP involved mean that a simple contract manufacturing system can no longer reconcile response to customer needs with profitability. In an effort to improve overall efficiency in design, foundries are now providing libraries of IP which is commonly used in a wide range of products, leaving fabless companies to concentrate on development of the core design. Because clients are placing orders on shorter notice, foundries are trying to provide SoC solutions through global collaboration with upstream partners such as fabless companies and electric design automation (EDA) tool vendors.

4. Traditionally, U.S. companies have held an overwhelming edge in fabless operation, i.e. specializing in the design and development of semiconductors without a fabrication plant (fab). Indeed, a vertical international specialization model has developed between fabless companies in Silicon Valley and Taiwanese foundries. However, some fabless companies in Taiwan are growing rapidly as they receive design contracts from mainland China. Thus, Taiwan's semiconductor industry is shifting to a tandem structure comprising both manufacturing and designing companies.

5. Against the benchmark of Taiwanese and other overseas counterparts, the weaknesses of the Japanese semiconductor manufacturers include: (1) a lack of products with an overwhelming market share or unique features; (2) insufficient investment; (3) a delay in responding to emerging business models; (4) a decline in cost competitiveness (particularly in terms of efficiency of sales, administrative expenses and R&D expenditure); (5) weak sales in overseas markets; (6) financial bases that are vulnerable to volatility; and (7) slow progress in partnerships between industry, government and academia. Japan's share of the world market has been declining since 1985, when it reached a peak of 51%, to only 24% in 2004. The country's semiconductor manufacturers have not been successful in halting the decline of their international competitiveness.

6. The SoC business, along with memory and power semiconductors/sensors, is expected to become one of the future pillars of the Japanese semiconductor industry. It is difficult for a company to design and develop a SoC on its own because of the huge volume of IP integrated on one chip. Since the decision on "what to make" is a major factor in differentiation, success depends not only on process technologies but also on skills in designing, developing and marketing. While improving the efficiency of user support and product development – both of which tend to be costly for application-specific products – Japanese manufacturers, if they are to enhance their competitiveness in the SoC business, must redouble their efforts to: (1) refocus their operations on design and marketing, (2) participate actively in global alliances, (3) rebuild their relationships with final set product departments and (4) overhaul corporate management, organizational control and personnel evaluation.

[by Makoto Shimizu (e-mail: report@dbj.go.jp)]

Introduction

In recent years, discussion has been heating up over emerging business models in the semiconductor industry. An example may be found in the SoC (system on a chip: system LSI) business, which is expected to become one of the pillars of the industry along with memory and power semiconductors. Since SoCs require sophisticated design, marketing and manufacturing, even a small enterprise may enter the market if it comes up with an original idea or business model. New developments such as the sale of IP (intellectual property) licenses and the building of alliances involving various companies, ranging from upstream design tool makers to downstream foundries, remind us that competition in the semiconductor industry is not only for state-of-the-art manufacturing processes, but also for innovative business models.

No single business model can be the absolute standard for application-specific products like SoCs. Each company has to develop its own optimum business model, depending on its product structure, business relationship with major clients, the level of microfabrication achieved in its plants, cost competitiveness and its skills in designing hardware and software. The relationship between the set product and semiconductor departments also comes into play for a general electronics manufacturer. Thus, trial and error is the only way for a semiconductor manufacturer to find its own SoC business model.

Taking into account the fact that developing an SoC requires integration with the application involved, it would be better, in terms of the overall strength of the industry, to have a variety of original business models rather than to have a large number of domestic companies using similar business models. It is hoped that steady efforts by individual companies for business reform will create a common view on the necessity of cross-industrial partnerships and consolidation, culminating in the realization of an optimal structure for the industry as a whole.

Based on the perception described above, this report aims to suggest some strategies to enhance the international competitiveness of the Japanese semiconductor industry along with concrete policies to implement them, with special emphasis on SoC businesses.

Chapter I analyzes structural changes affecting the world semiconductor market. It demonstrates that the performance of semiconductor manufacturers has come to depend on their success or failure in increasing shares in general-purpose product markets and in standardizing application-specific products, because the use of semiconductors has diversified, enhancing the importance of a global marketing strategy that focuses on markets in Asia and the West as well as in Japan.

Chapter II analyzes the international competitiveness of Japanese manufacturers with major general-purpose and application-specific products. The analysis indicates that Japanese manufacturers, since their exit from the DRAM market, have been focusing on application-specific products and have thus gained a considerable edge in the ASIC (application-specific integrated circuit) market. They are, however, falling behind in the highly promising ASSP (application-specific standard product) market.

Chapters III and IV rely partly on on-site research to provide an overview of the Taiwanese semiconductor industry, the recent development of which is largely attributable to a new business model based on vertical specialization. These chapters present some concrete cases to show how Taiwanese manufacturers are responding to the challenges of the SoC business by enhancing partnerships between fabless companies and foundries.

Chapter V examines issues facing the Japanese semiconductor industry as identified by an international comparison with Taiwanese and other overseas competitors. It argues that those issues are essentially related to the nature of business management.

Chapter VI draws on the above discussion to suggest four strategies for restoring the international competitiveness of the Japanese semiconductor industry in the SoC business, along with concrete suggestions on how to put these strategies into practice.

I Long-term Trends and Structural Changes in the World Semiconductor Market

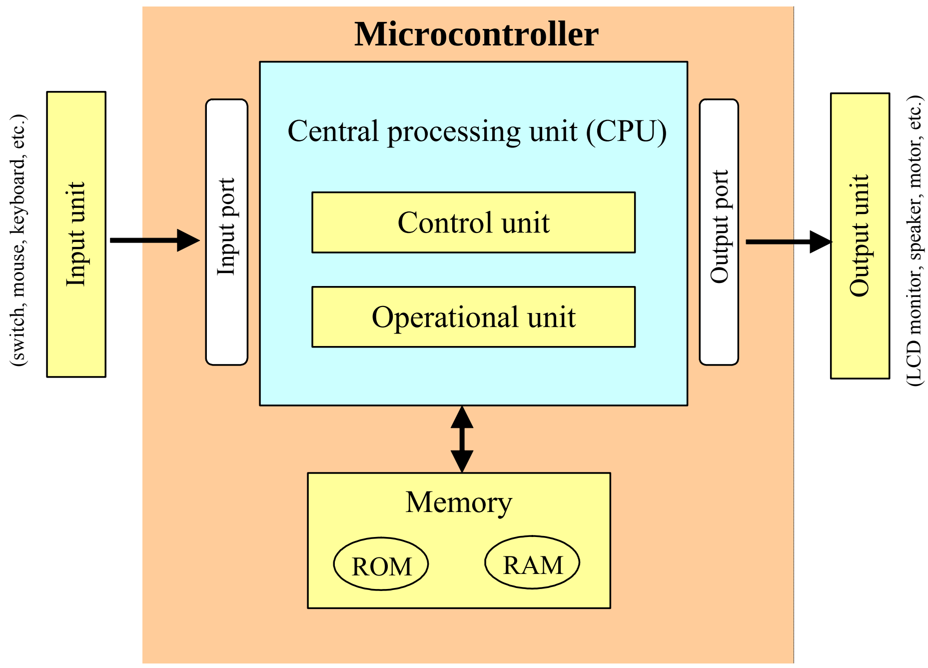
1. What is a Semiconductor?

A semiconductor is a material with an electrical conductivity that is intermediate between that of a conductor and an insulator. Silicon is one of the best known semiconductors. A circuit composed of numerous discrete devices made from semiconductors, such as transistors, diodes and condensers, is known as an integrated circuit (IC). When we say semiconductor, we usually refer to an IC. Unless otherwise specified, this report uses the term "semiconductor" in this sense.

In terms of function, a semiconductor integrates one or more of the five basic elements of a computer: input, calculation, memory, control and output. Thanks to progress in microfabrication technology, a semiconductor can now perform huge amounts of data processing which could previously be achieved only by a mainframe.

A central processing unit (CPU), which is at the heart of a computer, retrieves an instruction from program memory to execute arithmetic processing, sending out data and controlling the operation of equipment. These CPU functions may be integrated on one chip, called a microprocessor unit (MPU). MPUs that perform high-speed processing of large volumes of data with an extended operating frequency range, are now in wide use, particularly in personal computers (PCs), personal digital assistants (PDAs) and consoles.

Programs needed by the processor are housed in ROM memory (read only memory). Unlike RAM (random access memory), which temporarily stores the results of arithmetic operations, data stored in ROM do not disappear when equipment is turned off. A microcontroller unit (MCU), widely used in electronics, integrates various devices such as CPUs, memory on a chip and interfaces with peripherals (input/output ports). The MCU executes arithmetic operations based on inputs from various parts of the equipment like switches, keyboards and sensors, and it controls the equipment by using outputs from those operations (see Figure 1-1).



Source: Toshiba Semiconductor, "Microcontroller Interface".

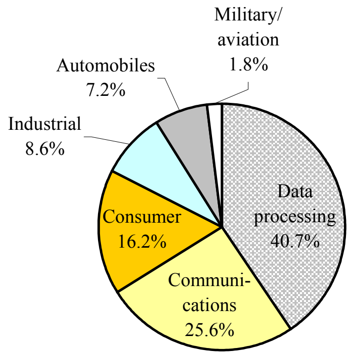
Figure 1-1. Functional Blocks of a Microcontroller (MCU)

2. Composition of Semiconductors by Use

Semiconductors are most commonly used for data processing, particularly in PCs and servers. 40.7% of the semiconductors marketed in 2005 (a preliminary figure) are used for this purpose (see Figure 1-2). Gartner Dataquest reports that world PC shipments in 2005 (a preliminary figure) reached some 220 million units, up 15.3% from the previous year. This uptrend continues with the surge of emerging markets, including BRICs, and increased demand for equipment replacement in developed countries (see Figure 1-3).

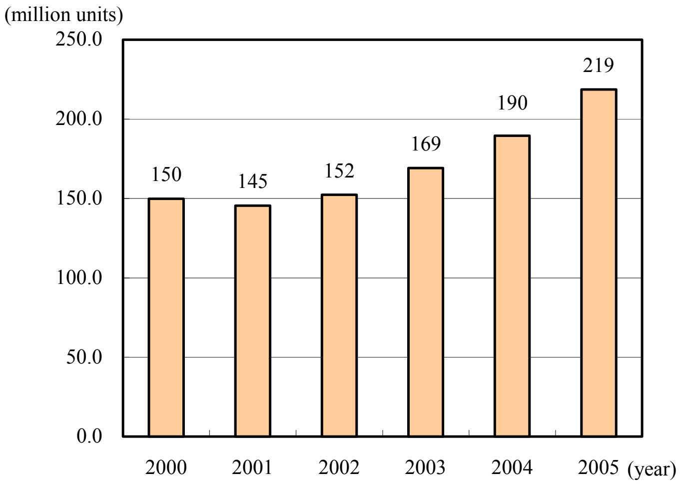
The second most common use of semiconductors is for communications, which accounts for a quarter of semiconductors marketed. Global shipments of cellular phones increased from 410 million units in 2000 to 670 million units in 2004 and seem to have reached the 810 million mark in 2005, up 20% from the previous year (see Figure 1-4). Although replacement demand will surpass new demand in developed countries, cellular phones will become increasingly popular in emerging markets, including BRICs. It is expected that cellular phones will require more sophisticated semiconductors as their communication functions are supplemented by various new applications, such as camera, music and TV.

The semiconductor market for consumer use will also expand, with growing sales of digital home electronics such as flat-screen TVs and portable music players. Moreover, semiconductors for automobiles are receiving increased attention, as the popularity of car navigation systems and the sophistication of computerized con-



Source: Gartner Dataquest (February 2006) GJ06044

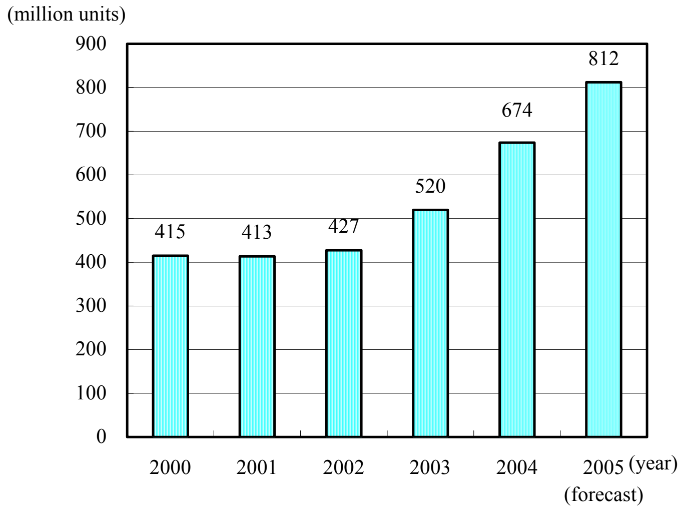
Figure 1-2. Composition of Semiconductors by Use[1] (2005)



Source: Gartner Dataquest (February 2006) GJ06075

Figure 1-3. World PC Shipments

[1] Figures do not necessarily add up to the total due to rounding. (The same applies throughout this report.)



Source: Gartner Dataquest (December 2005) GJ06047

Figure 1-4. World Cellular Phone Shipments

trol technology have led to an increase in the number of semiconductors mounted in vehicles.

The use of semiconductors has diversified. Manufacturers must now take the initiative in developing new uses to create their own markets.

3. Long-term Trends in the Semiconductor Market

3.1. The Silicon Cycle and Slowdown in Growth

The semiconductor market has experienced repeated booms and busts in a four- to five-year cycle ("the silicon cycle"). Recent developments indicate that the market stagnated for several years after peaking in 1995, when it recorded a substantial growth of 41.7% over the previous year. Indeed, the silicon cycle is characterized by its volatility: the market surpassed the $200 billion mark for the first time in 2000 because of rapid growth during the IT boom, only to record a substantial drop in the following year (see Figure 1-5).

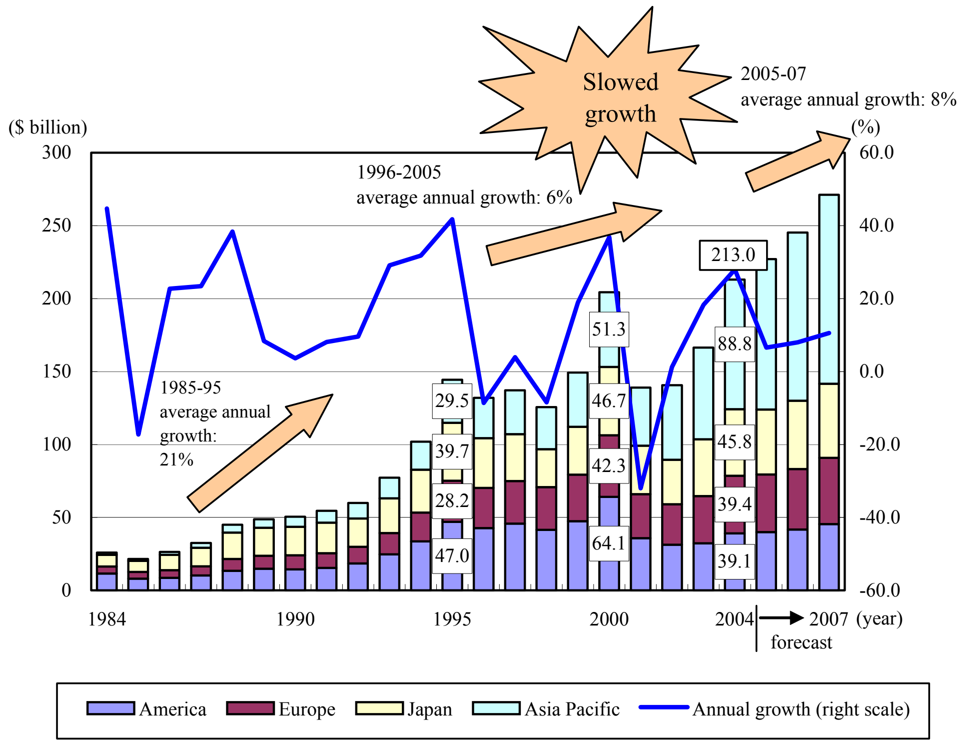
Since the 1980s, the semiconductor market has generally followed an uptrend, with some ups and downs resulting from the silicon cycle. However, growth seems to be leveling off. Looking at the last 20 years, a significant average annual growth of 21.0% in the first 10 years (1985-95) slowed substantially in the latter half (1996-2005) to only 6.2%.

According to the World Semiconductor Trade Statistics (WSTS), the world semiconductor market will continue to grow reaching record highs until 2007, but the annual growth rate will remain single-digit between 2004 and 2007: 8.4% on average. Although the volatility of the silicon cycle will be somewhat subdued, largely due to the diversification of semiconductor use for non-computer purposes, market expansion will be slowed. These developments indicate that competition among manufacturers may intensify further in the years ahead, producing clear winners and losers.

3.2. Market Development by Region: Rapid Growth of the Asian Market

Substantial changes can also be seen in the regional composition of the world semiconductor market. As shown in Figure 1-5, Japan was the world's largest semiconductor market from the mid-1980s to the early 1990s. Then the U.S. took over this position, which it held until 2000. Since 2001, however, the Asia-Pacific region has been the largest semiconductor market, as more production facilities have been transferred to Asian countries. This region's share in the world market is expected to reach 47% in 2007, up from 29% in 2001.

Meanwhile, annual growth of the Japanese market between 2004 and 2007 is expected to be 3.5% on average, which is substantially lower



Source: WSTS (World Semiconductor Trade Statistics)

Figure 1-5. Annual Growth of the World Semiconductor Market and Regional Trends

than the world average (8.4%). The slowdown of the Japanese market, which recorded slightly negative growth in 2005, is particularly remarkable when compared with other regions. This makes it all the more important for Japanese manufacturers to implement marketing strategies that focus on the Asian and Western markets as well as the market at home.

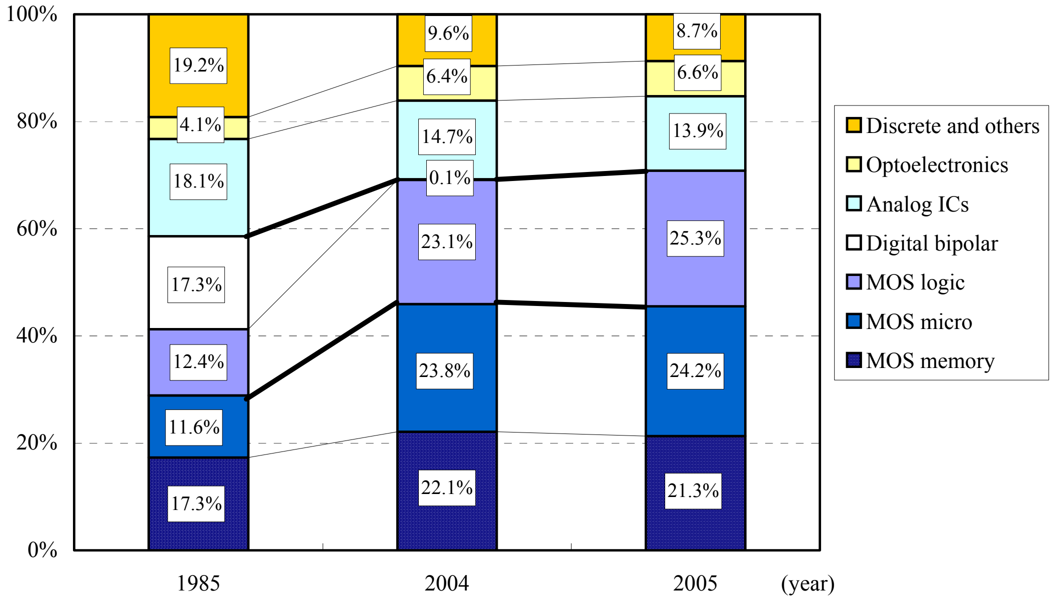
3.3. Market Trends for Major Products: Emergence of MOS Micro and MOS Logic

The semiconductor market expanded more than tenfold from 1985 to 2005, from $21.5 billion to $227.1 billion. What changes in product composition have accompanied this expansion?

Figure 1-6 shows the rapid growth of the MOS micro (MPUs and microcontrollers) and MOS logic markets as bipolar semiconductors have been replaced by MOSs (metal oxide semiconductors). Used widely in computer peripherals, communication equipment and consumer electronics, logic has various processing functions, such as control (including exchange and handling of digital signals) of the system; numeric calculation; logical operation; and comparative judgment. The expansion of these markets may be attributed to a substantial increase in the demand for processors and logic semiconductors, as the multi-functionality and value-added of electronic equipment have improved with the advent of PCs, PDAs and digital consumer electronics.

Meanwhile, the share of MOS memory has stayed in the lower 20% range in recent years after exceeding 30% in the mid-1990s. Memory is a semiconductor device that stores data and programs. Typical memory includes DRAMs, which are used in the main memory of a computer, and flash memory, which is used primarily in memory cards for digital cameras.

Although still insignificant at the global level, the opto-electronics market – CMOS sensors and LEDs, among others – seems to hold promise as it continues to expand steadily.



Notes: 1. 2005 figures are based on the WSTS Autumn 2005 Forecast.
2. For 2005, digital bipolar is included in MOS logic.
3. The products included in MOS micro and MOS logic have changed slightly over the years.

