The Competitive Advantage
– A Case Study of Taiwan's Semiconductor Industry

by

James J.M. Fang

B.S. Physics National Tsing-Hua University Taiwan 1982

Submitted to the Sloan School of Management
In Partial Fulfillment of the Requirement for the Degree of

Master of Business Administration

at the

Massachusetts Institute of Technology

June 2002

Signature of Author : ______________________________
MIT Sloan School of Management
May 6, 2002

Certified by : ______________________________
D. Eleanor Westney
Society of Sloan Fellows Professor of International Management
Thesis Supervisor

Accepted by : ______________________________
Stephen J. Sacca
Director , Sloan Fellows Program

The Competitive Advantage
- A Case Study of Taiwan's Semiconductor Industry

by

James J. M. Fang

Submitted to the Alfred P. Sloan School of Management
on May 6, 2001
in Partial Fulfillment of the Requirements for the Degree of
Master of Business Administration

ABSTRACT

As the world enters into the twenty-first century, technology is now more than ever the key factor in the promotion of industrial development and economic growth. Countries must carry out their industrial technology development in such a way as to create strong high-tech industries that can successfully compete in the global markets, while moving their national economies in the direction of prosperity. In light of these challenges, an overall technology development strategy has became the critical factor for success.

This thesis investigated the competitive advantages of Taiwanese semiconductor industry; specific areas of study included:

- The development of Taiwan's semiconductor industry,
- The competitive advantages of semiconductor companies in Taiwan,
- Evaluation of the competitive strategies and its value chains,
- The sustainability of the competitive advantages of Taiwanese companies,
- Taiwan's industry value chain and the growing China market,
- The challenges confronted in the future strategic direction.

Taiwan's semiconductor industry is excellent in its quality manufacturing and operation management. How can it move its semiconductor industry in an innovation-oriented and high value-added direction? This is the most significant challenge confronting industry and government in the next few years.

Thesis Advisor: D. Eleanor Westney
Title: Society of Sloan Fellows Professor of International Management

Acknowledgements

This thesis was made possible with the assistance and encouragement from a variety of sources, for which I want to extend my sincere thanks and appreciation.

I would like to thank all our professors for their professional knowledge and instruction and the Sloan Fellows Program director and staff for their dedication during the year here at MIT Sloan. I will remember all my Sloan Fellows colleagues for their sincere friendship and hospitality throughout the year. They have enhanced the value of Sloan experience in many ways; my memories will be cherished for a lifetime.

Special thanks to my thesis advisor, D. Eleanor Westney, for her inspiration and support, and the colleagues from my company, Winbond Electronics Corporation, especially Hui-Chen Ku Lai, for their assistance and encouragement which accompanied me throughout the process.

I also would like to thank Y.C. Chiao, chairman, and C.C. Chang, president of my company. They made my dream come true and supported me during my study at MIT Sloan.

Finally, I would like to express my appreciation to my families, especially my wife Susan Chang, and my sisters Amy Fang and Janet Fang and their families. They have given me everything. Their attention and support made this possible.