Source: WSTS

Figure 1-6. Trends in the World Semiconductor Market (Year-on-Year Change by Product)

3.4. Market Trends for General-Purpose and Application-Specific Products

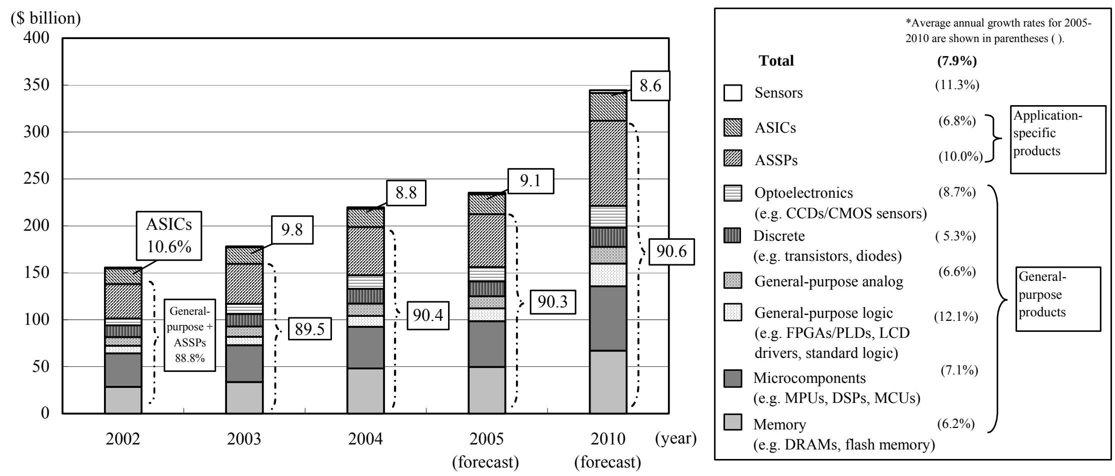
The previous subsection focused on the functions of semiconductors to examine market trends by product. It is also important to analyze the same trends at the level of versatility.

Semiconductors are classified into two main categories, general-purpose products and application-specific products, according to whether they were developed for specific purposes or for applications. The market for typical general-purpose products like MPUs and memory has expanded rapidly since the 1980s with the spread of PCs. From the late 1980s to early 1990s, however, demand increased for the development of semiconductors customized to user specifications, leading to the emergence of application-specific integrated circuits (ASICs). In most cases, the design of an ASIC is integrated into the development of the corresponding set product. This process is known as “design-in.”

Market trends for general-purpose and application-specific products, as shown in Figure 1-7, indicate that general-purpose products – ranging from memory to opto-electronics – represent the volume zone, accounting for two thirds of the semiconductors marketed. Huge markets exist for memory (including flash memory and DRAMs) and for microcomponents (MPUs, MCUs and DSPs) in particular. Most of the world’s leading semiconductor manufacturers are actually winners in those two markets.

Application-specific products are largely classified into ASICs and ASSPs (application-specific standard products). For statistical purposes, an ASIC is defined as a specific product developed for a single client, whereas an ASSP is sold to two or more clients. In 2004, the ASSP market exceeded the ASIC market by a factor of over 2.6. As this significant growth is expected to continue until 2010, ASSPs are now establishing a predominant status over ASICs.

Data indicate that the share of “standard products,” comprising general-purpose products and ASSPs, in the semiconductor market increased from 88.8% in 2002 to 90.4% in 2004. It is expected that general-purpose products and ASSPs will continue to hold more than 90% of



Note: ASICs: application-specific integrated circuits.
ASSPs: application-specific standard products.
FPGAs/PLDs: field programmable gate arrays/programmable logic devices.

Source: Gartner Dataquest (February 2006) GJ06045

Figure 1-7. Trends in the World Semiconductor Market for General-purpose and Application-specific Products

the semiconductor market.

Semiconductors are manufactured by the hundred in the form of wafers upon which circuits are constructed with a mask. Production costs decline if more wafer chips can be manufactured from a single mask (the advantage of scale). Securing an overwhelming market share for a general-purpose product is the best way to ensure profitability in the semiconductor business. Likewise, successful operation in application-specific products depends on standardizing to allow sales to as many customers as possible, rather than clinging to a small number of specific clients. In other words, the success of a semiconductor manufacturer largely depends on it increasing its share in the general-purpose product market and standardizing its application-specific products.

Have Japanese manufacturers been able to sustain their international competitiveness by responding properly to the substantial structural changes described above? We need to answer this question by exploring future strategies. The next chapter examines the current position of Japanese manufacturers in major segments of the industry.

II Analysis of Japanese Manufacturers' International Competitiveness by Major Semiconductor Product Segment

This chapter analyzes the international competitiveness of Japanese manufacturers of major general-purpose and application-specific products. The current position of Japanese manufacturers will be identified with regard to typical general-purpose products including processors, microcontrollers (MCUs), FPGAs/PLDs, memory and analog semiconductors, as well as for the two categories of application-specific products: ASICs and ASSPs.

1. Analysis of Japanese Manufacturers' Competitiveness in General-Purpose Products

1.1. Processors

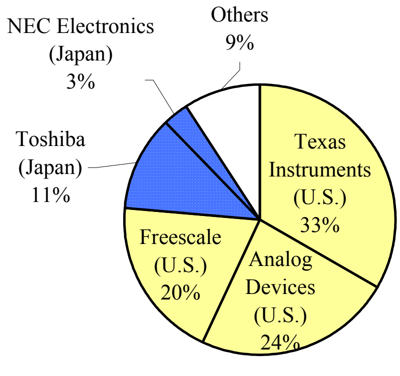
An MPU, a key device in a PC and server, integrates all functions of the central processing unit (CPU) on one chip to execute arithmetic operations and control. The MPU market is virtually duopolized by two U.S. manufacturers, Intel and AMD. Meanwhile, DSPs (digital signal processors) – another type of processor – are mainly used for processing digital signals and moving images in communication equipment, including cellular phones. Again, U.S. manufacturers, led by Texas Instruments (TI), have an overwhelming share of the market, with Japanese companies trailing far behind (see Figure 2-1).

In a processor, logic operation software is embedded in the hardware. Because hardware is used for general purposes, a client may adapt a processor to any specific use by rewriting the software. The performance of a processor thus depends heavily on software development capacity. The superiority of U.S. companies in processor manufacturing may be explained by their excellent software development capacity and a pro-active strategy to protect their software as intellectual property.[2]

Once introduced, a processor requires its own compilers (translation tools for programming languages) and software. Changing processors necessitates a complete rewrite of software. Thus, processors form the core of semiconductors and exert a substantial influence on peripheral products. Indeed, the first processor product to be popularized is likely to dominate all related markets as the *de facto* standard.

1.2. Microcontrollers (MCUs)

A microcontroller is a semiconductor that integrates memory and input-output circuits around the core CPU. These are used in all sorts of electronics, primarily as embedded controllers. Mi-



(World market total: $1 billion)

Source: Gartner Dataquest (April 2005) GJ06046

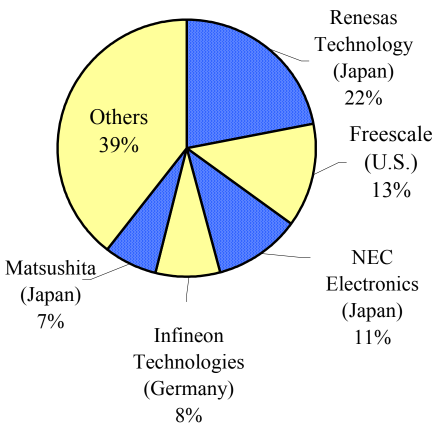
Figure 2-1. Composition of World DSP Market by Manufacturer (2004)

[2] Hiroyuki Itami, Japanese Semiconductor Industry: Why Have the "Three Reversals" Happened? p. 180 et seq.

crocontrollers range from 4-bit and 8-bit products used for the control of remotes, keyboards, mouse devices and white goods, to 16-bit and 32-bit products used in digital consumer electronics, printers and electrical components for automobiles. There is a current shift towards large-bit microcontrollers with the ongoing sophistication of electronics. Microcontrollers for automobiles are in particularly heavy demand as vehicles become increasingly electronically controlled to accommodate such popular features as ABS, air-bags and navigation equipment.

Japanese manufacturers have maintained a competitive edge in microcontrollers. The largest share in world markets belongs to Renesas Technology, established in April 2003 following the merger of the semiconductor operations of Hitachi, Ltd. and Mitsubishi Electric Corporation. Although microcontrollers are less susceptible to market fluctuation than memory, their average unit price is lower than that of other semiconductor products. Figure 2-3 shows the average unit prices of semiconductors manufactured in Japan. On average, the price of flash memory exceeds ¥1,000 per unit. The unit price of DRAM and semi-custom logic has stayed in the ¥400-500 range. In contrast, the price of microcontrollers has not yet reached ¥300 per unit.

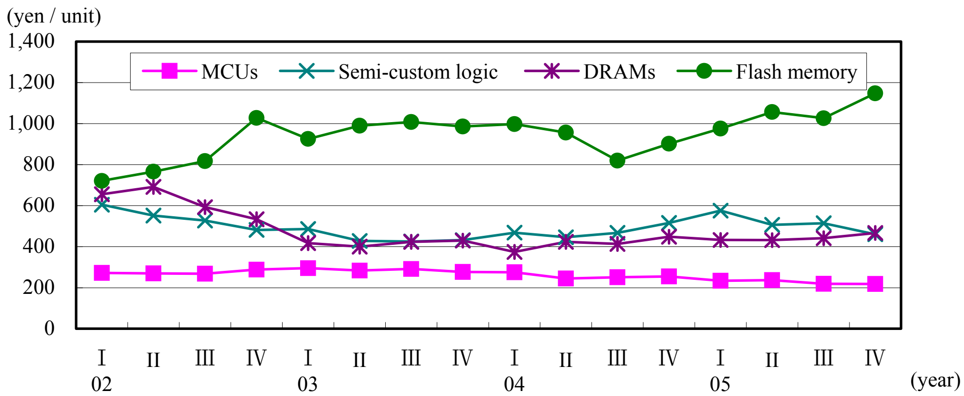
Japanese manufacturers can expect to face serious competition from foreign companies in the years ahead as the latter try to increase their share of the microcontroller market. Major chal-



(World market total: $13.2 billion)

Source: Gartner Dataquest (April 2005) GJ06046

Figure 2-2. Composition of the World MCU Market by Manufacturer (2004)



Source: Ministry of Economy, Trade and Industry, "Preliminary Report on Machinery Statistics."

Figure 2-3. Trends in the Average Unit Prices of Major Semiconductor Products (domestic production)

lenges for microcontroller producers include the introduction of microcontrollers with built-in flash memory to facilitate program re-writing, increased sophistication of CPUs and the enhancement of peripheral functions.

1.3. FPGAs/PLDs

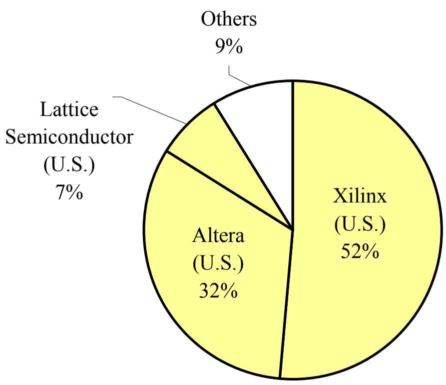
As mentioned earlier, advantages of scale operate in the semiconductor business: production costs are reduced proportionally by the number of wafers processed with a single mask. Increased customer preference for customized products provides a profit opportunity for companies that can develop ASICs in ASSPs and thus increase sales. Another, more technological way, is to develop new chips.

A product called FPL provides an example. FPL stands for field programmable logic. These devices allow users to design various circuits by electrically programming internal circuits. These are also known as a FPGA (field programmable gate array) or PLD (programmable logic device).

Since ASIC circuits are tailor-made for individual clients, mask production usually involves substantial cost and a development period of one to two years. Any last-minute change in design, or any design defect found at the prototyping stage, will entail redesigning the entire circuit. Traditional ASIC manufacturers might miss business opportunities in digital consumer electronics and PDAs as these products have relatively short life cycles and are subject to frequent specification or standard changes.

In contrast, FPGAs/PLDs, which allow users to rewrite circuitries at will, have the flexibility to accommodate eleventh-hour design changes and to speed up development time. Advances in low power consumption and cost reduction in recent years have expanded the use of FPGAs/PLDs from communication equipment and server storage to digital consumer electronics. Although they are somewhat inferior in their degree of integration and processing capacity, manufacturers are attempting to meet this challenge by actively introducing advanced microfabrication processes.

U.S. manufacturers dominate the FPGA/PLD business, with the top two companies, Xilinx and Altera, controlling more than 80% of the market between them (see Figure 2-4). The powerful patents held by these two leading companies have allegedly deterred other major semiconductor manufacturers, including Japanese companies, from making serious efforts to enter this market.[3] Xilinx, Altera and Lattice are all U.S.-based fa-



(World market total: $3.1 billion)

Source: Gartner Dataquest (April 2005) GJ06046

Figure 2-4. Composition of the World FPGA/PLD Market by Manufacturer (2004)

[3] For recent developments in patents related to FPGA/PLD technologies, see Japan Patent Office, "Survey of Patent Applications on Programmable Logic Device Technologies." (http://www.jpo.go.jp/shiryou/pdf/gidou-houkoku/pld.pdf).

bless ventures that were launched in the 1980s. Specializing in product development, they ensure high profits by outsourcing production to foundries. For example, the market leader Xilinx increased its sales by more than 50% between FY2001 and FY2004, from $1,015 million to $1,573 million, with a solid financial standing: an operating margin of 24% and an equity ratio of 88% – both for FY2004.[4]

Faced with this offensive by FPGA/PLD manufacturers, ASIC vendors are trying to stem the tide by introducing a semi-customized product called "structured ASIC." This product aims to reduce the time and cost required for development and verification by adding the customer's original logic circuit to verified design assets (IP). Looking ahead, it is worth considering how far FPGAs/PLDs can affect the ASIC market, which includes products for PDAs and digital consumer electronics.

1.4. Memory

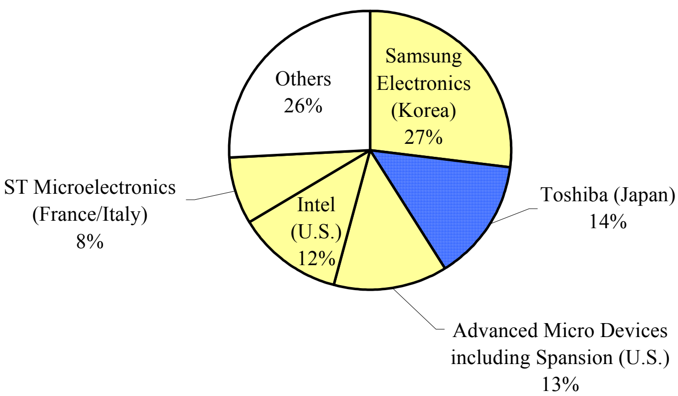
Memory is a typical general-purpose product, along with processors. DRAMs and flash memory comprise significant shares of the memory market.

Japanese manufacturers held an overwhelming share of the DRAM market in the 1980s, but substantial market volatility and huge investment burdens led to successive business consolidations and exits. The market is currently dominated by overseas manufacturers, including Samsung Electronics (Korea), Hynix (Korea) and Micron Technology (U.S.). Elpida Memory is the only Japanese company specializing in DRAMs, supplying products for PDAs and digital consumer electronics in particular.

Unlike DRAMs, which are volatile, flash memory is non-volatile: i.e. it can retain data even when the equipment is turned off. Flash memory is classified into two types: NOR and NAND. With a high writing speed, NOR memory is mainly used for housing programs, whereas NAND memory is suitable for storing large volumes of data.

In addition to its traditional use in memory cards for digital cameras, NAND memory is now being used for new purposes such as portable music players. Moreover, it is increasingly being used in cellular phones, which now require greater data capacity for images and sound. Toshiba reported that the NAND market would exceed ¥1 trillion by the end of FY2005, to be followed by a substantial growth of 28% per annum until FY2008.[5]

Only a handful of manufacturers supply NAND flash memory, with Samsung Electronics,



(World market total: $15.4 billion)

Source: Gartner Dataquest (April 2005) GJ06046

Figure 2-5. Composition of the World Flash Memory Market by Manufacturer (2004)

4 See Xilinx website.

5 Toshiba, materials presented at the briefing on management strategies, August 2005.

Toshiba and SanDisk (U.S.) taking up the lion's share of the market. Reportedly, Samsung Electronics uses the same production lines to manufacture flash memory and DRAM. This enables it to respond flexibly to market fluctuations, producing more flash memory when the DRAM market stagnates and switching back to DRAM production when the flash memory market weakens.

Among Japanese manufacturers, Toshiba is committed to flash memory production, regarding the product as one of its strategic items. Although many of the Japanese manufacturers anticipate reduced sales or profits, or even a deficit for FY2005, Toshiba has revised its semiconductor business profit upwards, buoyed by the strong sales of flash memory. In a joint venture with SanDisk, Toshiba has invested some ¥270 billion to build a new 300mm wafer production facility in its Yokkaichi Plant, to be completed by the end of FY2006. As part of its effort to catch up with the top-ranked Samsung Electronics, the company also launched volume production of flash memory using 90mm processing technology in the second half of 2005.

Companies such as Hynix and ST Microelectronics have already entered the NAND market. Competition is expected to intensify as Intel announced its entry to the market in a joint venture with Micron in late 2005. Since economies of scale will lead directly to profitability in the memory business, each manufacturer is racing to establish an efficient production system by introducing state-of-the-art equipment. Looking ahead, success in the market will depend not only on the yield of new facilities and the capacity of memory, but also on cost competitiveness.

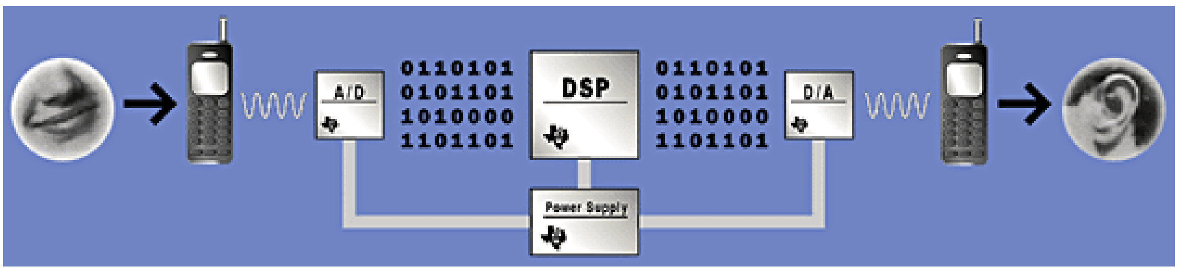
1.5. Analog Semiconductors

While most semiconductors, including processors and memory, perform digital processing using zeros and ones, analog semiconductors use absolute values to control supply voltages or to transform analog signals to digital ones. Typical products include operational amplifiers used to magnify supply voltage and converters used for digital transformation of analog signals, including sound and images. They are indispensable in communication equipment and in digital consumer electronics.

In the case of a cellular phone, for example, the speaker's voice (analog signal) is digitized by an analog IC and transmitted, after being processed (compressed), by a digital signal processor (DSP). On the receiving side, the DSP decompresses (elongates) the signal to restore the original digital signal, which is then transformed into an analog signal by the analog IC to complete the conversation. In this way, high performance processors and analog ICs enable real-time signal processing by performing a series of tasks efficiently and stabilizing the control of supply voltages (see Figure 2-6).

The functioning of analog semiconductors depends on the identification of absolute values including voltage and signal strength. In designing a circuit, care must be taken to minimize external noise, variation and fluctuation that might produce improper operating signals. Although the production process does not necessarily require cutting-edge processing technology, it does require highly atypical circuit design and production processes, with no established simulation techniques. Clearly, much depends on the experience and expertise of individual engineers.

According to Gartner Dataquest, general-purpose semiconductors accounted for 6% of the whole semiconductor market in 2004. This ratio has changed little for several years. No matter how



Source: TI Japan website (http://www.tij.co.jp/jcorp/docs/dsps/index.html).

Figure 2-6. Mechanism of Signal Processing in Cellular Phones

far digitization progresses in electronics, analog-to-digital conversion is always necessary to reproduce sound and images in a form that is perceivable to human beings. Digital equipment always requires analog semiconductors.

The general-purpose analog market is dominated by U.S. manufacturers such as TI, Analog Devices and National Semiconductor, with the top five companies (all U.S. manufacturers) holding almost 60% of the world market (see Figure 2-7). In Japan, some smaller companies have specialized in analog production, including Rohm and New Japan Radio. Major Japanese companies, however, have shifted the focus of their design development and production technologies to digital semiconductors, which they now consider to be their core products. Some argue that the shift has undermined the strength of analog semiconductor manufacturers in Japan.

The progress of digital technology raises the importance of the role to be played by analog technology. For mixed signal products which integrate analog and digital signal processing technologies on one semiconductor, success depends on the availability of engineers who are capable of blending analog and digital technologies. Analog oriented manufacturers, who seek to acquire expertise in digital technology by building on their considerable analog experience, will continue to hold a certain edge even as digitization makes headway.