James J. M. Fang, SF02

April 17th, 2002

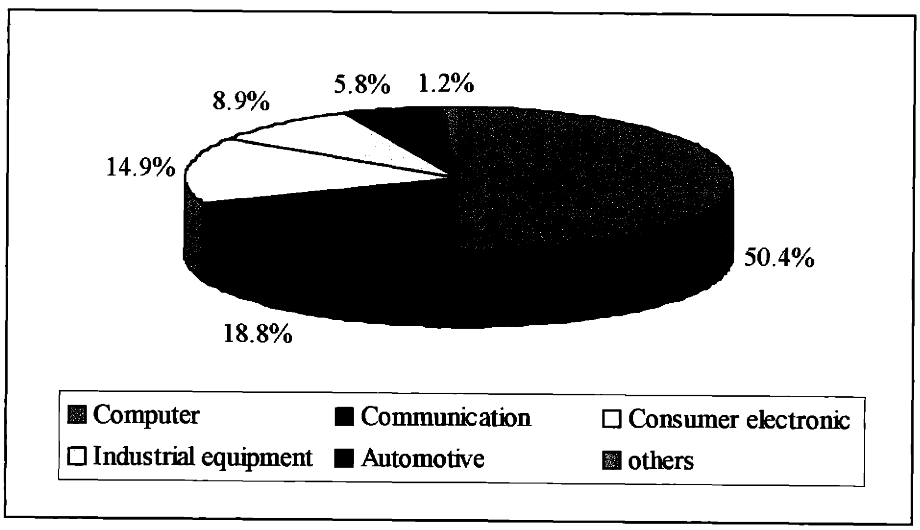
TABLE OF CONTENTS

Chapter 1

A look at the world semiconductor industry

1.1 An overview of semiconductors

Semiconductors are used in most electronic products and systems, including computers and other data processing equipment, consumer electronics, industrial machinery, tele-communication equipment, automobiles, other transportation systems, medical equipment, analytical instruments and military electronic systems. According to the World Semiconductor Trade Statistics (WSTS) organization, the computer industry was the largest end user of semiconductors in 1998. It accounted for 50.4% of worldwide semiconductor sales. Communication products represented 18.8% of global semiconductor demand. The consumer electronic product sector was the third-ranking end user and took 14.9% of the worldwide sales. The industrial equipment sector and automotive industry followed with 8.9% and 5.8% respectively. (See Figure 1-1).



Source : Dataquest 2001

Figure 1-1 World semiconductor consumption by product

Semiconductor manufacturing is a capital and research intensive industry. The cost of semiconductor manufacturing plants have been steadily increasing. A state-of-the-art semiconductor wafer manufacturing facility cost an average of $1.5 billion in 1999. This huge capital investment amount has led to the growing numbers of mergers, collaboration agreements and contract manufacturing in the industry worldwide. According to the Semiconductor Industry Association (SIA), around one third of the industry revenue was invested into technology development and capacity expansion capital spending. The report indicated that the U.S. semiconductor industry invested 13% of sales revenue in R&D in 1997; total spending in plants, properties, and equipment by the U.S. companies was roughly about 18% of the sales in 1997. The combined investment of 31% of sales revenue is much higher than any other manufacturing industry.

1.2 What is a semiconductor?

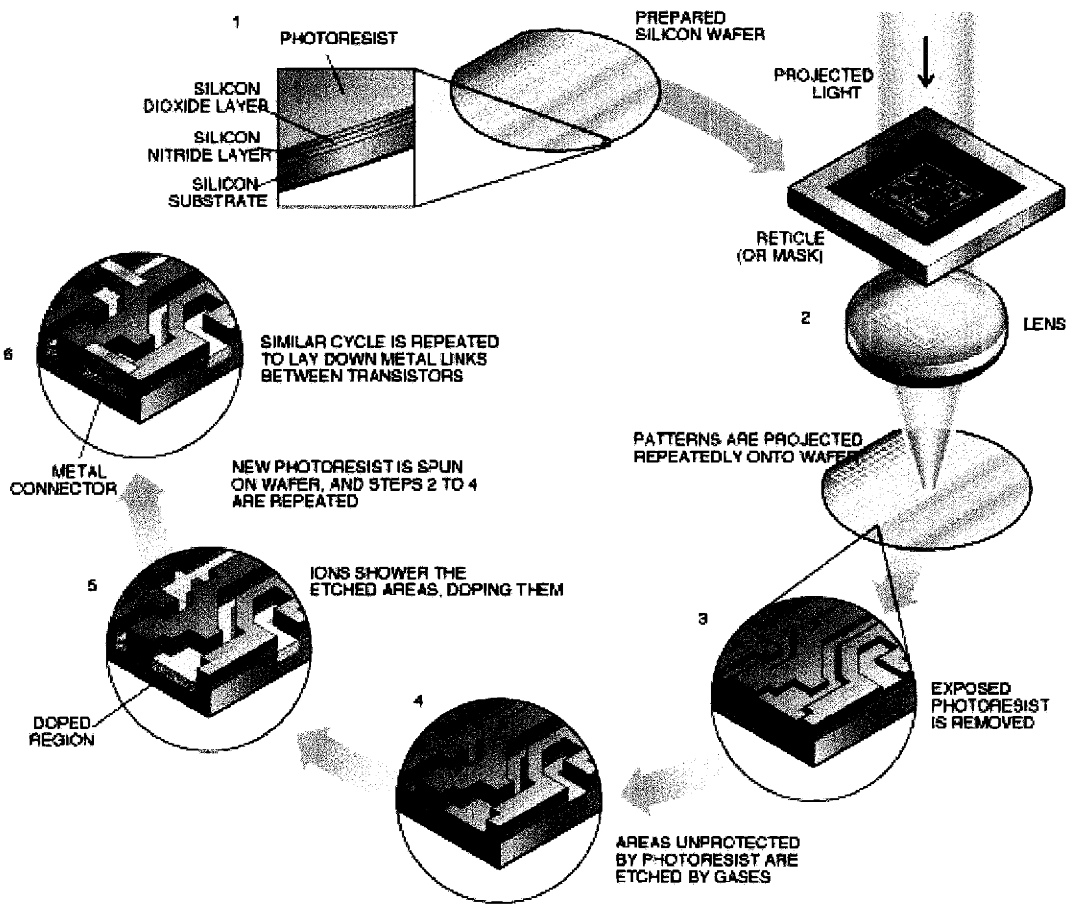
Semiconductors are referred to as "the crude oil of the information age"; they are a pervasive, but generally unseen, aspect of everyday life. The tiny electronic circuits etched on chips of silicon are critical to the operation of virtually all electronic products, from coffee makers and antilock breaking systems of automobiles to cellular phones and superconductors in laboratories.

Semiconductor chips are manufactured in "clean rooms, "free of contaminating dust facilities, where thin and round "silicon wafers" are processed in batches. Chipmakers buy polished blank wafers from companies that specialize in growing silicon crystals, from which the wafers are cut into slices and put through polishing, cleaning and annealing processes. Each wafer piece is about half a millimeter thick and microelectronic circuits are built up on the silicon wafer layer by layer.

The circuit patterns are built by the collection of transistors, capacitors and associated components and their interconnections. These devices are inscribed on a 5 or 6 inches glass plates called photomasks. These photomasks patterns are later reduced through photolithograthically projection onto the silicon wafers. Such photo-masking steps are typically needed around twenty to thirty times in the latest process technology. (See Figure 1-2 for an illustration of the chip fabrication process). Each photomasks set comprises a complete integrated circuit design.

Chip Fabrication

CHIP FABRICATION occurs as a cycle of steps carried out as many as 20 times. **1)** Many chips are made simultaneously on a silicon wafer, to which a light-sensitive coating has been applied. **2)** Each cycle starts with a different pattern, which is projected repeatedly onto the wafer. **3)** In each place where the image falls, a chip is made. The photosensitive coating is removed and **4)** the light-exposed areas are etched by gases. **5)** These areas are then showered with ions (or "doped"), creating transistors. **6)** The transistors are then connected as successive cycles add layers of metal and insulator.