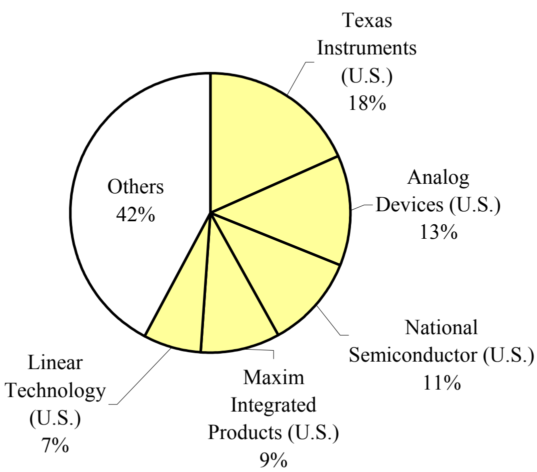
2. Analysis of Japanese Manufacturers' Competitiveness in Application-Specific Products

2.1. ASICs and ASSPs

Although existing general-purpose logic products may be used in set products for data processing and control, this will eventually limit flexibility in customizing a system. The need for customization is increasing in parallel with the sophistication of electronics. In order to secure necessary functions for the differentiation of their products, semiconductor manufacturers have involved themselves in design-ins to develop custom chips in close coordination with their clients.

Raising the customization level ensures a proper response to the different needs of individual clients. However, manufacturing an ever wider variety of products in small quantities might undermine production volume efficiency. Also, increased integration means that more circuits are constructed on one chip, thus necessitating more time and greater cost to develop ASICs and to verify hardware requirements.

Under these circumstances, attention is now focused on ASSPs (application-specific standard products), which, unlike ASICs, are supplied to



(World market total: $13.2 billion)

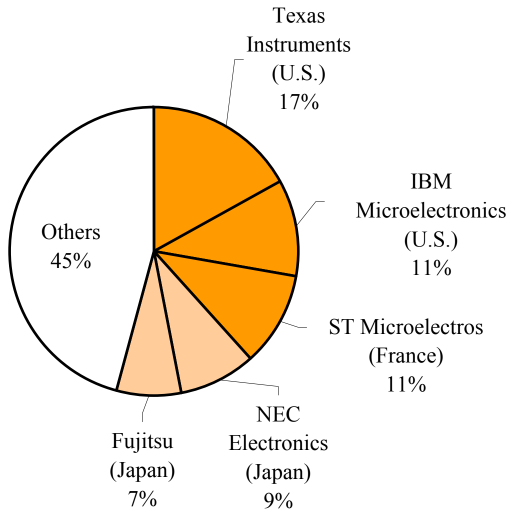
Source: Gartner Dataquest (April 2005) GJ06061

Figure 2-7. Composition of the World General-purpose Analog Market by Manufacturer (2004)

multiple clients. In developing ASSPs to be used for radio communication, image enhancement and automotive control, among others, manufacturers intend selling these to a wide range of clients, ensuring compatibility with as many interfaces and standards as possible. Increasingly, a product originally developed as an ASIC gradually becomes an ASSP as sales widen. Indeed, the ASSP market is growing faster than the ASIC market.

In the ASIC market, Japanese manufacturers hold a decent position compared to such Western companies as TI, IBM and ST Microelectronics (see Figure 2-8). However, in the emerging ASSP market, which already exceeds the ASIC market by over 160%, the largest shares are held by overseas manufacturers including Philips, Intel, Qualcomm, Infineon and TI, with Japanese companies trailing far behind (see Figure 2-9).

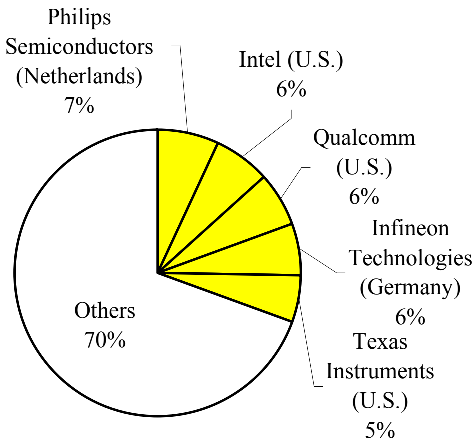
In some cases, Japanese manufacturers actually took an early lead in the development of ASICs for specific clients, but were progressively overtaken by overseas manufacturers as the



(World market total: $19.4 billion)

Source: Gartner Dataquest (April 2005) GJ06046

Figure 2-8. Composition of the World ASIC Market by Manufacturer (2004)



(World market total: $51.5 billion)

Source: Gartner Dataquest (April 2005) GJ06046

Figure 2-9. Composition of the World ASSP Market by Manufacturer (2004)

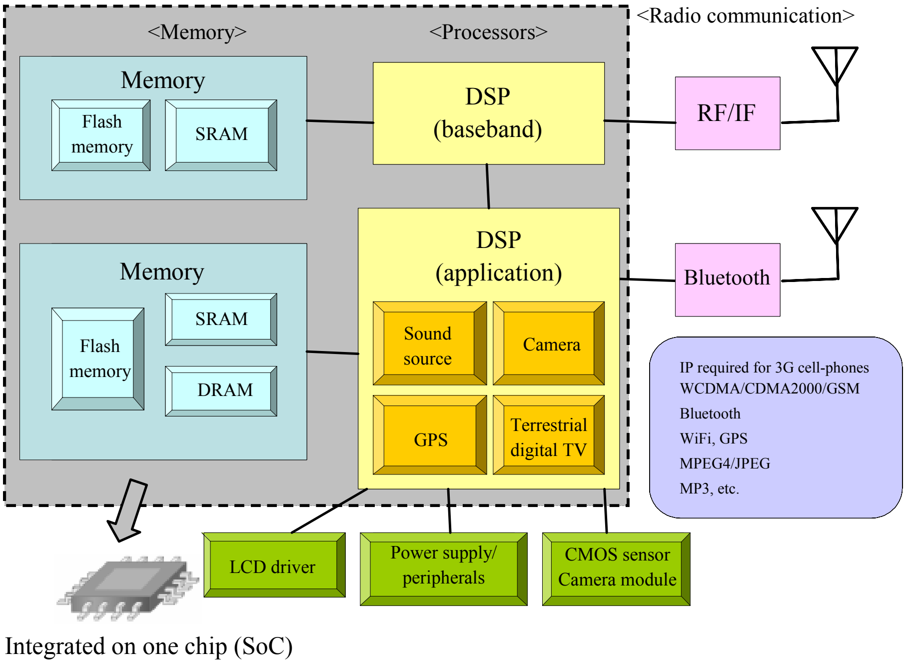
ASICs turned into ASSPs through generalized use and volume production. Thus, Japanese manufacturers need to develop their own approach to the application-specific product business.

2.2. SoCs (System LSIs)

Among application-specific products, special attention is focusing on SoCs (systems on chips: system LSIs). Gartner Dataquest defines a SoC as an ASIC or ASSP that integrates one or more computer engines, such as ARM, MIPS, a DSP core or a graphic engine, in addition to memory and logic. Although most ASICs and ASSPs contain memory and logic, SoCs are different in that they also integrate one or more computer engines.[6]

Commercialization of an LSI like SoC owes much to the progression of semiconductor circuit miniaturization from 130nm to 90nm and then to 65nm, effectively allowing a chip to integrate numerous semiconductor devices. By integrating all the devices that were traditionally combined on a substrate on one chip, SoCs are contributing to downsizing, improved performance, power saving and cost reduction. In expectation of a further expansion of the SoC market, semiconductor manufacturers are strategically concentrating their investment and R&D resources on SoCs, regarding the product as a core device for digital consumer electronics and portable communication equipment.

So, what kind of chip is it exactly? A SoC integrates all, or a major part, of the system in an electronic product. Let's take an example of a SoC used in a third-generation (3G) cellular phone (see Figure 2-10). When cellular phones were used mainly for voice communication, most of them were equipped with a baseband processor. With the development of camera phones in recent years, various applications have been attached to cellular phones including music distribution, global positioning system (GPS) and TV. Due to this sophistication, most portable termi-



Sources: Interviews and various data.

Figure 2-10. Typical Composition of SoC for 3G Cellular Phones

[6] Gartner, "SoC Market is Set for Years of Growth in the Mainstream," Bryan Lewis, 17 October 2005, GJ06073.

nals are now equipped with an application control processor in addition to the traditional baseband processor. Moreover, further needs for downsizing, higher performance, cost reduction and power saving have initiated a trend to integrating the whole system, including processors and memory, on a single SoC.

Thus, most functions of electronic products, including cellular phones and digital consumer electronics, are already being performed by core semiconductors. These chips require intellectual property protection of the technologies underlying moving and still images, voice compression and radio techniques. In this sense, the value of a product now depends on the quality of the embedded IP.

SoC production entails large-scale business investments to introduce cutting-edge microfabrication processes. Among major Japanese companies, Toshiba invested ¥200 billion to build a 300mm wafer[7] production line at its Oita plant, introducing a leading-edge 65nm processing technique. The production line became operational in the autumn of 2004. Other manufacturers are following suit. Fujitsu announced that it would build a 300mm wafer fab for volume production of logic LSI in Tado, Mie Prefecture. Total investment in the fab, which is equipped with two lines for 90nm and 65nm processing, amounted to ¥280 billion. NEC Electronics also constructed a new facility in Tsuruoka, Yamagata Prefecture to produce LSI chips for digital consumer electronics and high-end computers. Investment is clearly accelerating in the construction and expansion of 300mm wafer SoC lines.

Profits from such SoC operations seem to be insignificant so far. This is partly due to the huge initial investment in state-of-the-art processes that has resulted in considerable depreciation

Table 2-1. Trends in 300mm Wafer SoC Investment of Major Domestic Manufacturers

Company	Plan announced in	Plant	Description	Amount	Operational in
Fujitsu	March 2004	Mie (1st wing)	Construction of a 90nm processing facility for volume production of logic LSI: capacity of 15,000 chips/month (to be realized by the end of FY2006)	¥160 billion	April 2005
	January 2006	Mie (2nd wing)	Construction of a 65nm processing facility for volume production of logic LSI: capacity of 10,000 chips/month (to be realized by the end of FY2007)	¥120 billion	April 2007
Toshiba	April 2003	Oita	Construction of a new 65nm processing production facility for leading-edge system LSI: capacity of 12,500 chips/month	¥200 billion	Autumn 2004
NEC Electronics	November 2003	Yamagata	Construction of a new 130-90nm processing production line for system LSI: capacity of 11,000 chips/month (to be realized by mid-FY2006): primary focus on system LSI for cellular phones and digital consumer electronics	¥80 billion	End 2004
Sony	April 2003	Isahaya, etc.	Introduction of a 65nm processing semiconductor facilities: production of system LSI including a next-generation general-purpose processor (CELL): capacity of 15,000 chips/month	¥200 billion (FY2003-2005)	2005
Matsushita Electric Industrial	June 2004	Uozu	Construction of a new wing for 65nm processing: production of system LSI required for DVD, digital TV, mobile communications, networks, image sensors, etc. Capacity of 6,500 chips/month	¥130 billion	October 2005

Sources: Company websites

[7] The total silicon surface area of a 300mm wafer is 225%, or more than twice that of a 200mm wafer, and the number of computer chips is increased by 240%. Using 300mm manufacturing technology consumes 40 percent less energy and water per chip than a 200mm wafer factory. According to industry experts, bigger wafers lead to a spectacular increase in chip production while diminishing the cost of manufacturing (see Intel website).

expenses. Additionally, the retail prices of final products such as digital consumer electronics have been falling faster than expected, negatively affecting profits by exerting downward pressure on the price of SoCs which were originally intended as a high value-added product.

SoCs require substantial development cost as most are custom made for a particular client. At the same time, the life cycle of electronic products is becoming shorter. For a SoC developed with a substantial number of man hours, a return on investment will be hard to achieve if the final product fails to find a market. Although many Japanese manufacturers have turned to special-purpose ASICs as a means of financial survival, they have not always been successful in turning their efforts into profits. Immediate measures should be taken in the SoC industry to prevent history from repeating itself.

This chapter has analyzed the competitive advantage of Japanese manufacturers in major general-purpose and application-specific products. The result indicates that they are trailing further behind overseas competitors, as they have been unsuccessful in increasing their share of general-purpose markets and in standardizing application-specific products. The challenge facing Japanese manufacturers of improving profitability in application-specific businesses should also be a major issue for overseas companies. In reflecting on policies to reactivate the Japanese semiconductor industry, it is essential to understand, from a global perspective, how overseas manufacturers are trying to develop their own application-specific businesses.

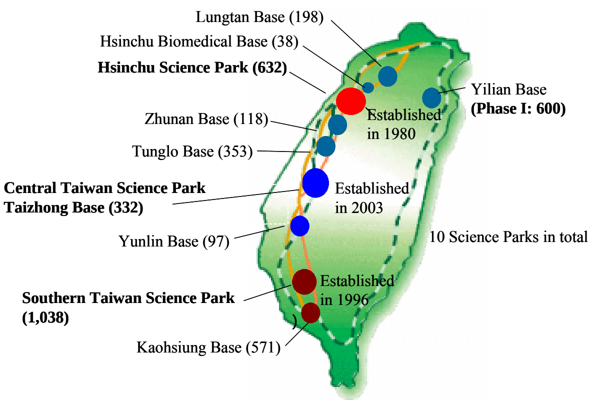
In this regard, we conducted a field survey on the Taiwanese semiconductor industry, which has experienced significant growth in recent years. By comparing the strategies of Taiwanese and other foreign manufacturers, the following chapters try to identify current conditions and future challenges that face the Japanese semiconductor industry.

III Taiwanese Semiconductor Industry on the Move: Business Model of Vertical Specialization

1. Concentration of the Semiconductor Industry in Hsinchu Science Park

Taiwan has three Science Parks: Hsinchu Science Park in the north (established in 1980), Central Taiwan Science Park (2003) and Southern Taiwan Science Park (1996).[8] Of these, the Hsinchu Science Park is considered to be the Taiwanese version of Silicon Valley. With an area of 632ha, the Hsinchu park accommodates large-scale fabs (factories) and research facilities for 384 enterprises (as of December 2004). By industry, 164 companies – over 40% of the total – are semiconductor manufacturers, followed by 61 opto-electronic companies, 58 computer/peripheral device manufacturers and 52 communication companies. Thus, the Science Park constitutes a major hub of electronic industries, with semiconductor devices at the core (see Figure 3-1 and Table 3-1).

The Hsinchu Science Park is administered by the Science Park Administration, placed under the direct control of the Executive Yuan. Since its inception in 1980, a total of $1.68 billion (about ¥200 billion) has been invested in infrastructure and facility development. The Industrial Technology Research Institute (ITRI), located near the Science Park, not only facilitates research in leading-edge technologies and technology transfer to private enterprises, but also provides financial support, having invested in



Note: Area is in parentheses (ha).
Source: Science Park Administration

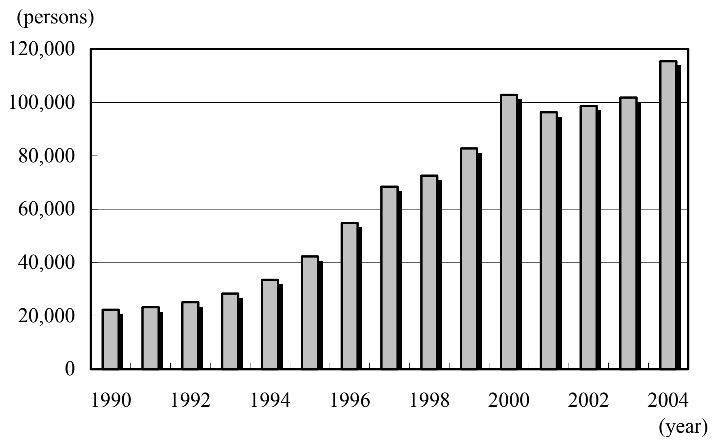
Figure 3-1: Science Parks in Taiwan (including those under consideration)

Table 3-1. Companies in Hsinchu Science Park by Industry (as of December 2004)

	No. of companies	No. of employees	Sales ($ million)	Change in sales from previous year (%)
Integrated circuits	164	66,467	22,309	32
PCs/peripherals	58	14,268	4,147	3
Communications	52	7,258	1,816	10
Optoelectronics	61	24,932	3,927	39
Precision machinery	21	1,529	277	60
Biotechnology	28	1,023	76	39
Total	384	115,477	32,552	27

Source: Science Park Administration

[8] Including those under construction or consideration, 10 Science Parks will be constructed in total.



Source: Science Park Administration

Figure 3-2. Number of Employees in Hsinchu Science Park

more than 40 companies operating in the Park.

As shown in Figure 3-2, the number of employees of the Science Park has grown rapidly since the mid-1990s to reach a present level of 115,000. This number includes more than 4,000 who, having studied abroad, went on to create 116 enterprises over the 24 years since the opening of the Science Park. Indeed, people who have studied abroad or returned from Silicon Valley have played a key role in the development of the Taiwanese semiconductor industry.

Generous public support measures are available to the companies operating in the Science Park. In addition to exemption from business income tax (at a maximum rate of 25%), they can obtain loans from the Chao Tung Bank, a public financial institution, with interest reductions of 2.15 to 2.5%. They are also exempt from import and freight taxes when importing semiconductor manufacturing equipment, and from business tax when exporting processed goods. An R&D grant of some 5 million Yuan (¥17.5 million) is also provided to projects that qualify. It appears that these support measures are all the more effective because they are implemented in conjunction with other measures such as technology transfer, human resource development and the provision of infrastructure to facilitate partnerships between SMEs, which are very common in Taiwan. Moreover, Taiwan has made the development of its semiconductor industry a clear priority. It is easy to understand why such close collaboration between industry, government and academia has contributed substantially to the growth of the Taiwanese semiconductor industry.

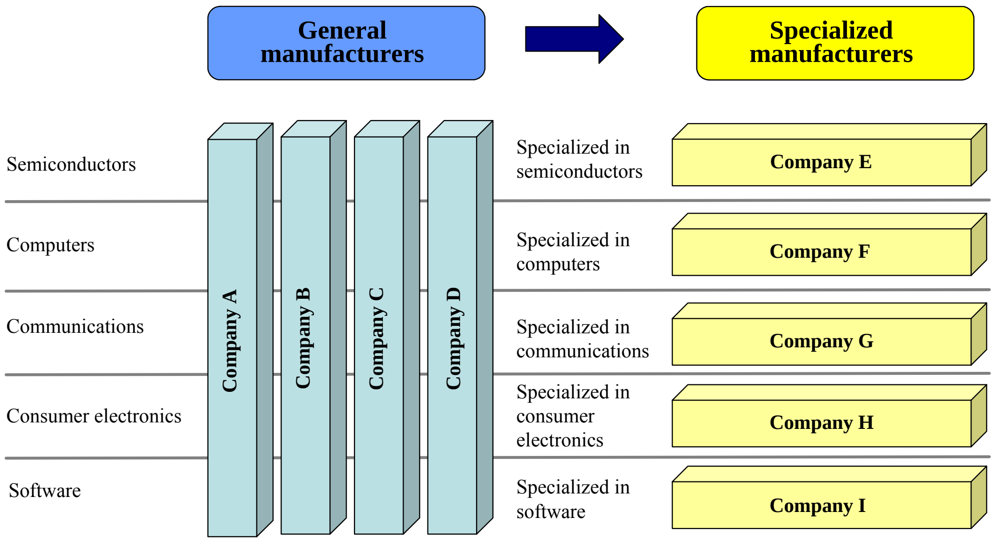
In Taiwan, as in many developed countries, volume production facilities have been transferred overseas in recent years mainly due to concerns about production cost. Under these circumstances, an increasing number of manufacturers are making design the core of their operations. The Science Park Administration also envisages measures to attract more R&D-oriented enterprises, including fabless companies.

2. Taiwanese Semiconductor Industry: Development of the Business model of Vertical Specialization

2.1. Two Business Models in the Semiconductor Industry

Two types of business model exist in the semiconductor industry: integrated device manufacturers (IDMs), which deal in the whole manufacturing cycle, ranging from upstream logic/circuit design to downstream production processes, and companies specializing in either the upstream or downstream segment.

Most of the major Japanese semiconductor manufacturers are IDMs. Moreover, many of them function as part of a general electronics manufacturer. Each of the Japanese general electronics manufacturers is a group with diverse business interests ranging from computers, communication equipment, white goods and AV



Source: Japan Electronics and Information Technology Industries Association, "IC Guidebook."

Figure 3-3. Business Models: General Electronics Manufacturers and Specialized Companies

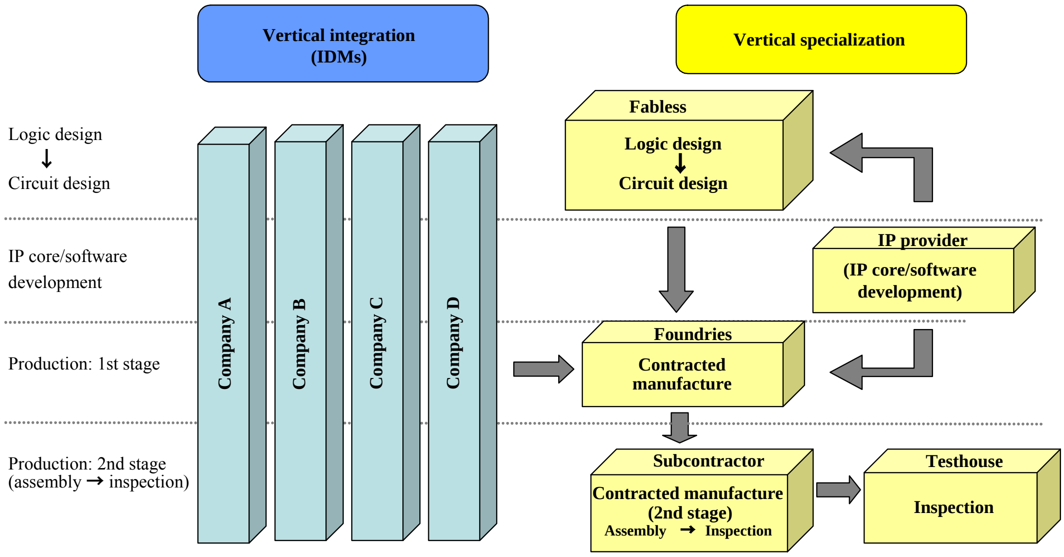
equipment to system development. Within a group, the semiconductor department has traditionally developed semiconductors for the group's set products (internal sales). In contrast, most of the major foreign manufacturers, including Intel and TI, have specialized in semiconductors. Other companies, such as IBM and Qualcomm, have also narrowed down their core businesses to a considerable extent, specializing in computers and semiconductors, or in communications and semiconductors (see Figure 3-3).

Major Japanese manufacturers tend to have full lineups in their semiconductor departments, ranging from memory and microcontrollers to analog and discrete devices. Meanwhile, successful overseas manufacturers are concentrating their managerial resources on specific products: Korean manufacturers are still focusing on memory as they expand their activities, while U.S. manufacturers retain overwhelming market shares in key products such as processors and FPGAs/PLDs.

Most Taiwanese companies, which are relative newcomers in the market compared to U.S. and Japanese manufacturers, have specialized in specific areas through vertical integration, rather than covering the entire business process from design to in-house production. In particular, Taiwanese companies specializing in manufacture under contract (foundries) have established global partnerships with fabless ventures in Silicon Valley which specialize in design, achieving significant growth through the synergy effect gained from this division of labor (see Figure 3-4). The business model of "vertical integration," which emerged very rapidly in the 1990s, has brought about radical changes in the world semiconductor industry.[9]

Taiwan is also a global hub of PC and peripheral manufacturing under contract. In a sense, the existence of PC and other supply chains provided a growth opportunity for the numerous Taiwanese SMEs, eventually consolidating the system of specialization and interdependence. The development of a unique business model, completely different from the traditional IDMs, may be attributed to their effort to overcome the constraints of market size in Taiwan by building interdependent relationships in a framework of international specialization.

[9] In the vertical integration model, the relationship between fabless companies and foundries differs from the simple specialization scheme of "specialization in design/contracted manufacture." It should be noted that fabless companies and foundries are deepening their relationship throughout the vertical business flow beginning with design and ending with product output. As will be described later, fabless companies and foundries are seeking to enhance their complementary relationship. This type of close partnership may be described as "virtual integration based on specialization."



Note: IDMs: integrated device manufacturers.
Sources: Japan Electronics and Information Technology Industries Association, "IC Guidebook;" interviews.

Figure 3-4. Vertical Integration and Vertical Specialization Business Models

2.2. Business Flow in a Vertical Specialization Model

Typically, a vertical specialization model adopts the following business flow. First, a fabless company, at the request of an end user, designs and develops a semiconductor that meets the needs of the client. Once the design is completed, the fabless company sends the design data to a foundry to outsource production. The foundry usually executes the earlier production processes in its own fab, but outsources assembly and inspection to a subcontractor or testhouse.

In the world of semiconductors, functional circuit blocks and software are referred to as intellectual property (IP). Thus, companies that specialize in the development and external sales of IP are known as "IP providers." In the vertical specialization model, they design semiconductors by combining the IP developed by fabless companies with those retained by clients. If any prevailing IP serves as a *de facto* standard, however, its use requires licensing from the provider.

2.3. Vertical Specialization Structure in the Taiwanese Semiconductor Industry

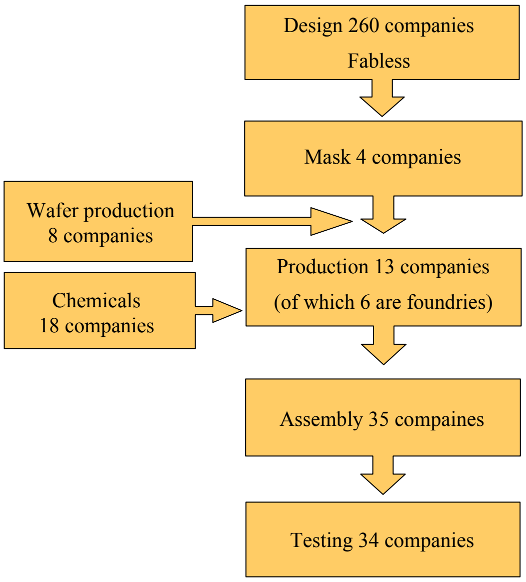
Figure 3-5 shows the structure of the semiconductor industry in Taiwan. Needless to say, Taiwan has an advantage in the production department, where foundries play a key role. Many manufacturers that specialize in the later production processes of assembly and testing are also operating under contract for a wide range of overseas clients.

It should be noted that Taiwanese fabless companies have been growing very rapidly in recent years. As of 2004, Taiwan had 260 fabless companies, an increase of more than 80% from the 140 companies that existed in 2000.[10] Thus, Taiwanese companies are increasingly making their presence felt, in upstream design as well as downstream production.[11]

The composition of sales by business category verifies this trend. Taiwanese foundries' sales amount to $11.9 billion (2004), of which the leading company TSMC (Taiwan Semiconductor Manufacturing Company) accounts for $7.7 billion. Although the figure does not reach the level of Samsung Electronics ($17.3 billion) or of TI ($10.9 billion), it is comparable to the sales figures of major Japanese semiconductor manufacturers.

Non-foundry manufacturer sales figures have almost reached those of foundries ($11.2 billion). Although these statistics include DRAM

[10] Industrial Technology Research Institute, "Semiconductor Industry Yearbook 2005."
[11] Taiwanese fabless companies will be described in detail later in this chapter.



Source: Industrial Technology Research Institute, "Semiconductor Industry Yearbook 2005."

Figure 3-5. Structure of Vertical Specialization in Taiwanese Semiconductor Industry

Table 3-2. Sales of Taiwanese Foundries (2004)

Company	Sales ($100 million)
TSMC	77
UMC	35
Others	7
Total	119

Source: Gartner Dataquest (May 2005) GJ06003

Table 3-3. Sales of Major Taiwanese Semiconductor Manufacturers (excluding foundries: 2004)

Company	Sales ($100 million)
Nanya Technology	12
Media Tek	12
Powerchip Semiconductor	11
Others	77
Total	112

Source: Gartner Dataquest (May 2005) GJ06003

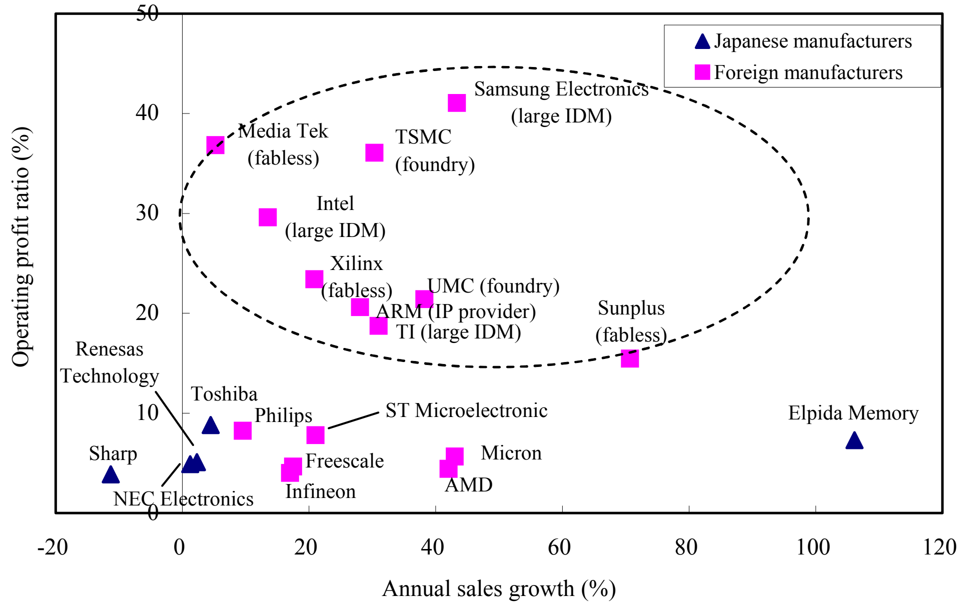
manufacturers, leading fabless companies already have total sales figures comparable to major DRAM manufacturers. This points to the spectacular surge of fabless companies in Taiwan.

2.4. Comparison of Profitability between Japanese and Overseas Manufacturers

The increased presence of Taiwanese manufacturers is clear, not only in terms of their sheer scale, but also in terms of their strong earning power.

According to the World Semiconductor Trade Statistics (WSTS), the world semiconductor market grew by 28% from the previous year to reach $213 billion in 2004, hitting a new record high over the previous peak of $204.4 billion in 2002, at the height of the IT bubble. Annual market growth almost reached the previous high recorded in 2000. The boom in the world semiconductor market may be explained by new uses for semiconductors in fields like digital consumer electronics and automobiles, in addition to existing uses in PCs and cellular phones.

Against this backdrop, a substantial gap in earning power has emerged between major Japanese and overseas semiconductor manufacturers. To compare the performance of major Japanese and foreign manufacturers in FY2004, Figure 3-6 plots annual sales growth and operating profit ratio for the two categories. High operating profit ratios were attained by Intel (29.6%),



Note: Financial year ends in March for Japanese manufacturers and in December for foreign manufacturers except for Micron (August) and Infineon (September).

Sources: The Semiconductor Industry News; corporate closing statements.

Figure 3-6. Earning Power of Major Domestic and Foreign Semiconductor Manufacturers (FY2004)

TI (18.7%) and Samsung Electronics (41.1%), among others. These companies also recorded a healthy sales growth. Taiwanese manufacturers also achieved high operating profit ratios: 36.1% for SMC, 21.4% for United Microelectronics Corporation (UMC), and 36.8% for fabless Media Tek. In comparison, sales growth for most of the Japanese manufacturers stayed far below the overall average. Their sub-par performance is also apparent in single-digit operating profit ratios.

Highly profitable manufacturers may be grouped into the following four categories:

1) Leading IDMs (Samsung Electronics, Intel, TI)
2) Foundries (TSMC, UMC)
3) Fabless companies (Xilinx, etc.)
4) IP providers (ARM, etc.)

Among IDMs, only the top three companies are reaping high profits. They seem to be enjoying the advantage of scale by maintaining an overwhelming market share in their core products. In comparison, other IDMs have clearly fallen behind the top group in terms of profitability. This second-tier group includes European IDMs like Infineon and Philips, as well as Japanese manufacturers, who are all struggling to make respectable profits. This trend continued well into FY2005.

In the final analysis, overseas manufacturers have seized market expansion opportunities to improve their performance by responding quickly to the new business model of vertical specialization, while Japanese manufacturers have failed to capitalize on emerging business opportunities. If this trend continues, Japanese manufacturers could be left further behind in the years ahead.

3. Factors behind the Emergence of a Vertical Specialization Business Model

The vertical specialization model which has changed the semiconductor industry was born out of the industry's structural metamorphosis. In the late 1980s and early 1990s, application-specific products gradually took center stage from the once-mighty DRAM. Key differentiation factors for application-specific products included techniques to design logical and efficient circuits in shorter time periods, as well as production process technologies like microfabrication and yields. As a result, most of the added value was created in the design department, prompting successive design venture startups, particularly in Silicon Valley.

In the meantime, widespread use of electronic design automation (EDA) tools, which automate the plotting of transistor configuration and wiring on silicon boards, enabled logic designers, who were not silicon specialists, to design circuit layouts. This also boosted the separation and independence of the design and production departments. Market entry became easier as process development expertise, traditionally accumulated in-house by semiconductor manufacturers, was integrated into manufacturing equipment. It became possible to manufacture semiconductors just by procuring technologically advanced equipment.

Among the first to detect these changes in the semiconductor industry was Morris Chang, who founded the world's first foundry, TSMC, in 1987. He thought that talented designers were likely to start up their own fabless companies, now that anyone could launch a semiconductor business without a sizable initial investment by specializing in design. He saw a golden opportunity in the foundry business, operating under contract to the potentially thriving fabless sector.[12] Preoccupied with their own brands, IDMs at that time could not partner with fabless ventures.

Fabless companies find it difficult to outsource production to IDMs, which, with their own design departments, could become direct competitors. The advent of foundries provided them with trustworthy partners. Thus, fabless companies began to develop in tandem with foundries acting as their subsidiaries. This relationship created a win-win situation: the growth of foundries expanded the scope of activities for fabless companies and IP providers, which in turn brought further growth to foundries.

Even a venture business, without production facilities, could commercialize self-developed semiconductors with the help of a foundry. It could even exert substantial influence on the semiconductor industry if its superiority was recognized. In the 1990s, innovative semiconductor ventures in Silicon Valley established a business practice of supplying their original products to the market while contracting out the production to foundries. Xilinx and Altera, global leaders in the FPGA/PLD market, are two such Silicon Valley ventures which have grown into world-class fabless companies. Vertical specialization has freed semiconductor manufacturers from the risk of business investment and has encouraged new entries.

Today, it is increasingly difficult for corporate managers to grasp the entire scope of the semiconductor industry, and make unerring business judgments, unless they are particularly well-informed about the nature of the business. Specializing in specific fields such as design, development of core IP, wafer production, packaging and testing allows companies to make prompt business judgments from a professional viewpoint. This may also serve to encourage a division of labor.

A substantial degree of coordination between design and production is required in the semiconductor industry. In order to compete with IDMs, which retain both functions in-house, companies specializing in design or production seek to adopt a comprehensive approach within the framework of a vertical specialization model by establishing complementary relationships while sharpening their own business focus.

4. Increased Presence of Taiwanese Manufacturers in the World Semiconductor Market

This chapter identifies the position of Taiwanese manufacturers in the world semiconductor market.

4.1. Foundries

Worldwide foundry sales totaled $18.7 billion in 2004. This figure has almost doubled since 2001, driven by the growth of fabless companies. Foundries are reported to produce one quarter of the world's semiconductors on a sales basis.[13]

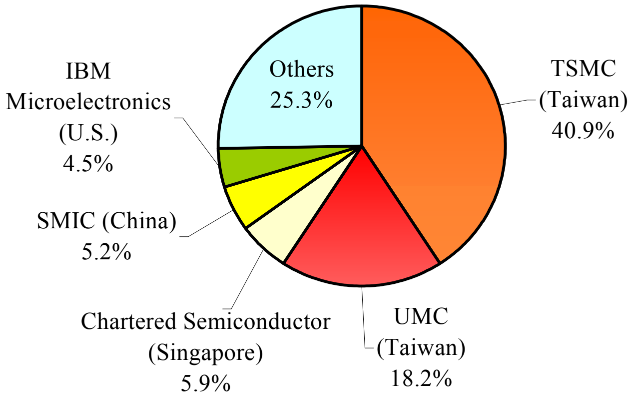
[12] See Wu (2004), p.76 for developments leading to the establishment of TSMC.

[13] Gartner Dataquest, "Foundries Enhance the Semiconductor Value Chain," James F. Hines, April 27, 2005, GJ06062.

TSMC holds an overwhelming share in the world market, followed by UMC, Chartered Semiconductor (Singapore) and Semiconductor Manufacturing International Corporation (SMIC: China) (see Figure 3-7). The basic strategy of a foundry is to maintain competitiveness by concentrating managerial resources on production to increase capacity and to use economies of scale for cost reduction. Both TSMC and UMC have high ratios of business investment to sales (some 30-40% in 2004), attesting to the foundries' commitment to maximize economies of scale.

4.2. Assembly under Contract

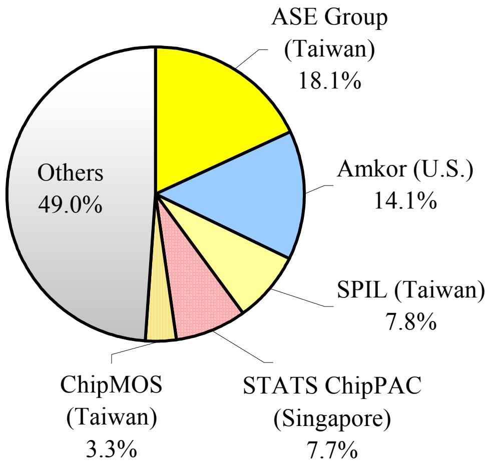
Most foundries focus their activities on the initial processes, outsourcing the later processes and testing. The contracted assemblers, also known as "subcontractors," are mainly located in Asia. Three of the five world-leading subcontractors are in Taiwan: Advanced Semiconductor Engineering (ASE), Siliconware Precision Industries (SPIL) and ChipMOS. Those specializing in the testing process, known as "testhouses," are also located in Taiwan for the most part.



(Total: $18.7 billion)

Source: Gartner Dataquest (October 2005) GJ05446

Figure 3-7. Composition of World Foundry Sales by Manufacturer (2004)



(Total: $13.5 billion)

Source: Gartner Dataquest (October 2005) GJ05446

Figure 3-8. Composition of World Assembly/Testing Subcontract Market by Manufacturer (2004)

The labor cost ratio is considered to be higher in the later processes than in the increasingly unmanned initial ones. AEA, the leading subcontractor, has a workforce of 34,000.[14] For this reason, even IDMs have traditionally outsourced wafer testing, packaging and final testing. In recent years, some manufacturers have outsourced the later processes in an effort to restructure their production system. For example, NEC Electronics sold its NEC Yamagata's Takahata plant to the ASE Group in 2004, in line with its stated policy to outsource the production of general-purpose products.

Foundries that used to receive orders primarily from fabless companies are increasingly involved in production under contract with IDMs. In the case of TSMC, orders from IDMs account for 28% of total production.[15] Some IDMs are actually adopting the "fab-lite" strategy, using their own fabs in parallel with foundries. This business model is expanding because it reduces the investment burden yet maintains a flexible production capacity.

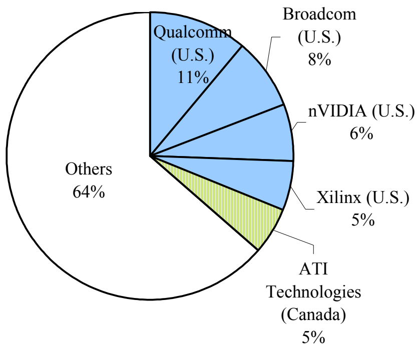
4.3. Fabless Companies

Being specialists in design and development, fabless companies do not have their own production facilities: production is contracted out to foundries. Many ventures enter the fabless market as they do not need huge amounts of initial capital to do so. Indeed, fabless companies form a major colony in Silicon Valley.

The market leader Qualcomm has developed CDMA technology, currently a global communication standard for cellular phones. The company also designs and markets *de facto* standard products using this technology. nVIDIA and ATI Technologies (Canada) excel in graphics processors (GPUs), while Xilinx has the edge in FPGAs/PLDs. Most fabless companies concentrate resources on their core business area and retain an overwhelming share in a specific market, making effective use of the *de facto* strategy and partnerships.

Recently, fabless companies have been showing spectacular growth in Taiwan. The number of fabless companies has increased from 160 in 2000 to 260 in 2004. On the back of significant improvements in design skills, substantial sales growth has been recorded by companies such as Media Tek, VIA Technologies and Sunplus Technology.

The distribution of clients for Taiwanese fabless companies indicates that their share of Taiwanese clients dropped from 59% in 2000 to 37% in 2004, while that of Chinese clients soared from 22% to 55%.[16] As production bases continue to be transferred overseas, Taiwanese



(Total: $29.1 billion)

Source: Gartner Dataquest (April 2005) GJ05447

Figure 3-9. Composition of World Fabless Sales by Manufacturer (2004)

14 According to the ASE website.
15 Actual figure for Q4 2005 according to the TSMC website.
16 Industrial Technology Research Institute, "Semiconductor Industry Yearbook 2005."

fabless companies seem to have achieved sustainable growth by securing the fast-emerging Chinese electronics industry.

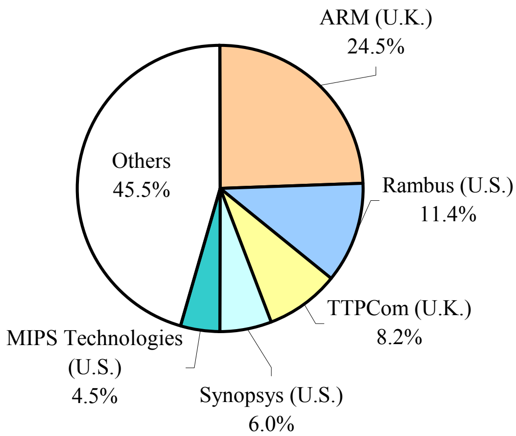
4.4. IP Providers

Semiconductor manufacturers develop the IP required for differentiating performance or functions in-house, but procure *de facto* standard IP from external sources to reduce development periods and costs. “IP providers” develop the design assets (IP) that form the core of semiconductors and provide licenses to semiconductor manufacturers. Since IP is legally protected, semiconductor manufacturers enter into contracts with companies that own the IP and pay licensing fees.