Source : Scientific American 2002

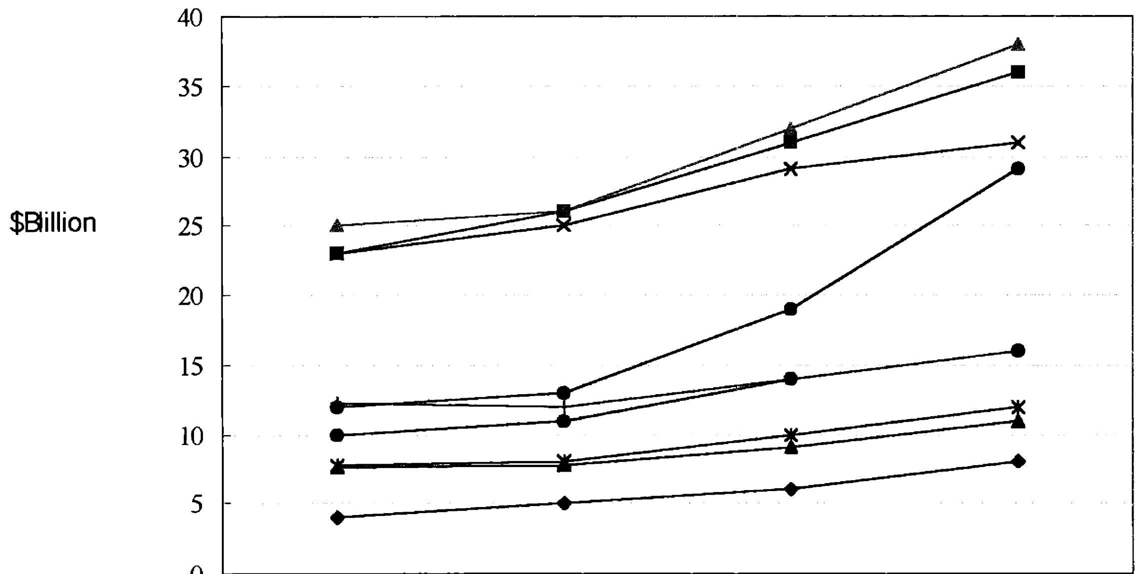
Figure 1-2 Chip fabrication process

Semiconductor companies design and manufacture primarily two types of products: discrete devices and integrated circuits (ICs). A discrete semiconductor is a individual circuit that performs a single function affecting the flow of electrical current, for example a transistor that amplifies electrical signals, a rectifier or diode that converts alternating current into direct current, a capacitor that blocks the flow of alternating current at a controlled levels, or resistors that limit current flow and divide or drop current. Discrete component manufacturers can use existing facilities and technology for quite a long time without huge capital investment.

ICs are also called chips. Integrated circuits are the collections of microminiaturized electronic components, such as transistors and capacitors, placed on a tiny rectangle of silicon. A single integrated circuit can perform the functions of thousands of discrete transistors, diodes, capacitors and resistors. There are three basic types of integrated circuits: memory devices, which are used to store data or computer programs; logic devices, which perform operations such as mathematical calculations; and components which combine the two (a type of integrated circuits which can function sophisticatedly and repetitively, such as microprocessors and microcontrollers).

Memory ICs include many different types: DRAM (dynamic random access memory), SRAM (static random access memory), EPROM (Erasable, programmable, read only memory) and flash memory.

A DRAM stores digital information and provides high speed storage and retrieval of data. It is called a "dynamic" circuit because the data are stored in a temporary medium that allows them to fade and so must be constantly refreshed electronically. DRAM is by far the type used most in computers. The DRAM is the most significant semiconductor product from the perspective of total worldwide semiconductor revenue. It comprises more than 10 % of the total semiconductor market of 2000. (See Figure1-3 for the world share forecast of different types of IC products).



	2001	2002	2003	2004
DSP	4	5	6	8
Analog	23	26	31	36
MOS Logic	25	26	32	38
Microprocessor	23	25	29	31
Flash	7.8	8.1	10	12
Microcontroller	10	11	14	16
Discrete	12.3	11.9	14	16
DRAM	12	13	19	29
Optoelectronics	7.6	7.7	9	11

Source: SIA 2001; Topology 2001/11

Figure 1-3 2001-2004 World semiconductor product market forecast

SRAMs perform many of the same functions as DRAMs, but with a higher speed. Unlike DRAMs, they do not require constant electronic refreshing, hence the term “static.” They contain more circuitry and are more expensive to produce than DRAMs of same density.

Non-volatile memories, such as EPROM and flash memory, hold information in the absence of power supply. EPROM typically stores a computer’s BIOS (basic input/output system) information. Flash memory is gaining ground in portable devices, including PDAs, digital cameras and audio recorders.

Most logic devices semiconductors are customized and integrated to the specific needs of each customer. These application–specific, integrated circuits can be divided into full-custom ASICs, standard cells, semi-custom chips and programmable logic devices, which are different in the degree of customization of the chips. ASICs tend to be more expensive than integrated circuits built from the off-shelf components. Yet, because they combine several specialized functions on a single chip, they offer some important advantages, such as smaller size, simpler structure and a smaller number needed in a electronic system. They allow a greater degree of integration, which leads to a more efficient use of circuitry and the enhancement of overall performance.