IDMs have accumulated numerous chip designs and IP in-house. Some even do without any third-party IP and develop their own products. However, leading IP providers issue IP licenses to IDMs as well as to fabless companies. Apparently, IDMs have come to think that from the time-to-market perspective, self-development of all products is not worth the substantial costs and time required.

Sales of semiconductor IP (to third parties) totaled $1.3 billion in 2004, up 21% from the previous year. In particular, substantial needs exist for IP related to the processor core; this is predominantly provided by ARM (U.K.) and MIPS Technologies (U.S.). As described in Chapter II, a processor, once introduced, requires its own compiler and software. The first product to be popularized is likely to become the *de facto* standard. Indeed, processors form the core of semiconductors, exerting a substantial influence on peripheral products. Failure to integrate IP that meets the *de facto* standard on a semiconductor might eventually inhibit sales of the set product. For example, ARM has set the *de facto* standard for power-saving processor cores, currently used in a wide range of products including cellular phones. Elsewhere, the need for interface IP is also growing as interconnection via networks gains importance.

IP providers are under heavy pressure as their businesses will not be viable unless they acquire partners to spread their IP. The success of an IP provider depends on the development of IP that can lead the pack in performance and provide a proper support structure for building partnerships and ensuring market penetration on a global scale. Without full logistic support for setting a global standard, including software and the design environment, no IP will stand the test of time and hence, no asset value can be expected from it.



Source: Gartner Dataquest (October 2005) GJ05446

Figure 3-10. World Sales of IP Providers (2004)

So far, Western IP providers have dominated the market, and no Asian companies, including those in Taiwan, are in a position to catch up. Taiwanese manufacturers are trying to compensate for their weakness in IP by making the most of the international specialization model, sourcing top-level IP from all corners of the earth. Enhancement of skills in semiconductor design and IP development is also pursued through industry-academia-government collaboration, including efforts to develop human resources and improve the design environment in universities.

IV Response of the Taiwanese Semiconductor Industry to the SoC Business: Enhanced Partnerships between Fabless Companies and Foundries

The previous chapter provided an overview of the Taiwanese semiconductor industry, which has achieved spectacular growth using the vertical specialization business model. The strengths of Taiwanese foundries include: (1) cost competitiveness, (2) quality service, (3) leading-edge technology, (4) broad product lineups and (5) provision of IP libraries. In addition, Taiwanese fabless companies have also been growing rapidly, gaining recognition as new outsourcing partners for semiconductor design.

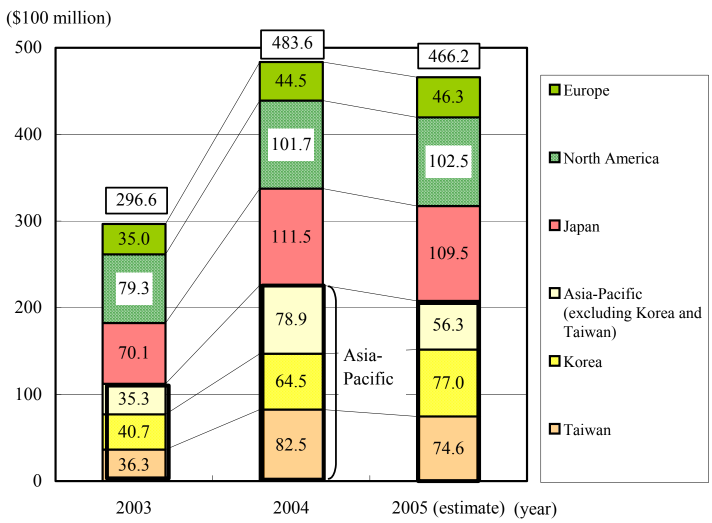
With the progress of semiconductor miniaturization to the nano-level, collaboration between the design and production departments has become increasingly important in recent years to solve problems resulting from the integration of multiple functions on one chip. Against this backdrop, foundries are taking various steps to evolve from mere manufacturers under contract, to solution providers. Fabless companies are also seeking to improve design efficiency through closer partnerships with foundries.

This chapter outlines the steps taken by Taiwanese fabless companies and foundries to respond to the emerging SoC business.

1. Evolution of Foundries from Contract Manufacturers to Solution Providers

1.1. Large-Scale Investments in 300mm Wafer Fabs

The strength of Taiwanese foundries lies in their pro-active investment stance. Figure 4-1 shows the amount of business investment in the world semiconductor industry by region.[17] Total investment reached $48.3 billion in 2004, with a similar amount expected for 2005. Investment in the Asia-Pacific region largely exceeded that in North America, which demonstrates that Asia has now become the global hub of semiconductor production. Above all, investment in Taiwan surged to $8.25 billion in 2004, surpassing that of Korea and equivalent to three quarters of investment made in Japan. This substantial increase is due to large-scale investments made by the two major foundries, TSMC and UMC, for the construction of 300mm wafer fabs (see Table



Source: Gartner Dataquest (December 2005) GJ06004

Figure 4-1. Business Investment of World Semiconductor Manufacturers by Region

[17] Based on the location of investment.

4-1). Investment by the leading foundry TSMC reached $2.48 billion in 2005, thus exceeding the investment levels of most Japanese manufacturers.

Compared to Japanese manufacturers, Taiwanese foundries are characterized by a greater production capacity per fab. They have been improving cost competitiveness by achieving economies of scale derived from overwhelming investment. Maximum flexibility is the most compelling criterion in selecting new equipment. Meeting the various needs of clients is the key to a foundry's survival. In this respect, it is essential to increase the flexibility of products and to maintain broad product lineups. It is reported that TSMC has more than 300 active customers and manufacturers for the 5,000 products in its fabs.[18] Having multiple clients also leads to risk diversification. Since the client base of a foundry covers a broad area including communications, consumer equipment and computers, it can expect to reduce volatility by offsetting a decline in one segment against an increase in another.

With respect to microfabrication, Taiwanese foundries have already achieved volume production with the leading-edge 90nm processing method and are expected to launch prototypes for 65nm processing by the end of 2006. Although there are some pending issues, including yields, it is certain that they are catching up in the field of leading-edge technologies.

1.2. Sources of Cost Competitiveness

This sub-section analyzes cost competitiveness, one of the strengths of Taiwanese foundries, from the financial aspect. As shown in Table 4-2, the sales/cost ratio of the market leader TSMC has remained at the extremely low level of 55%.

Table 4-1. Operation of 300mm Fabs by Taiwanese Foundries

Company/fab	Operational in	Maximum capacity (,000 chips/month)	Minimum line width (nm)	Remarks
TSMC				
12 A	2002	25	130	
Fab 14A	2004	35	90	65 nm processing to be started in Q2/06.
12B	2005	25	90	
UMC				
Fab 12A	2001	40	90	65nm processing prototype to be launched in H1/06.
Fab 12 i	2004	40	130	Singapore

Sources: Industrial Technology Research Institute, "Semiconductor Industry Yearbook 2005;" company websites.

Table 4-2. Cost Advantage of Taiwanese Foundries (FY2004)

	TSMC		UMC		NEC Electronics	
	(¥100 million)	Ratio	(¥100 million)	Ratio	(¥100 million)	Ratio
Sales	8,323	100.0%	4,181	100.0%	7,080	100.0%
Sales cost	4,575	55.0%	2,988	71.5%	4,859	68.6%
Gross profit	3,748	45.0%	1,192	28.5%	2,221	31.4%
Operating cost	885	10.6%	485	11.6%	1,889	26.7%
Sales & marketing expenses	109	1.3%	90	2.1%	810	11.4%
General and administrative expenses	371	4.5%	157	3.8%		
Research and development expenses	405	4.9%	238	5.7%	1,079	15.2%
Operating profit	2,863	34.4%	706	16.9%	332	4.7%
Pre-tax profit	2,976	35.8%	1,027	24.6%	264	3.7%
Net profit	2,987	35.9%	1,030	24.6%	160	2.3%

Notes: 1. The financial year ends in December for TSMC and UMC and in March for NEC Electronics.
2. Exchange rate (2004 average) T$1＝¥3.236.

Sources: Corporate annual reports.

[18] See "TSMC 2004 Business Overview."

Foundries have achieved growth by specializing in production and concentrating managerial resources on capacity enhancement to realize the economies of scale that reduce costs. Japanese manufacturers need to identify any potential to reduce production cost by conducting a thorough review of their operations against the Taiwanese standard.

In addition to high profit margins, Taiwanese manufacturers have achieved substantial profitability by curtailing sales/marketing, general/administrative and R&D expenses, measured against sales. The lower level of R&D expenses may be natural because foundries and fabless companies have specialized in contract manufacturing and product design/development, respectively. However, it should not be overlooked that sales/marketing expenses and general/administrative expenses, as percentage of sales, are also lower in Taiwan than in Japan. The large sums of money invested by Japanese IDMs in sales and R&D have not necessarily resulted in improved profits. Without doubt, this fact reflects some of the serious problems facing Japanese manufacturers.

1.3. Challenges in Developing Nano-Level SoCs

As manufacturing processes shift to the nano-level (below 90nm), foundries have been required, in recent years, to deal with chips with extremely high degrees of integration, such as SoCs. A nano-level SoC requires a highly complicated system design and is fraught with technical problems, including time delays, due to the complexity of wiring and the noise arising from the interaction of neighboring circuits (crosstalk noise). The design department and the production department need to collaborate closely to manufacture this type of chip. Manufacturing processes have changed radically from the established process used to produce previous-generation chips.

Taiwanese manufacturers were once thought to rely on their cost competitiveness to gain profits, focusing on the volume zone rather than venturing into high-tech fields that require coordination of design and production. The recent entry of foundries into the SoC business may be explained by their awareness that a simple contract manufacturing model, which only prescribes a strict division of labor between fabless companies (design) and foundries (production), is not sufficient to meet the new challenge of SoCs.

1.4. Efficient Design and Manufacture through IP Libraries

How are foundries responding to the SoC business under these circumstances?

Because various IP is integrated on a single SoC, it is impractical for a company to develop all the IP from scratch. This would take too long and cost too much, affecting profitability and possibly even leading to the loss of clients. For this reason fabless companies have to focus their

Table 4-3. Challenges in Designing/Developing Nano-level SoCs

Challenges in developing nano-level SoCs (less than 0.09μm=90nm)
(i) Complexity of system design (ii) Solution of issues related to timing, crosstalk noise, etc. (iii) Improvements in design efficiency through effective use of EDA tools (EDA: electronic design automation) (iv) Increases in mask cost (v) Development/procurement of optimum IP
・ It is difficult for a company to develop any SoC on its own. ・ It is important to develop optimal chips in a prompt manner by combining in-house IP with other IP developed around the globe.
→ Increased international specialization and interdependence

Source: Development Bank of Japan

operations on core design. They need to build a system of international specialization to ensure the speedy supply of proper SoCs to their clients by combining their own design assets with other companies' resources.

In developing a SoC for image processing, for instance, the fabless company dedicates itself to the time-consuming development of graphic design, while the foundry prepares an IP library for input-output circuits, peripheral circuits related to memory and power supply. This dual mechanism serves to reduce total design time, because foundries create in advance libraries of essential IP that is commonly used on many chips. Foundries are also recruiting design engineers in an effort to develop the bare minimum IP for memory and peripheral circuits in-house. Thus, foundries have now extended their operations upstream to support design activities, working closely with fabless companies from the initial stages of chip development. By enhancing their partnerships with fabless companies, foundries are attempting to supply clients with their own SoC solutions.

IP manufactured on a foundry's production line is verified before being included in its library. Chips designed in this way are therefore likely to function properly. Since multiple IP is combined on a single SoC, many chips do not function properly at the production stage, even if problems were not detected at the design stage.

By disclosing their IP libraries to the clients, foundries aim to win production contracts for their own fabs. IP libraries are also essential for fabless companies to improve design efficiency, as smooth production will be ensured on foundry lines if they use verified IP. IP libraries also benefit IP providers: they can ensure a wider use of their IP by licensing large-scale foundries to include this in their IP libraries.

In recent years, alliances have also been developing with vendors of EDA (electronic design automation) tools used in the development of IP. The U.S. vendors' share in the EDA tool market is so overwhelming that it is almost impossible to design a semiconductor without the help of a tool marketed by them. Indeed, IP providers and fabless companies are strengthening collaboration with EDA tool vendors to improve design efficiency. Foundries have also entered into partnership with EDA tool vendors in an effort to expand business opportunities by facilitating orders from clients using the same design tools.

The three players in the vertical specialization model – fabless companies, foundries and IP providers – are enhancing their partnerships and contributing potential standard IP and required production capacities to expand the area that may be covered by the model. It is worth reiterating that "standardization" is a key term that defines the success of the vertical specialization model.

1.5. Development into Prototype Services

Foundries are also providing support services for chip prototyping. One of the aims of supporting chip development from the prototyping stage may be to retain prospective clients in view of the upcoming volume production stage. Although revealing chip prototypes might result in leakage of design information, foundries are introducing rigorous information management systems to eliminate concerns about possible divulging of IP in the process of contract manufacturing.

Some IDMs have entered into the foundry market. However, fabless companies see IDMs as potential competitors who manufacture their own brands. For this reason, they need to be cautious about outsourcing production to IDMs. In contrast, fabless companies can easily contract out production to dedicated foundries such as TSMC and UMC, because these firms do not have their own brands. In a sense, the penetration of foundries into prototype services attests to the trust relationship that they have developed with their clients.

2. Growth of Taiwanese Fabless Companies in Partnership with Foundries

Emerging Taiwanese fabless companies have been gaining the attention of world semiconductor manufacturers as alternative candidates to their U.S. counterparts for design outsourcing. This section outlines the efforts of Taiwanese fabless companies to reconcile their response to the various needs of clients with efficient design techniques, as reflected in a case study on Sunplus Technology – a company committed to the design and development of consumer ICs.

2.1. Outline of Sunplus Technology

Established in 1990, Sunplus Technology is a fabless venture based in the Hsinchu Science Park. The company initially focused on audio semiconductors for toys, but its rapid expansion started in the late 1990s, when it became involved in the development of semiconductors for image processing. The company's sales reached T$18.9 billion (about ¥61.2 billion), up 180% from 2000. Its operating profit amounted to T$2.9 billion (about ¥9.4 billion), with an operating profit margin of 15%. The company employs approximately 1,150 workers, 75% of whom are employed in the R&D department comprising chip design and system design sections.[19]

The semiconductors marketed by the company for toys and consoles are very application-specific, and typically need to be developed specially for individual clients. The final products have short life cycles. Low-cost and speedy chip development are required, as new models are marketed every Christmas.

The increasing multi-functionality of toys and consoles in recent years has enlarged the scale of integration required of embedded semiconductors. In the past, semiconductors for toys could be designed by a few engineers. At present, the same task often requires dozens of engineers. Efficient design and development of semiconductors represents the most serious business challenge facing the company.

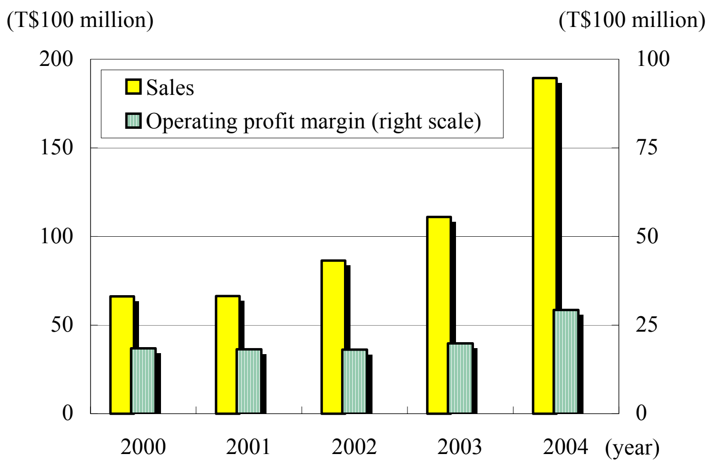
2.2. Development of Efficient Design Techniques

(i) Re-usable IP

To meet this challenge, Sunplus Technology introduced the concept of "re-usable IP." In designing a new chip, the company does not start from scratch but re-uses stable IP as much as possible to speed up the process.

Even with this technique it still takes a lot of time to integrate core blocks of different IP. In response, the company uses the same IP for hardware as often as possible and only modifies embedded memory to meet the demands of different clients. This method substantially curtails design time as it reduces the design workload. Such design techniques are being applied to most semiconductors used in toys.

Nonetheless, client demand for early delivery is insatiable, with some toy manufacturers complaining about "too much lead time." In other words, profits depend heavily on reducing



Note: Financial year ends in December.
Source: Annual Report

Figure 4-2. Performance of Sunplus Technology in Past 5 Years

[19] In some fields, including analog and communication-related semiconductors, the company adopts the strategy of procuring complementary development resources through partnerships with European fabless companies.

the time-to-market. Short-notice orders from clients may be met to some extent by immediate shipments from stock of general-purpose products, but this type of response is difficult when it comes to custom products. Because each custom product is designed for a specific client, any surplus cannot be supplied to another client in standard form.

(ii) Wafer Bank Strategy

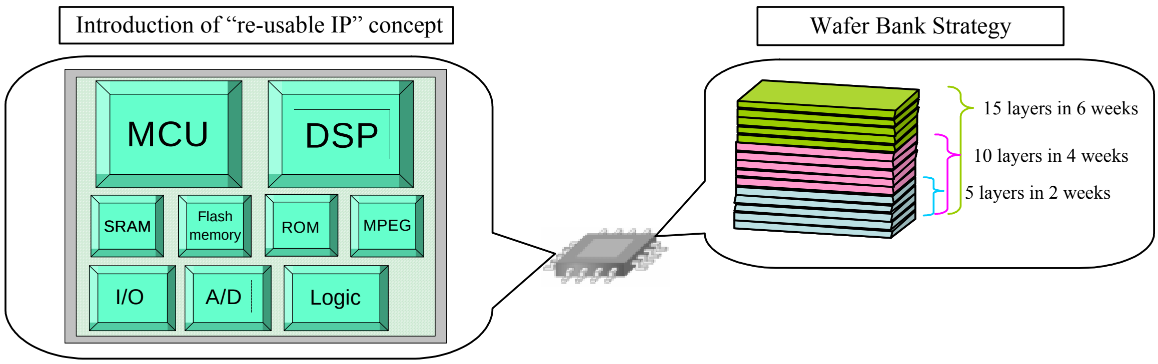
To minimize lead-time, Sunplus Technology devised a "Wafer Bank Strategy" in collaboration with a foundry.

Most of the chips designed by the company are multilayered. For example, 15 masks are required to produce a chip with 15 layers. In this case, the Wafer Bank accumulates common circuit blocks that are needed in every type of chip on the 1st to 10th layers, for example, and then builds a stock of wafers made up of these 10 layers. On receiving an order from a client, the company draws a 10-layered wafer from the Wafer Bank and customizes the remaining five layers. In this way, delivery time may be curtailed compared to the case where all 15 layers are designed from scratch.

Some might say that this design technique is nothing new in comparison to methods used with structured ASICs. What is noteworthy, however, is that even in the vertical specialization model, fabless companies and foundries are working together in an effort to develop efficient design techniques.

Fabless companies need to develop original products incessantly if they are to increase turnover by raising unit prices. In outsourcing production, it is also essential to select the most competitive process for any given design. This is why it is so important to work with foundries from the initial design stages. For their part, foundries are brushing up on their production technologies so that they can respond flexibly to small orders from fabless companies.

The combination of fabless companies' own efficient design techniques and foundries' small-volume production technologies in Taiwan, aims at creating a win-win situation for fabless companies, foundries and clients. Closer corporate partnerships are being pursued to respond more promptly to the needs of clients, based on the common understanding that reduced time-to-market is a major source of profit.



Source: Interviews

Figure 4-3. Development of Efficient Design Techniques in Sunplus Technology (schema)

V Current Conditions and Issues Confronting a Stagnant Japanese Semiconductor Industry

The previous chapter provided an overview of the Taiwanese semiconductor industry, which is exploring responses to the SoC business through enhanced partnerships between fabless ventures and foundries. In recent years, arguments have been made in support of either vertical integration or vertical specialization as the optimal business model for the semiconductor industry. Regardless of which model is chosen, closer collaboration between design and fabrication is more important than ever in the nano-level SoC business. We have already seen that in the vertical specialization model, fabless companies and foundries are trying to adjust themselves to the SoC business by achieving "virtual unity" through enhanced partnerships. Among vertically integrated manufacturers, a movement towards active outsourcing has also been observed, including a "fab-lite strategy." The reality is that the two business models are evolving to stand the test of time, integrating each other's advantages.