Microprocessors are the central processing units in all micro-computer-based systems. These processors perform a variety of tasks by manipulating data within a system and controlling inputs, outputs, peripherals and memory devices. Two types of microprocessors are used: CISCs (complex instruction set computing) and RISCs (reduced instruction set computing). Though CISCs used to be the basis for all microprocessor operations, RISCs became increasingly popular in the 1990s because of their faster operating speeds, their ability to run more sophisticated software, and their better graphics delivery capability.

Intel Corporation has dominated the microprocessor segment throughout most of the history of personal computers. The first processor in an IBM PC was Intel's 8088. That processor operated at 4.7 MHz and could handle eight bits of data at once. By comparison, the 80486 processor can operate at 133 MHz and handle thirty two bits of data. Intel's microprocessors currently power the majority of the world's personal computers. The most recent microprocessor offers the speed of up to 1.5GHz and handles sixty-four bits. Competitors in the market, such as AMD and others, are increasingly gaining market shares against the monopoly giant.

Microcontrollers combine a microprocessor, memory circuits and input/output circuits. They are used as embedded controllers in virtually every electronic product. They perform such repetitive tasks as controlling the antilock break systems in automobiles and many other automatic electronic equipment.

1.3 Global market players in semiconductor industry

The U.S. semiconductor companies

U.S. companies are major players in the global electronic industry; roughly half of the U.S. semiconductor revenues are derived from foreign sales. According to Dataquest's estimate, the U.S. semiconductor industry's share of the world market is around 51%. (See Figure 1-4). The largest market for U.S. semiconductor exports is the Asia-Pacific region. The exports to the Philippines and Malaysia are mostly unfinished parts that receive further processing (mostly assembly and testing) and are re-exported to the U.S. and other countries. Most of the exports to Taiwan and Korea are personal computers and cellular phones which need ICs (CPUs and DSP chips). American companies are generally the new product developers; as they possess a huge domestic market, they can easily access market trends and changes. With the creative environment and opportunities, they dominate the definition of new product standards, specifications and intellectual property rights. This capability is far beyond imitation from the other countries.

The Japanese semiconductor companies

The Japanese electronic giants have lost billions of dollars in the DRAM business during the downturn of semiconductor cycle 1997-1998 and the 2001 recession because of dramatic falling memory prices. These severe losses set the stage for a wave of consolidation, mergers, restructuring and other cost-cutting moves. For example, NEC and Hitachi merged their core DRAM business in 1999; other Japanese firms restructured operations, closed plants, streamlined management, slashed capital spending, reduced employments, forged joint ventures (mostly with Taiwanese companies), and outsourced production (most OEMs by Taiwanese companies). Many of them, forced to exit from the commodity DRAM business, focused on non-memory, high-end computing, digital consumer electronics and communications products. The Japanese market share of world semiconductor industry is roughly around 25%, according to Dataquest's estimate. Japanese companies, however, still possess a very competitive semiconductor industry infrastructure, including all the peripheral supporting industries (raw materials, equipment, system products, etc.); its domestic market is also a comparable size. It is the only country whose semiconductor industry can compete with the United States. Even though Japanese companies lost their competitive position in the commodity DRAM market, they still occupy a relatively significant position of many different applications in semiconductor industry.