Under these circumstances, corporate success hinges on optimal management strategies to reconcile client satisfaction with self-interest. To achieve this goal, the vertical specialization model needs to establish subsidiaries to overcome the disadvantages of specialization, while the vertical integration model should ensure harmony between various corporate departments and focus on the attainment of common objectives. For a semiconductor manufacturer that has clearly identified its own management strategy, the business model to be adopted will emerge by itself.

This chapter first examines the trend of the Japanese semiconductor industry in terms of its share in the world market, followed by the identification of current conditions and issues confronting the industry, based on a comparison with Taiwanese and other foreign manufacturers. Finally, it demonstrates that problems facing Japanese manufacturers essentially come from the nature of their business management strategies.

1. The present Situation of the Japanese Semiconductor Industry: Falling Share of the World Market

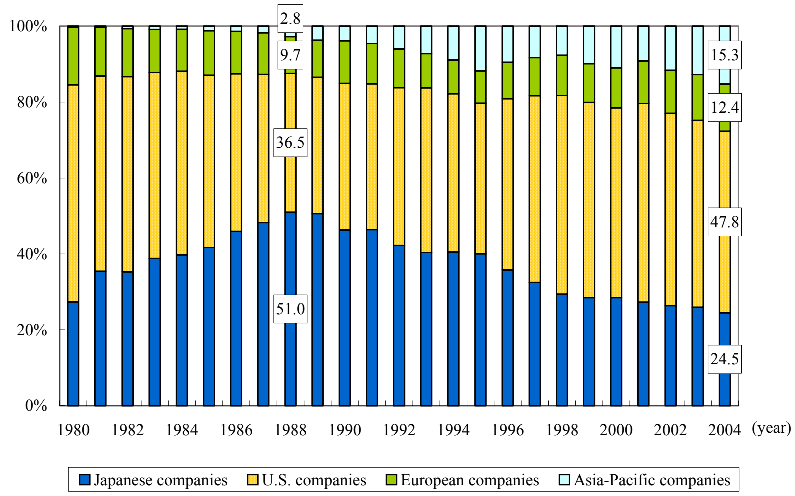
The widening gap between Japanese and foreign semiconductor manufacturers was already mentioned in Chapter III. This is not a temporary movement but has continued since the 1990s.

Figure 5-1 shows the composition of the world semiconductor market by region over the 24-year period from 1980 to 2004.[20] Japanese companies' market share soared in the 1980s, reaching a high of 51.0% in 1988, only to decline almost constantly ever since to only 24.5% in 2004, less than half of the peak level. Meanwhile, U.S. companies, on the defensive against Japanese manufacturers in the 1980s, regained the market leader position in 1993. Subsequently, their market share recovered to a little less than 50%. In recent years, the share of Asian-Pacific manufacturers has been increasing steadily, reaching 15.3% in 2004.

Thus, Japanese manufacturers have been fighting an uphill battle against Western and Asian companies in a three-way competition. The international competitiveness of Japanese manufacturers shows no sign of bottoming as overseas manufacturers are becoming increasingly aggressive even in the domestic market.

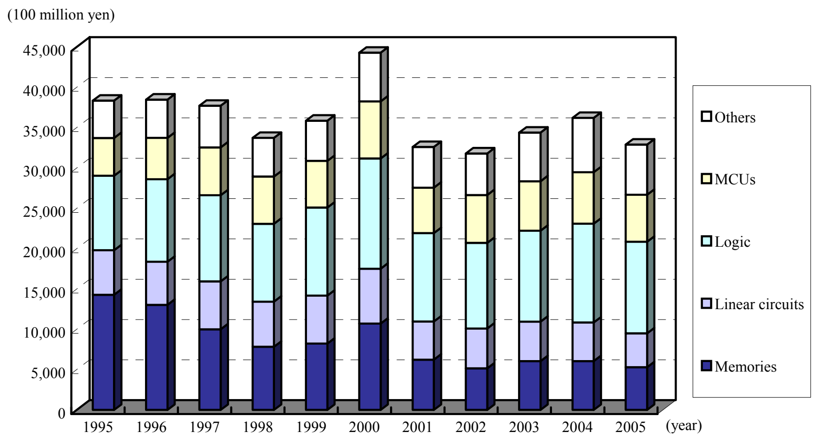
After exiting the DRAM market, many of the Japanese manufacturers adopted a policy of shifting their focus to application-specific logic products. The move is clearly reflected in the statistics: domestic memory production fell from more than ¥1.4 trillion in 1995 to just over ¥0.52 trillion in 2005 (see Figure 5-2). However, the growth of non-memory products including MCU and logic has not offset the decline in memory production. As a result, total domestic semiconductor production declined from some ¥3.83 trillion in 1995 to about ¥3.28 trillion in 2005. Although the transfer of production overseas in recent years should be taken into account, the slowdown in the earlier production process, which usually should create much of the value added, is considered to be one of the causes of

[20] Here, regional distribution is based on the location of head offices. For example, "U.S. companies" include the sales of semiconductor manufacturers based in the United States.



Source: Gartner Dataquest (April 2005) GJ05440

Figure 5-1. Composition of the World Semiconductor Market by Manufacturer Region



Source: Ministry of Economy, Trade and Industry, "Preliminary Report on Machinery Statistics."

Figure 5-2. Domestic Semiconductor Production by Major Product Category

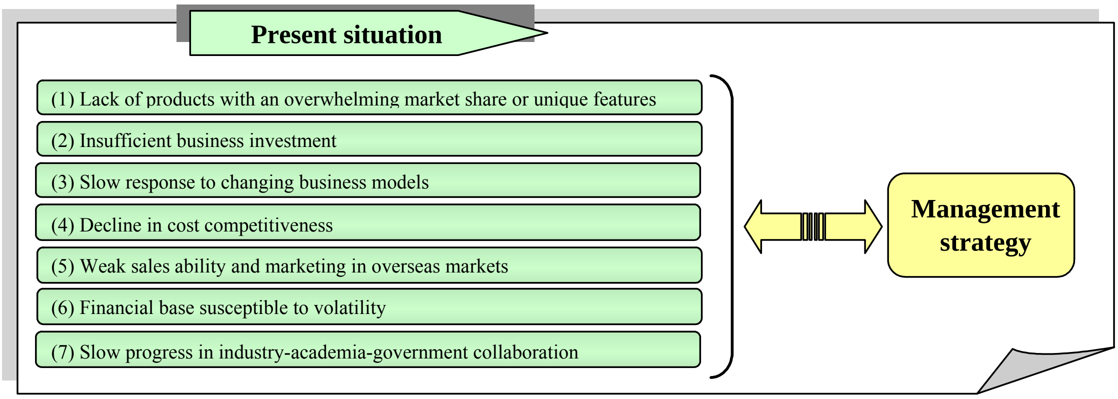
the decline in the international competitiveness of Japanese manufacturers.

2. Issues Facing the Japanese Semiconductor Industry

The long-term decline of the Japanese semiconductor industry may be explained by factors including the lack of products with an overwhelming market share, insufficient investment, slow response to changing business models, a decline in cost competitiveness, and weak sales ability in overseas markets (see Figure 5-3). All of these issues, far from being independent, are closely interrelated and directly linked to corporate management strategy. This section analyzes each of them in some detail.

2.1. Lack of Products with an Overwhelming Market Share or Unique Features

As analyzed in Chapter II, Japanese manufacturers in general face an uphill battle in general-purpose markets such as processors and memory nor do they have many products with an overwhelming market share. On the contrary, they have been routed by U.S. companies in such emerging products as FPGAs/PLDs. Furthermore, overseas manufacturers have been on the offen-



Source: Development Bank of Japan

Figure 5-3. Issues Facing the Japanese Semiconductor Industry

sive in the analog market since many leading Japanese companies left the market to concentrate their managerial resources on digital semiconductors. Japanese manufacturers have only managed to maintain a competitive edge in MCUs, the unit prices of which are lower than other semiconductor products.

Since their withdrawal from the general-purpose DRAM market, Japanese manufacturers have been focusing their operations on application-specific products. It is true that they hold a certain advantage in highly-customized ASICs. However, they have been slow to develop these products into world-standard ASSPs. As Japanese manufacturers shifted their business focus from commodity products to high-end, application-specific products in a "me-too" mentality, competition has probably intensified among them, with an adverse effect on their profits. Many Japanese manufacturers have a similar scope of business that focuses on microcontrollers, display drivers and ASICs. Individual companies seem not to have been able to develop a unique family of products.

2.2. Insufficient Business Investment

In 2004, Japan again replaced the U.S. as the world leader in semiconductor investment. The country seems to have maintained this position in 2005 (see Table 5-1). We should give a positive evaluation to the fact that business investment increased after staying at a low level following the bursting of the IT bubble in 2001. It should be noted, however, that Japan has a greater number of large- and medium-sized semiconductor manufacturers.

Table 5-1 shows the amount of business investment by Japanese and overseas manufacturers. Among the overseas manufacturers, Intel leads the industry in business investment, having spent approximately \$3.8 billion and \$5 billion in 2004 and 2005, respectively. In July 2005, the company invested \$3 billion to launch a new 300mm wafer fab in the U.S. It also announced plans to start MPU fabrication with 45nm processing technology in the second half of 2007.[21] TI and AMD have constantly been investing \$1.3-1.5 billion. In Asia, Korean Samsung Electronics has invested over \$5 billion in recent years. The company's investment seems to have reached about \$6 billion in 2005.[22] Taiwanese TSMC is also implementing a large-scale investment project of some \$2.5 billion, mainly for building a 300mm wafer fab using leading-edge microfabrication technology. Taiwanese foundries have a maximum production capacity of 30,000–40,000 chips on average. Eventually, this gap in scale will be reflected in cost competitiveness.

In comparison, investment by most Japanese manufacturers has not yet reached ¥100 billion. The only exceptions are Sony, which primarily invested in the new processor "CELL", Toshiba, which is committed to capacity investment in

21 See Intel website.
22 See Samsung Electronics website. Of the semiconductor investment of 6.3 trillion won in 2005, memory accounts for 5.33 trillion won and system LSI 0.99 trillion won. 1 won = ¥0.11 (2005 average).

Table 5-1. Business Investment by Japanese and Foreign Semiconductor Makers

	(¥100 million, %)	Business investment FY2004 (actual)	FY2005 (planned)	Annual change 05/04
Japan	Renesas Technology	900	800	-11.1
	Toshiba Semiconductor	2,030	2,250	10.8
	NEC Electronics	1,632	900	-44.9
	Matsushita Electric (Semiconductor Company)	810	800	-1.2
	Fujitsu	450	950	111.1
	Rohm	671	740	10.3
	Sharp	180	100	-44.4
	Sony	1,500	1,600	6.7
	Sanyo Semiconductor Company	212	124	-41.5
	Elpida Memory	1,250	1,900	52.0
	Oki Electric Industry	231	180	-22.1
	Seiko Epson	150	130	-13.3
	Nichia Corporation	397	400	0.8
	($ million)	FY2004 (actual)	FY2005 (planned)	Annual change
U.S.	Intel	3,800	4,900-5,100	-
	Texas Instruments	1,300	1,300	0.0
	AMD	1,440	1,500	4.2
	Micron	1,400	1,500	7.1
	Freescale	490	570	16.3
Europe	ST Microelectronics	2,050	1,500	-26.8
	Infineon	905	780-1,000	-
	Philips	500	550	10.0
Taiwan	TSMC	2,400	2,500-2,700	-
	UMC	1,530	1,000-1,500	-
Korea	Samsung Electronics	5,238	5,724	9.3

Notes: 1. The financial year ends in March for Japanese manufacturers and in December for overseas manufacturers except for Micron (August) and Infineon (September).
2. Toshiba revised investment in 2005 upwards to ¥289 billion.

Source: The Semiconductor Industry News (November 30, 2005 and April 6, 2005)

flash memory, and Elpida Memory, whose new DRAM fab is under construction. There is a wide investment gap between Japanese and overseas manufacturers. If this trend continues, Japanese companies may see their competitiveness decline in the medium to long term, as well as in the short term.

2.3. Delay in Response to Emerging Business Models

In the world of semiconductors, the vertical specialization business model has drawn attention in recent years. Not all IDMs are having difficulty in the global market. Some booming companies, including Intel, TI and Samsung Electronics, may be classified as IDMs. Among vertically integrated companies, however, many Japanese semiconductor manufacturers are typically part of a general electronics manufacturer that also has a department for set products for which its semiconductors are used.

Taking this advantage to the maximum, Japanese IDMs should be able to accelerate product development as they can start semiconductor design from the planning stage of their set products. It should also be easier for them to prevent leakage of design secrets and skills. Moreover, the set product department and the semiconductor department of the same IDM can collaborate in the co-development of final products right from the beginning, which should allow speedy development of original products with unique features and the potential to bring additional profits through external sales. Unfortunately, however, the performance of Japanese manufacturers indicates that they have not been able to capitalize fully on the advantages of vertical integration. So, how can Japanese IDMs claim that they have made serious efforts to restructure as new business models emerged with the advent of vertical specialization?

As noted in the previous chapter, Taiwanese foundries are seeking to find a breakthrough by building broad partnerships with other relevant players such as fabless companies, IP providers and EDA tool vendors, based on the understanding that they will not be able to respond to the nano-level SoC business with the simple business model of contracted manufacturing. Japanese manufacturers should make every effort to gain further insight into the vertical specialization business model and to integrate its comparative merits into their operation. A thorough comparison of their business model with that of overseas competitors should let them identify the challenges to be met.

2.4. Decline in Cost Competitiveness

In order to analyze the cost structures of major specialist semiconductor manufacturers in Japan and overseas, we conducted a comparative survey of the three categories of semiconductor manufacturers: fabless companies, foundries and IDMs, for which accounting data are available. The result is shown in Table 5-2. Here, foundries are represented by TSMC and UMC, fabless companies by Xilinx and Altera, and IDMs by NEC Electronics, TI and Intel.

As pointed out in the previous chapter, foundries excel in the low-cost production of semiconductors. Indeed, the leading foundry TSMC has a significantly low sales/cost ratio. It has also achieved a high profit margin by cutting back on sales, general administrative and R&D expenses. In comparison, the huge amount of money spent by Japanese manufacturers on sales, administration and R&D has not necessarily borne fruit.

The difference in profit structure becomes more apparent when we compare Japanese and U.S. IDMs. Although the ratios of sales, administrative and R&D expenses versus total sales are similar – from the 10% range to around 15% respectively – a wide gap appears in the operating profit ratio, which measures core business profitability. The low marginal profit ratio of Japanese manufacturers might be explained by relatively high production costs. However, it might also be because the consequences of huge R&D and sales expenses are not reflected sufficiently in the sale prices of products. As already mentioned, Japanese manufacturers have very few general-purpose semiconductors with an overwhelming market share. As final product prices continue to decline and their life cycles shorten, improvement of profitability is urgently needed, even for custom products developed with substantial man-hours. Sales, administrative and R&D expenses should be reviewed thoroughly so that these can contribute to an increase in sales volumes and unit prices.

Table 5-2 also shows that fabless companies, foundries and IDMs have substantially different cost structures. Foundries dedicate themselves to contracted manufacturing, while fabless companies are in charge of product research and development. Therefore, production costs, including raw materials and depreciation expenses, account for a large part of total costs in foundries. Fabless companies have a completely different cost structure, spending most of their money on R&D and sales.

Vertical specialization typically reveals the different cost structures between the design de-

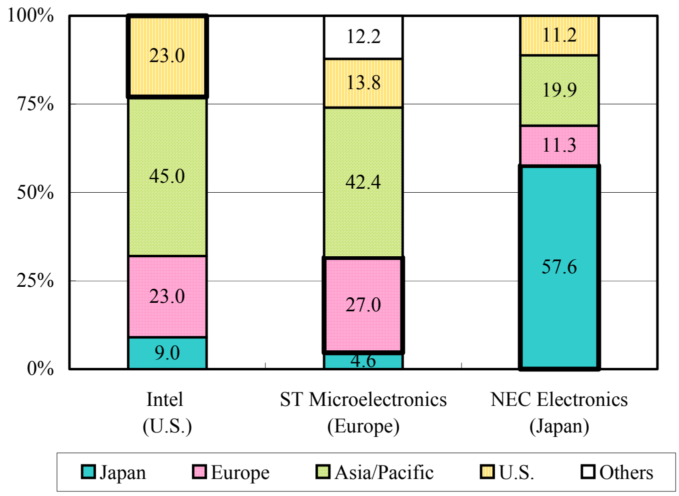
Table 5-2. Cost Structures of Major Foundries, Fabless Companies and IDMs (FY2004)

(¥100 million, ratio)	Foundries				Fabless companies				IDMs					
	TSMC		UMC		Xilinx		Altera		NEC Electronics		TI		Intel	
Sales	8,323	100.0%	4,181	100.0%	1,691	100.0%	1,099	100.0%	7,080	100.0%	13,609	100.0%	37,006	100.0%
Sales cost	4,575	55.0%	2,988	71.5%	619	36.6%	336	30.5%	4,859	68.6%	7,523	55.3%	15,645	42.3%
Gross profit	3,748	45.0%	1,192	28.5%	1,072	63.4%	764	69.5%	2,221	31.4%	6,086	44.7%	21,360	57.7%
Operating cost	885	10.6%	485	11.6%	672	39.7%	423	38.5%	1,890	26.7%	3,699	27.2%	10, 402	28.1%
Sales & marketing expenses	109	1.3%	90	2.1%	341	20.2%	228	20.7%	810	11.4%	1,559	11.5%	5,234	14.1%
General & administrative expenses	371	4.5%	157	3.8%										
Research and development expenses	405	4.9%	238	5.7%	330	19.5%	195	17.8%	1,079	15.2%	2,140	15.7%	5,169	14.0%
Operating profit	2,863	34.4%	706	16.9%	400	23.6%	341	31.0%	332	4.7%	2,387	17.5%	10,958	29.6%
Pre-tax profit	2,976	35.8%	1,027	24.6%	431	25.5%	358	32.5%	264	3.7%	2,619	19.2%	11,269	30.5%
Net profit	2,987	35.9%	1,030	24.6%	336	19.9%	298	27.1%	160	2.3%	2,013	14.8%	8,130	22.0%

Notes: 1. The financial year ends in December for TSMC, UMC, Altera, TI and Intel, and in March for Xilinx and NEC Electronics.

2. Exchange rates: T$1=¥3,236 (2004 average), $1=¥108.2 (2004 average), $1=107.5 (FY2004 average).

Sources: Corporate annual reports



Note: Areas within dark borders indicate sales in the "domestic market" (i.e. the region in which the company based).
Sources: Corporate annual reports, etc.

Figure 5-4. Sales of Japanese, U.S. and European Semiconductor Manufacturers by Region (2004)

partment (fabless companies) and the fabrication department (foundries). Data indicate that partners in the vertical specialization business model are improving competitiveness in their respective fields of specialization in the face of fierce competition for external clients, and can ensure stronger competitiveness as a whole through their complementary relationships.

By comparison, it is difficult for an outsider to identify the cost structure of an IDM, which integrates design/development and fabrication. Of course, this does not mean that the IDM model itself is problematic. Indeed, IDMs like Intel enjoy advantages of scale by developing and fabricating products that hold an overwhelming market share. The first step for Japanese IDMs in solving their problems is to compare their own cost structures with those of leading IDMs, fabless companies and foundries overseas.

2.5. Weak Sales and Marketing Ability in Overseas Markets

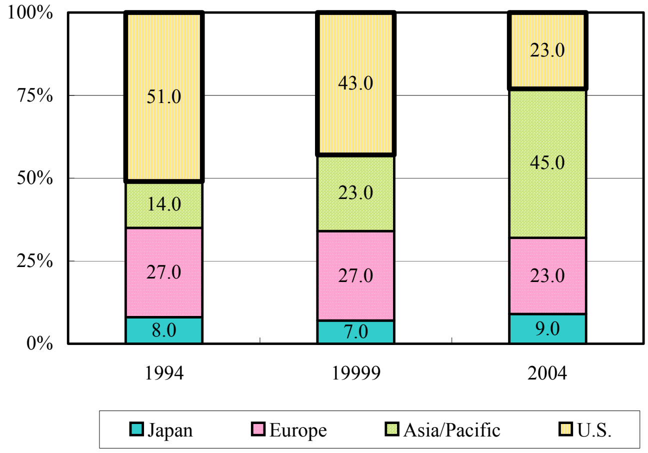
The regional composition of the world semiconductor market has changed substantially in the past two decades. Chapter I has already indicated that the development of a global marketing strategy has become increasingly important, focusing not only on domestic sales but also on the fast-growing Asian and Western markets. Have Japanese manufacturers succeeded in responding appropriately to the changing market environment and developed their businesses on a global scale?

To answer this question, we conducted a comparative survey of three semiconductor manufacturers each representing Japan, the U.S. and Europe, which disclose their sales data by region. Figure 5-4 shows the result. Defining "domestic market" as the region in which a company's head office is located, the share of the domestic market in total sales stands at around one quarter for overseas manufacturers: 23% for Intel (U.S.) and 27% for ST Microelectronics (Europe). In contrast, NEC Electronics realizes the majority of sales (57%) in the Japanese market.

Even Intel used to depend heavily on its domestic market. But the share of the U.S. market in world sales fell from 51% in 1994 to 23% in 2004, reflecting the emergence of the Asia-Pacific region (including Japan) as a major market (see Figure 5-5). As the core of the semiconductor market shifts from Japan to Asia via the U.S., the difference in the share of the domestic market in total corporate sales indicates the difference in the level of success in developing a comprehensive marketing strategy in prompt response to the changing global market structure. Having difficulty in expanding sales overseas, Japanese manufacturers are forced to engage in fierce competition for the domestic market, which in turn leads to a further deterioration in corporate profits.

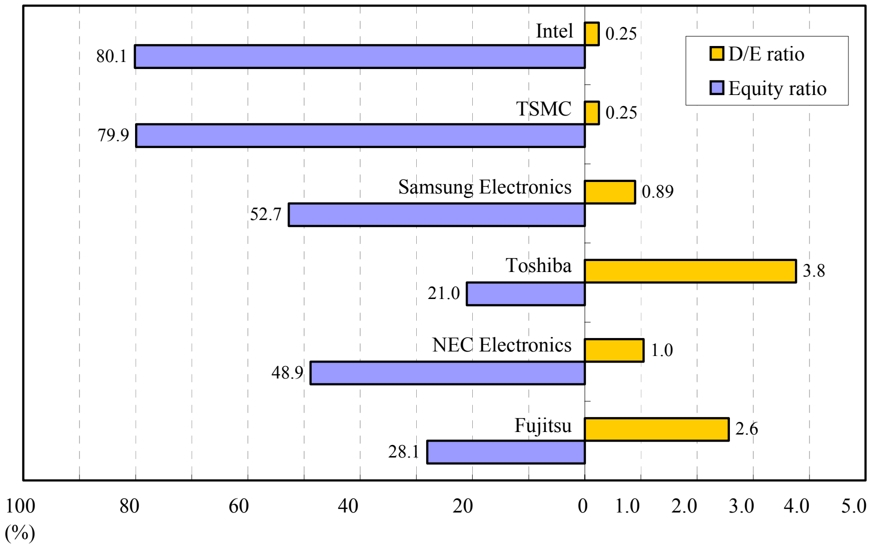
2.6. Financial Bases Vulnerable to Volatility

Profits of semiconductor manufacturers are heavily influenced by fluctuations in the silicon cycle: it is not unusual for a company to record a substantial deficit at the bottom of the cycle. World-leading semiconductor manufacturers therefore find it crucial to enhance equity capital in good times by accumulating profits and new stock issues, so that they may continue large-scale investment in bad times. According to Figure 5-6, the equity ratio stands at around



Note: Areas with dark borders indicate sales in the "domestic market" (i.e. the region in which the company is based).
Sources: Intel Annual Report, etc.

Figure 5-5. World Sales of Intel by Region



Note: The financial year ends in March for Japanese manufacturers and in December for overseas manufacturers.
Sources: Corporate accounting data.

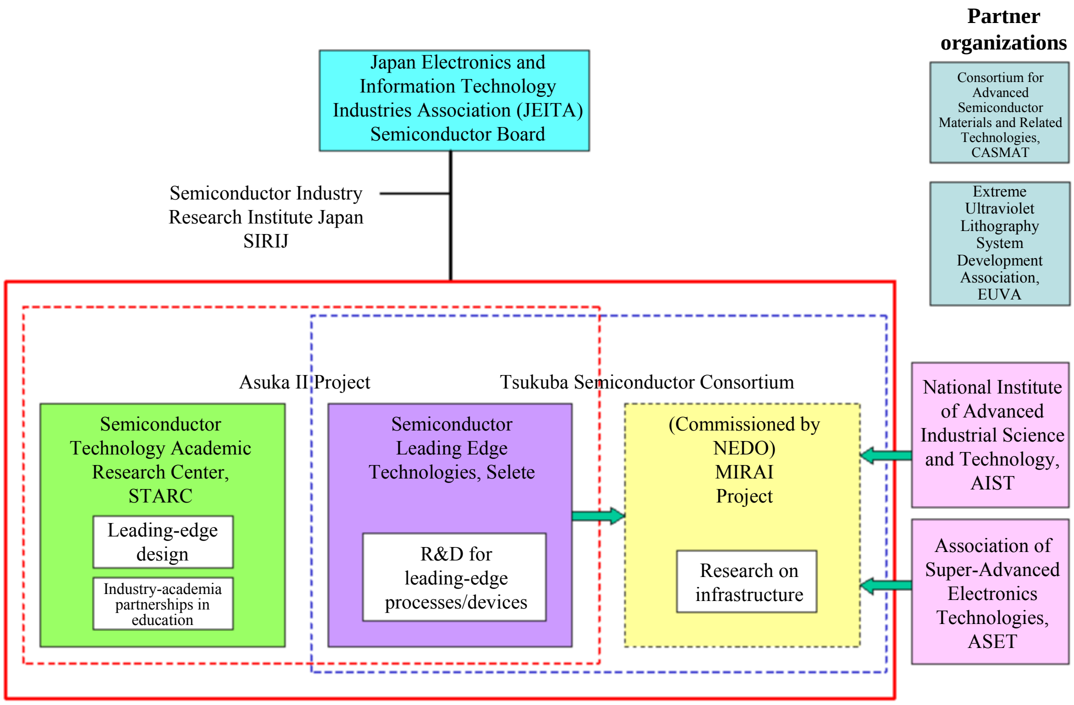
Figure 5-6. Financial Structures of Japanese and Overseas Semiconductor Manufacturers (FY2004)

80% for Intel and TSMC. Fabless companies have even higher equity ratios: 85% for Xilinx (U.S.) and 84% for Sunplus Technology (Taiwan).[23] In contrast, Japanese manufacturers are generally characterized by a greater dependence on loans, largely because they form a department in a general electronics manufacturer. In order to make a bold decision in the semiconductor business, a company requires a substantial buffer to absorb any shock resulting from a wide fluctuation in corporate performance. In the final analysis, the difference in the financial structure of Japanese and overseas companies has considerable implications for the nature of business management.

2.7. Slow Progress in Partnerships between Industry, Government and Academia

Revitalizing collaboration between industry, government and academia is another urgent issue. As time-to-market is a crucial source of value added in the semiconductor business, it is now crucial for a manufacturer to be the first to provide clients with new products by combining their expertise with quality resources gathered from around the world. Therefore, Japanese manufacturers, in conducting purely basic research and development that does not lead directly to product differentiation, should not pursue the principle of in-house development, but rather adopt a flexible attitude, incorporating the examples of consortiums created through industry-government-academia partnerships.

In March 2006, the Japan Electronics and Information Technology Industries Association (JEITA) announced the launch of "Asuka II," a joint development project for next-generation semiconductor technologies to facilitate pre-emptive R&D activities that meet prospective business needs and promote partnerships between the industry, universities and public research institutes. Led by the Semiconductor Technology Academic Research Center



Source: Japan Electronics and Information Technology Industries Association

Figure 5-7. Structure to Promote a Joint Development Project for Next-generation Semiconductor Technologies

[23] Data as at the end of FY2004 according to the company's website.

(STARC) and Semiconductor Leading Edge Technologies, (Selete), both financed by domestic semiconductor companies, the "Asuka II" project will invest ¥90 billion over five years until 2011 (see Figure 5-7).

Manufacturers need to clearly express their willingness to participate in these joint development efforts if they want to see such cross-sectional, joint projects lead to the restoration of the competitive capability of the Japanese semiconductor industry. For example, they may form a consortium for common technologies related to processing or materials development while conducting in-house R&D activities closely related to product commercialization. Universities and research institutes will also have to redouble their efforts in human resource development and select research subjects that meet actual needs in the field. In-depth discussions are urgently needed on key questions with reference to relevant cases overseas. Is the current budget sufficient for further promoting joint development? Do we need to expand the scope of government support for the development of common technological infrastructure?

This chapter has analyzed some of the problems facing the Japanese semiconductor industry in comparison to the conditions facing overseas manufacturers. What is important is that all these issues are closely interrelated and therefore cannot be considered separately from the nature of business management. For instance, the weak sales ability in overseas markets makes it difficult to secure profits by developing application-specific products into world standards. Also, the lack of a product with an overwhelming market share is partly responsible for the decline in Japanese cost competitiveness and insufficient business investment.

Building on the discussions in this chapter, the following chapter proposes some concrete measures to restore the international competitiveness of the Japanese manufacturing industry.

VI Policies to Restore the International Competitiveness of the Japanese Semiconductor Industry

1. Three Possible Directions of the Japanese Semiconductor Industry

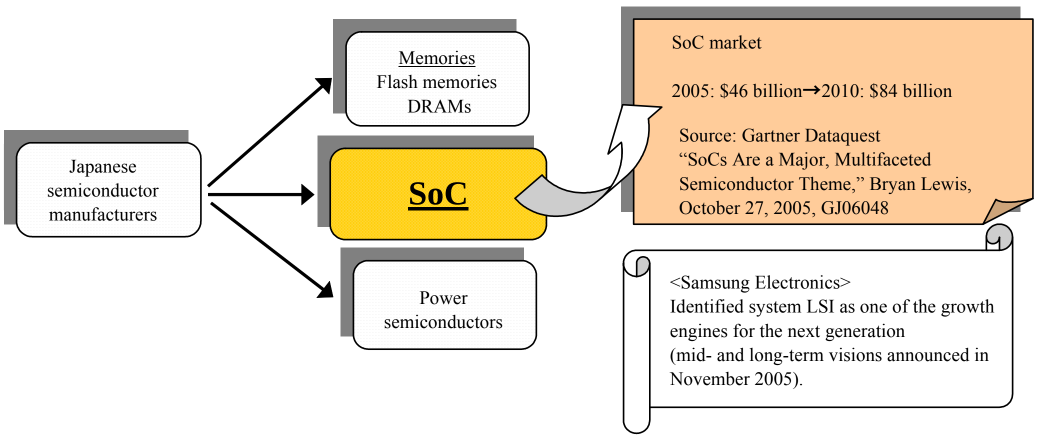
Basically, semiconductors are fit for volume production due to factors inherent in the manufacturing processes. Only those manufacturers whose products have significant market share, and thus enjoy overwhelming advantages of scale in production, can benefit from retaining their own fabs. Therefore, increasing market share for general-purpose products such as processors and memory is the best way to succeed in the semiconductor business. This is exactly how Japanese manufacturers once thrived in the DRAM market. Without doubt, they are hoping to make a spectacular comeback in the general-purpose market, no matter how long it takes.

Since the 1990s, many Japanese semiconductor manufacturers have shifted their focus from general-purpose to application-specific products. Since application-specific products require high-mix, low-volume production, an IDM has to adopt a different approach to that applied to general-purpose products in order to gain profits. This is where foundries and fabless companies found a golden business opportunity. Based on the business model of vertical specialization, they specialized in fabrication or design and then collaborated in a complementary manner to achieve substantial growth. Japanese IDMs will have to find an innovative business strategy immediately, if they are to withstand the challenge of specialist manufacturers.

Against this backdrop, the future of the Japanese semiconductor industry will depend on three categories of product: (i) memory, (ii) power semiconductors/sensors and (iii) SoCs. The following sub-sections focus on each of those three possible pillars.

1.1. Memory

Memory, the first pillar, represents a volume zone among general-purpose products. Competitiveness in this product largely depends on the scale of production facilities available and the microfabrication technology employed. Domestic players have already been selected for two representative products: flash memory and DRAM. Toshiba is leading the flash memory market together with Samsung Electronics. Elpida Memory is currently the only Japanese company specializing in DRAM, as many leading manufacturers exited the market or consolidated in the late 1990s. Players in the memory business must be ready to fight to the bitter end. It seems that this attitude is reflected in the business policies of Japanese manufacturers as they have successively announced plans for major investments to enhance their competitive capacities.



Source: Development Bank of Japan

Figure 6-1. Three Possible Directions of the Japanese Semiconductor Industry in Future

1.2. Power Semiconductors and Sensors

The second category of products, power semiconductors and sensors, is rather atypical in that it requires analog design/fabrication technologies. Digital semiconductors, including memory and logic, require huge investments to maintain competitiveness because they are highly dependent on manufacturing equipment. In contrast, analog products such as power semiconductors need to be customized and hence depend heavily on the experience and expertise of individual engineers. Typically, the investment burden is not so heavy, as they better lend themselves to relatively mature production processes, rather than leading-edge processes.

Power semiconductors, used for power transforming purposes including AC/DC conversion and power supply control, are mounted on a variety of products, ranging from power generators and rolling stock to industrial equipment and consumer electronics. In consumer electronics, for example, power semiconductors are used as the core device of inverters that control the rotation speed of motors at an optimum level by modifying power frequencies. Their importance has increased rapidly in recent years as an effective means of saving energy and improving the controllability of equipment. Demand for power semiconductors is also increasing in the automobile industry, mainly for engine control in hybrid cars. A high level of reliability and heat resistance is required of power semiconductors for automobiles, which raises the expectation that Japanese manufacturers will be able to show their skill in this area.

Sensors are devices that measure, with the help of semiconductors, the levels of light, sound, temperature, pressure and acceleration and transform these into electric signals. They are widely used in products such as digital cameras, camcorders and cellular phones. CMOS sensors, which have been gaining attention in recent years, provide the technical challenge of maintaining sensitivity while increasing pixel counts to give higher resolution. Sensors also play a key role in automatic control technology to improve the safety and mileage of automobiles. Indeed, a large number of sensors have come to be used in vehicles, including fuel injection sensors, hydraulic/pneumatic sensors and collision detecting sensors. Stable growth is expected in the medium to long term in the automobile sensor market, presenting an opportunity for Japanese semiconductor manufacturers to expand their businesses through enhanced collaboration with vehicle manufacturers.

1.3. SoCs

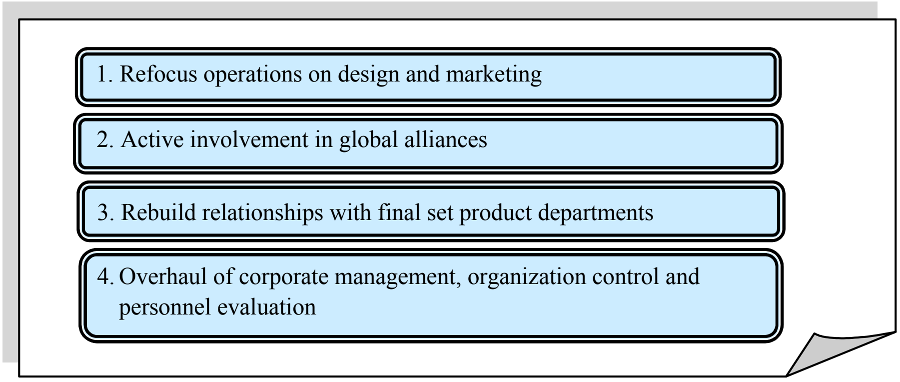
Finally, SoCs have drawn interest as a potential source of renewal for the Japanese semiconductor industry. As demand for application-specific products, ASSPs in particular, is expected to continue growing in the years ahead, SoCs which integrate a whole system on one chip will have further roles to play in realizing miniaturization, multi-functionality and low power consumption in various types of equipment. According to Gartner Dataquest, the world SoC market surpassed $46 billion in 2005 and will reach $84 billion in 2010 (see Figure 6-1). In its mid- and long-term vision announced in November 2005, Korean manufacturer Samsung Electronics identified system LSI as one of the growth engines for the next generation along with memory and displays.[24] Many semiconductor manufacturers, both in Japan and overseas, have already taken pro-active steps to develop their SoC operation as a primary focus of future business development.

2. Strategy to Enhance Competitiveness in the SoC Business

What strategies should Japanese manufacturers adopt to improve their international competitiveness in the burgeoning SoC business?

As described earlier in this report, it is important to determine what to manufacture in view of the functions required of SoCs in final products. Therefore, success in the SoC business depends not only on process technologies but also on skills in designing, development and marketing. As greater emphasis will also be placed on software, manufacturers must find out how to reconcile client satisfaction with self-interest,

[24] Samsung Electronics' mid- and long-term visions (announced in November 2005) identify eight growth engines for the future: memory, displays, mobile telecommunications, digital TVs, printers, system LSI, storage and air control systems.



Source: Development Bank of Japan

Figure 6-2. Strategies to Strengthen Competitiveness in the SoC Business

while minimizing the costs of product development and user support.

In this context, this section focuses on the SoC business and proposes four strategies to improve competitiveness: refocusing operations on design and marketing; participating actively in global alliances; rebuilding relationships with the final set product department; and overhauling business management, organization control and personnel evaluation.

2.1. Refocusing Business Operations on Design and Marketing

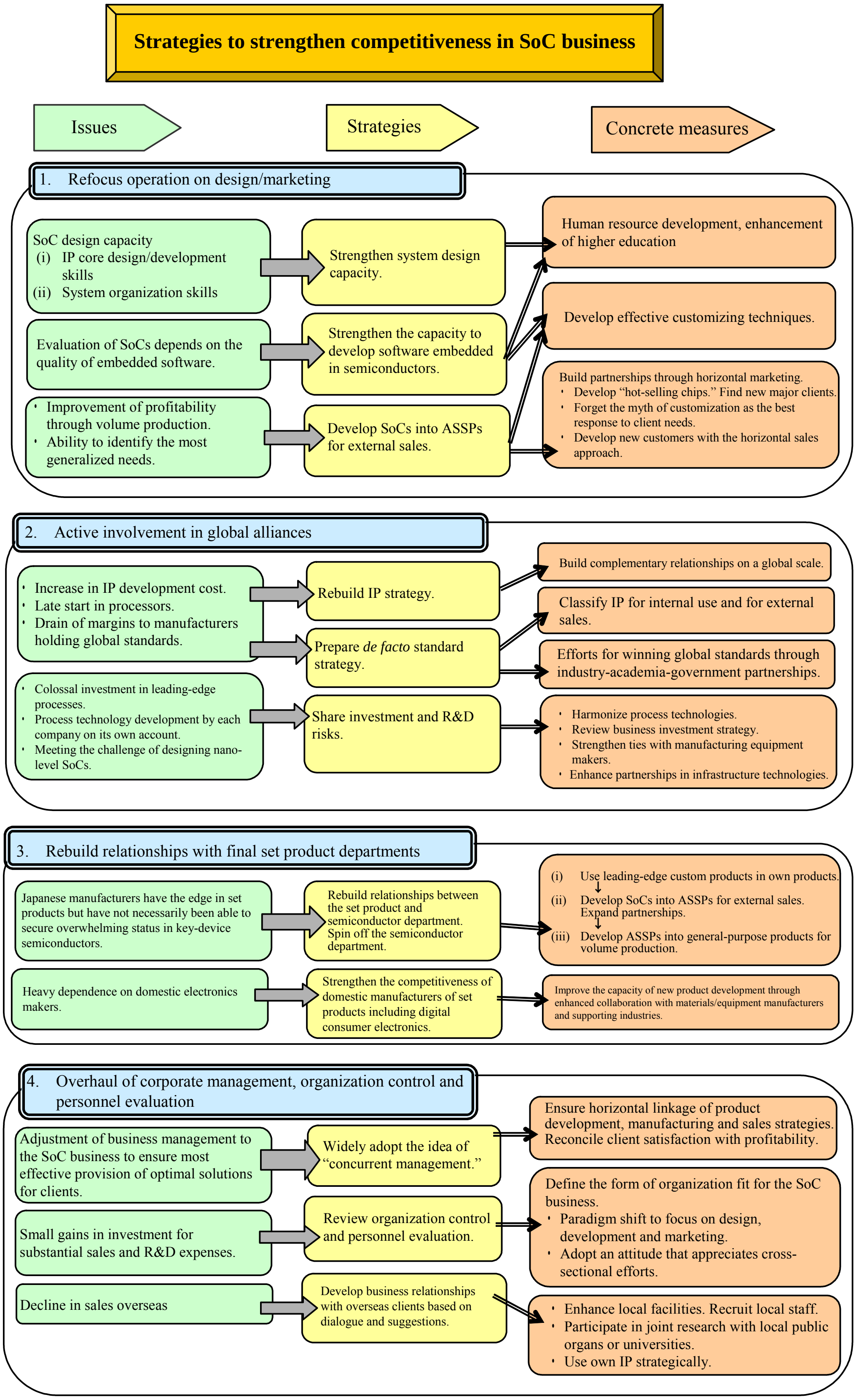
Design accounts for a considerable part of SoC development costs. There are two aspects of SoC design capacity. One is the design and development skills of the IP core, including processors and peripheral circuits, and the other is the ability to organize these devices into a system. The importance of the latter, system design, has been growing with the sophistication and complexity of systems used in equipment. However, it is not easy to train engineers in this type of skill, and some rightfully point out a delay in relevant human resource development. In developing the skill of organizing devices into a system, engineers should be required to work with clients to devise the set products for which the developed chips will be used and to efficiently design the necessary IP core to be included on the chip. Moreover, software contributes substantially to the cost of SoC development. The evaluation of set products therefore depends on the quality and versatility of the embedded software. Improving the development skills of software engineers is urgent in light of such product characteristics.

A SoC can hardly be profitable if it remains a chip for a specific final product. It is therefore essential to turn it into an ASSP fit for volume production by selling it to other clients. For this to happen, the manufacturer has to adopt a marketing technique that can be applied horizontally to the same or similar industries and find new clients. In order to ensure smooth application of this horizontal marketing approach, SoCs need to have some degree of versatility from the first stage of development. In this respect, engineers should be able to identify the most generalized needs that are common to two or more clients. A cross-sector arrangement to place design engineers in the marketing department would be effective in giving feedback to the development process. Some manufacturers might still believe in the old cliché: “response to client needs spells full customization.” They will have to abandon this belief as soon as possible and move towards accelerating development activities by making effective use of existing design assets.

2.2. Active Involvement in Global Alliances

(i) Rebuilding IP strategy through complementary relationships

With the progress of large-scale integration and multi-functionality in SoCs, it is virtually impossible for a single company to develop all IP on its own, in terms of both cost and time required. What is worse for Japanese manufacturers, Western companies retain global standards in



Source: Development Bank of Japan

Figure 6-3. Strategies to Strengthen Competitiveness in SoC Business

core processors, which also constitute the core of SoCs. Against this backdrop, it is urgent to develop an IP strategy based on global complementary partnerships, in which Japanese manufacturers develop in-house, high-value added IP that helps in product differentiation, while procuring other standard IP from suppliers both in Japan and overseas.

As examined in Chapter IV, fabless companies and foundries are working together to find answers to the emerging SoC business. Fabless companies are concentrating resources on the development of core IP, while foundries provide fabless companies with libraries of standard IP and those related to peripheral circuits, both in an effort to curtail development time and to win new clients. These alliances have become indispensable in meeting the challenge of nano-level design under a system of vertical specialization. Indeed, foundries are planning to further enhance their partnerships with EDA tool vendors, IP providers and manufacturing equipment makers. For example, TSMC, Cadence (a major EDA tool provider), ARM and Applied Materials have launched a Silicon Design Chain Initiative. Drawing on each company's domain of expertise, the Silicon Design Chain has correlated models, design and analysis tools, and IP to silicon results, providing customers with a proven path from design to volume production.[25] The move indicates that corporate collaboration has become a compelling requirement, as individual companies find it difficult if not impossible to develop such techniques on their own.

(ii) Preparation of a *de facto* standard strategy

The enhancement of global alliances also represents an effective strategy for nurturing self-developed IP into *de facto* standards. Winning as many clients as possible is the best way to develop a SoC to an ASSP that practically serves as a global standard. In this connection, a company has to classify self-developed IP into that reserved for internal use and that available for external sales. How to define this boundary is a crucial issue, closely related to the status of the final set product department and semiconductor department within the company. We will come back to this topic a little later.

(iii) Sharing investment and R&D risks

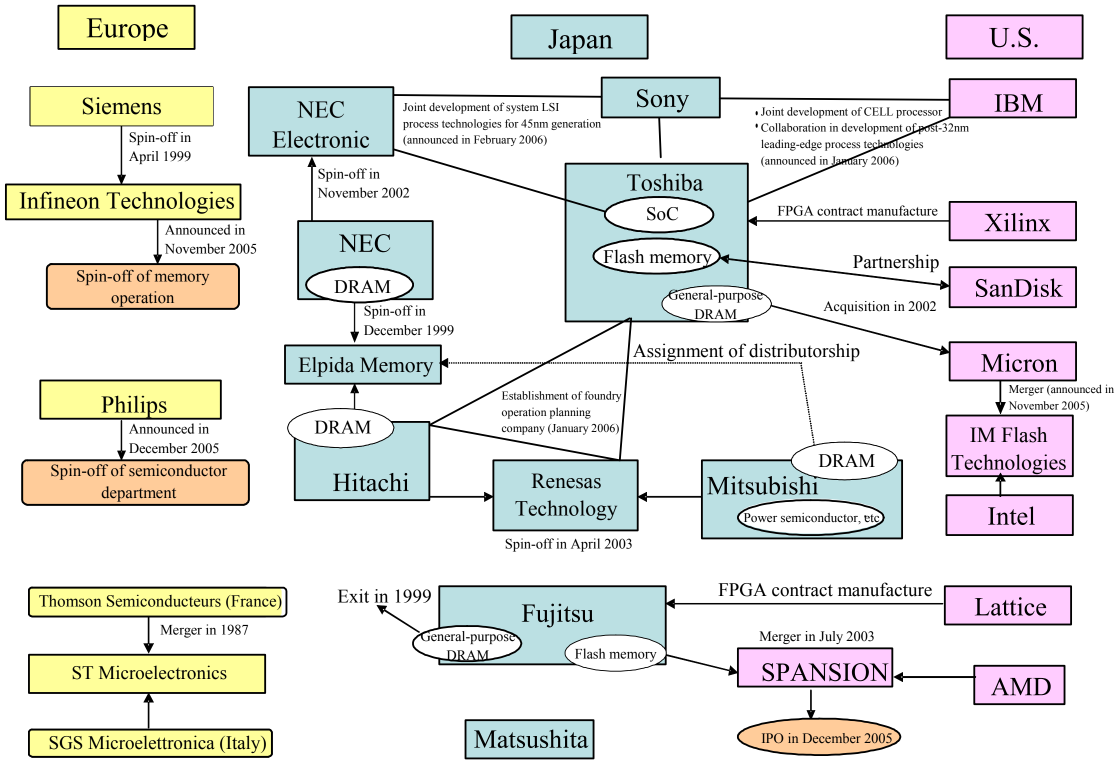
Hundreds of billions of dollars are required to build a leading-edge semiconductor fab. Few manufacturers, if any, can afford to shoulder such huge investment costs. Colossal R&D expenses are also required to overcome the problems confronting nano-level SoC design. Thus, sharing risks inherent in business investment and R&D between two or more companies has become a compelling reality. Due largely to differences in production processes, such full-scale collaboration has materialized only rarely.

The initial process of semiconductor manufacture alone contains hundreds of steps. Since Japanese manufacturers often incorporate custom specifications in manufacturing equipment, individual manufacturers adopt slightly different production processes and hence a chip produced on one company's line cannot easily be reproduced on another's. Thus, to carry out its responsibility as a supplier, each company has to continue manufacturing the products it developed in the past, even after sales start to decline. The resulting increase in the variety of products produced leads to a rise in production cost. This vicious cycle has already been repeated several times.

Design is a key differentiation factor in the SoC business. Establishment of a common production process would open the way to solving the problems described above, allowing more investment to be directed to design and marketing. In February 2006, three Japanese companies – NEC Electronics, Sony and Toshiba – agreed to jointly develop system LSI technologies for the 45nm generation (see Figure 6-4). By collaborating in the development of next-generation process technologies, the three companies aim to raise development efficiency and further accelerate the pace of development.[26] Similar agreements might result in joint utilization of fabs in the future. In this sense, this move should attract particular attention as a sign that a new SoC business model may be emerging in which each manufacturer does not necessarily utilize its own fabs.

[25] See Cadence website (press release dated March 21, 2006).

[26] See NEC Electronics, Sony and Toshiba websites (press release dated February 1, 2006).



Sources: Company websites, etc.

Figure 6-4. Movement towards Collaboration and Reorganization among Domestic and Foreign Semiconductor Manufacturers (as of March 2006)

2.3. Rebuilding Relationships with Final Set Product Departments

Most Japanese semiconductor manufacturers operate as IDMs, i.e. corporate groups with final set product departments. Figure 6-5 shows the production of Japanese IDMs by region and their share in world production as regards three typical set products: color TVs, video recorders (DVD video and VTR) and digital cameras. Although production facilities have been shifted overseas for all these products, Japanese companies maintain a substantial share in the world market: 41.6% for color TVs, 49.3% for video recorders and 76.6% for digital cameras (see Figure 6-5). The crux of the matter lies in the fact that, despite this competitive edge in set products, Japanese companies have not necessarily been able to retain an overwhelming share in key-device semiconductor markets.

One of the reasons why Japanese companies have not been able to capitalize fully on their abilities as general electronics manufacturers is the difficulty of defining a clear boundary between sales within the group (internal sales) and external sales. Application-specific products such as SoCs are customized to the needs of individual clients in terms of design and development. Therefore, the volume of production cannot be expected to increase as long as the product only meets the needs of a single client. Even the recovery of development costs might be at risk if the set product fails to find a market. In this context, Japanese manufacturers need to standardize custom products into ASSPs, because failure to do so means no external marketing and hence erosion of profits. They will have to start with product development in partnership with a leading-edge client, and then develop the output into a *de facto* standard by using horizontal marketing.

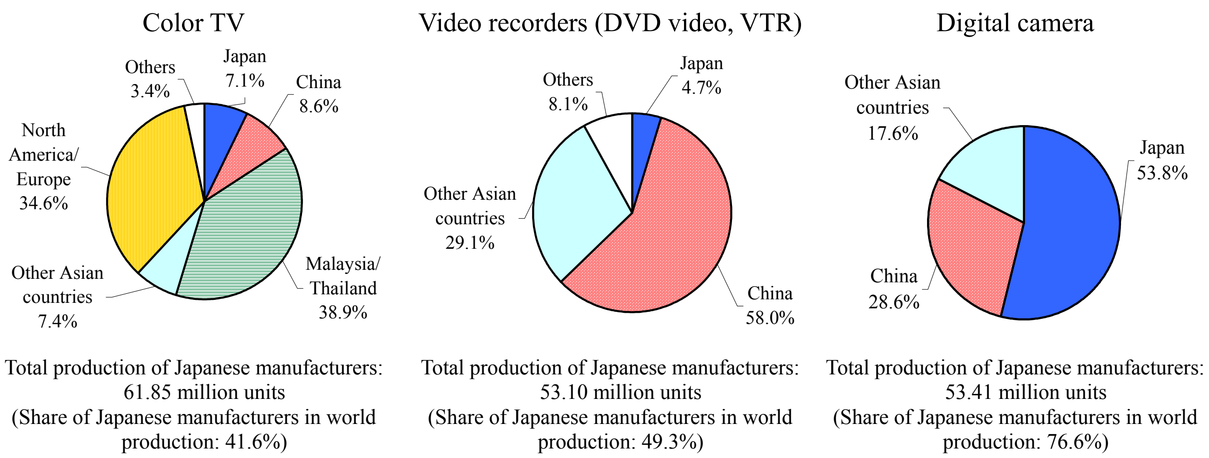
As long as a semiconductor manufacturer stays within the framework of an IDM, it will have to give preference to the internal set product department over external customers. Nonetheless, we should remember that more "leading-edge" clients are now found overseas than in Japan. Some companies have moved towards spinning off the semiconductor department in recent years. Real success in this effort entails reconstructing the relationship between the set product department and the semiconductor department so as to grant greater independence to the latter, and establish a regime that allows active involvement in alliances with global clients. The ability of management will be judged by how to build strategic partnerships in which all stakeholders will benefit from supplying the developed chips to a wider range of clients.

Striking a balance between internal and external sales is a major challenge affecting the basis of corporate business management, as optimal balance also depends on the competitive edge held by the internal set product department and the cost competitiveness of the chips concerned. No semiconductor company spun off from an IDM should give in to peer-pressure to adopt a half-hearted strategy.

Some general electronics companies may want to retain their semiconductor department. In this case, the most crucial role to be played by the semiconductor department is to supply key devices that contribute to differentiation of the group's products. However, a semiconductor manufacturer will not be able to gain sufficient profits from internal sales alone. External sales should be introduced by taking the following steps.

1st step: Develop a leading-edge, custom product with the potential to differentiate the set products.
Design assets of the set product and semiconductor departments should be integrated to develop a leading-edge custom product. As long as the semiconductor manufacturer serves as a department of the general electronics company, the chip has to be a powerful device that forms the core of product differentiation. Since the chip will be developed for the group's set products only at this stage, the semiconductor manufacturer will have to seek total optimization, even if this means sacrificing profits to maximize sales of the final products.

2nd step: Develop the custom product into an ASSP through external sales.
Once a considerable portion of the initial investment has been recovered by the sales of the set products, the manufacturer will start external sales of the custom chip at a premium. This may require a bold decision, especially when doing so may undermine the interest of the set product department. Given that other manufacturers may



Source: Japan Electronics and Information Technology Industries Association, "World Production of Major Consumer Electronic Equipment."

Figure 6-5. Japanese Manufacturers' Production of Major Consumer Electronics by Region and Share in World Production (2004)

start marketing less expensive chips sooner or later, management will need to exercise its judgment from a broader perspective so as not to miss a profit-making opportunity in the semiconductor business. Selling the custom chip to external clients may set off a vicious cycle. The market's evaluation of the chip will improve if it is used by a larger number of partners, winning new clients for the manufacturer and bringing it one step closer to a global standard.

3rd step: Develop the ASSP into a general-purpose product.
If the manufacturer succeeds in developing the custom chip into a *de facto* standard ASSP, opportunities for volume production will increase in emerging markets, including BRICs. The volume efficiency may ensure an even greater profit in the semiconductor business.

The vertical specialization business model aims at generating large profits by standardizing interfaces to bring down the cost of integration. In order to cope with this model, IDMs have to establish their own business model that takes full advantage of their strengths: i.e. to develop original chips that outclass others and then market them to external clients in a timely manner to receive maximum orders. They will have little chance of prevailing against vertically specialized alliances once a standard has been established for interfaces between elemental technologies. The best way to prevent this from happening is to bring internal resources together to invent set products and chips that cannot be copied by others; but first, the chips thus developed will have to be examined closely to see if they warrant the substantial cost of customization.

SoCs integrate entire systems on a single chip. Success in the semiconductor business will therefore depend heavily on whether the manufacturer can retain a powerful application product with an overwhelming market share. As was mentioned in the previous chapter, Japanese semiconductor manufacturers primarily target the domestic market and are highly dependent on domestic consumer electronics manufacturers. Therefore, the competitiveness of set product manufacturers, including digital consumer electronics companies, will remain crucial to the Japanese industry. Further upgrading of new set product development capacity will be required through enhanced collaboration with supporting industries, including material suppliers and manufacturing equipment makers.

2.4. Overhaul of Corporate Management, Organization Control and Personnel Evaluation

This chapter has so far identified some of the strategies for strengthening competitiveness in the SoC business. These include: shifting the focus of operations from fabrication to design/marketing; horizontal development of custom products to ASSPs in view of external sales; building global partnerships around IP; risk sharing in business investment and R&D; and rebuilding relationships with final product departments. All these items are closely related to the nature of business management and corporate strategies. As far as the SoC business is concerned, it is essential to focus on the concept of "concurrent management," which horizontally links, and simultaneously optimizes, product development, fabrication and sales strategies. High levels of expertise and a determination to make bold decisions are required of senior management.

Organizational control and personnel evaluation must also be revised to fit the SoC business. In order to ensure that substantial sales and R&D expenses will bring profits, it is necessary to conduct a thorough review of the production-oriented organizational structure and implement a paradigm shift to an organization focused on design and marketing. In personnel assessment, an attitude should be developed to thoroughly evaluate cross-departmental efforts, in addition to the traditional evaluation by individual departments such as production and design.

To revitalize sales overseas, some point out the necessity of developing relationships with local clients based on dialogue and proposals. Indeed, Japanese semiconductor manufacturers are seeking to enhance their establishments overseas by building up development staff. If they are to build powerful alliances on an equal footing with world-class fabless companies and IP providers in Silicon Valley and elsewhere, Japanese manufacturers should also consider strategic moves under a give-and-take policy, such as speeding up development by providing clients with high-performance IP and combining these with clients' IP.

3. In search of a New Business Model for Japanese IDMs

In the general-purpose semiconductor market on which many Japanese companies focused their operations, difficulties are clearly reflected in the fact that a company's competitiveness largely depends on the business model it adopts. SoCs require a shift in business focus from production to design/marketing. It is not an exaggeration to say that the adjustment of management structure to this new paradigm is the key to survival for a semiconductor manufacturer. Specialized manufacturers have succeeded in expanding their commercial opportunities by successively creating brand-new business forms and models such as fabless ventures, foundries, IP providers, IP libraries and the Wafer Bank Strategy. In responding to the SoC business, IDMs will have to face one fundamental question: are their fabs indispensable to earning profits?

A manufacturer with its own fab can expect coordination between design and production as well as huge profits in good times. At the same time, however, it has to bear the heavy burden of fixed cost in bad times, and may even be forced to reduce prices to keep up production rates. Any constraint by the specification of its own fabs on product design and lineups could become an obstacle to marketing an application-specific product to a wider range of clients.

Although Intel and TI also have their own fabs, these major IDMs focus their operation on a narrow range of products, such as MPUs and DSPs, that enable them to set global standards before starting volume production. Indeed, they ensure high levels of profit by maintaining price levels while holding down costs. In comparison, Japanese IDMs are focusing on consumer electronics markets, where many final product makers are engaged in a fierce competition for a larger market share. This, along with a strong preference of clients for custom products, makes it difficult for them to secure a large volume of production per item, as seen in the case of processors. What is worse, they can hardly expect stable profits, as digitization accelerates the commodity market.

It is therefore essential for a manufacturer with its own fabs to produce global-standard semiconductors that may be sold in sufficiently large quantities to recover investment cost. A manufacturer of world-leading digital consumer electronic equipment may rightfully retain a semiconductor department, mainly for differentiating its products. However, it is hard to imagine that all IDMs are in such a position. Most of them should identify the size of the potential client base for horizontal marketing in the first place. If it is difficult to improve profits, they will have to consider utilizing external fabs. If they are to maintain their focus on digital consumer electronics as an application for SoCs, they will have to revise their business management accordingly. The traditional IDM model will not do in either case.

There is no fixed business model for SoCs. On the contrary, various options may exist. Having distinctive manufacturers compete in their respective areas of specialization would be much better than to have a large number of players using similar models. Venturing into joint development is definitely a viable option in infrastructural fields where product differentiation is difficult. In this respect, development of common process technologies is a potential trigger for such a choice. Elsewhere, concrete methods of developing custom products into ASSPs through horizontal marketing should include narrowing down the scope of their application. A SoC maker constantly needs to monitor trends in various industries, as the chip is used for a range of products including cellular phones, consoles, digital consumer electronics and automobiles and hence requires joint development with end users from the outset. In some cases, it will be more efficient to concentrate managerial resources on a specific area, and subsequently expand the client base, than to cover a full range of applications with limited resources.

In any case, the first step for any manufacturer will be to revisit the fundamentals of management strategy in light of the four strategies presented above to increase competitiveness in the SoC business, while taking account of its own particular conditions. Does it really make economic sense to maintain its own fabs? Is it impossible to ensure differentiation in design and marketing while using common process technologies? These questions should be examined fully, followed by cross-sector discussions. It is time for Japanese semiconductor manufacturers to renew their business models to meet the challenge of SoCs.

Conclusion

In Europe and the U.S., emerging design ventures such as fabless companies and IP providers have been flying high on the wings of their original expertise. As was noted earlier in this report, fabless companies are also growing rapidly in Taiwan, the home of world-leading foundries. Although semiconductor production requires huge investment, the design of circuits and the development of IP depend essentially on ideas. For this reason, the market is relatively easy to penetrate even for a small venture, provided that it has unique skills and a capacity for market cultivation. This has directly increased the competitiveness of the semiconductor industry as a whole.

Although some semiconductor ventures have started up in Japan, they lag far behind overseas counterparts in number and scale. Most Japanese semiconductor manufacturers take the form of IDMs, which perform the whole manufacturing process in-house, from design to fabrication. It is not easy for these firms to further expand their operations as long as they supply the domestic market. Some observers note that fabless companies will not be able to expect a flexible response from IDMs even if they wanted to outsource chip fabrication, because they tend to give priority to manufacturing their own products. It has also become increasingly difficult for a small venture to design a SoC on its own, as a large number of functional blocks have to be integrated on a chip.

The vertical specialization model prescribes a clear division of labor between fabless companies and foundries. Thus, fabless companies actively sell the outcome of their development and design activities to external clients, while foundries try to win more contracts by providing IP libraries and otherwise building global alliances. In contrast, many of the leading Japanese semiconductor manufacturers find it difficult to adopt a bold external sales strategy out of consideration for set product departments in the same group. In this way, they may be missing out on a chance to have their excellent designing and manufacturing techniques appreciated by outsiders.

Design is by far the most crucial process for SoCs. In this connection, EDA has become so valuable that many consider it impossible to design any semiconductor without the help of an EDA tool. Although leading Japanese semiconductor manufacturers used to develop their own EDA, they have phased out in-house development as tools manufactured by U.S. vendors gradually established their products as global standards. In the world of SoCs, coordination between fabrication and design is paramount. Observers have alerted Japanese manufacturers of the risk of allowing overseas manufacturers to control the crucial design tool market. Recently, multiple EDA ventures have been created by former engineers involved in research and development on EDA in major Japanese electronics manufacturers, as well as by academic faculty members. A Japan EDA Venture Consortium (JEVec) was established in January 2006. It is worth monitoring whether these movements will help revitalize the Japanese semiconductor industry.

An unconventional, innovative approach is often required when designing a semiconductor. If IDMs stop clinging to their own fabs and further increase the effective use of external resources, Japanese semiconductor ventures will be able to expand their field of activity, possibly increasing the competitiveness of IDMs. Alternatively, if Japanese IDMs are to uphold the model of “vertical integration” in the SoC business, they should redouble their efforts to enhance collaboration between the device and set product departments. One of the strengths of a general electronics manufacturer lies in its ability to increase the value added to a product with a total approach encompassing devices, production, sales and customer service. Management’s skills will be judged by whether the company can achieve the convergence of compartmentalized business departments.

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