The European semiconductor companies

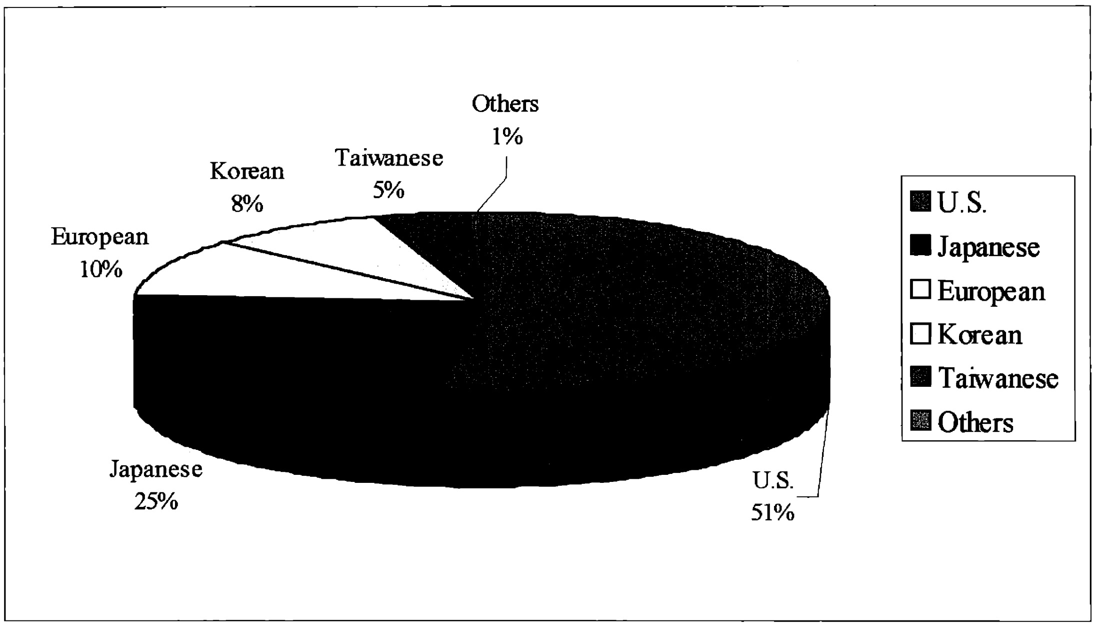
The European semiconductor companies are well positioned in key growth markets, including the mobile phone, digital TV, set-top box, IC cards and automobile electronics markets. Only one European manufacturer, Infineon (spun off from Siemens), remains in the DRAM market, but it relies heavily on the joint venture and alliance with Taiwanese companies in DRAM production. The other two are ST Micro and Philips Semiconductor. As the transition from the personal computer to a communication-driven market accelerates, European semiconductor companies are likely to gain more market share growth. Their share of world market was around 10% in 2000, according to Dataquest's estimate. All three of these companies ranked among the world's top ten semiconductor manufacturers in 2001. (See Table 1-1). The European semiconductor companies are somewhat different from other companies in the State or Japan; they focus more on their telecommunication territories and European markets. They also suffered less in the silicon cycle downturn.

The Korean semiconductor companies

South Korea semiconductor companies had been a leader in the DRAM segment. Confronted with the memory market downturn in 1996-1998, Korean companies slashed capital spending, curbed DRAM production and, in the wake of Asian financial crisis and economic reforms, Hyundai Electronic and LG Semicon were urged by the Korean government to merge their DRAM operation in 1999. This merger created the world's second-largest DRAM manufacturer, Hynix, just behind its competitor Samsung, the world largest DRAM maker. But due to the drastically eroded price in DRAM products in 2001 and the highly leveraged financial situation of Hynix Electronics, the company has been in risk of bankruptcy since the third quarter of 2001. Korean semiconductor companies rely on commodity memory products which put them in a worse position compared to other competitors in the world semiconductor market recession in 2001. Their share of the world market was around 8%, according to Dataquest's estimate. The Korean semiconductor companies are supported strongly by their government in the early stage of industry growth. They focused on single-product, high-volume production strategy. As its overall risk is much higher than other countries, after the long downturn during 1996-1998, they are also trying to diversify their product lines gradually. Foundry and logic product line are their targets, which means the big threat to Taiwanese companies.

The Taiwanese semiconductor companies

Taiwan has emerged as an important semiconductor production location in the Asia-Pacific region. Taiwanese companies are among the world's 10 top capital spenders in the past few years. (See Table1-2). Semiconductor Equipment and Materials International trade association forecasts that Taiwanese capital investment could reach US$80 billion over the next ten years. Its total production registered a 69% growth in year 2000, and reached a revenue of US$22.7 billion. Taiwanese semiconductor companies are world leaders in the contract manufacturing of semiconductor chips. Its IC design industry is also the most competitive sector in the world; however, as over-investment in electronics sectors and the serious slump for dot-com companies have damaged the world economy since last quarter of 2000, Taiwan as one of the leading manufacturing countries in the world, also suffered from the serious recession in 2001. Its semiconductor market share is around 5% of the world market. The competitiveness of Taiwanese semiconductor companies was built on high quality of engineering talent and the capability of speedy and flexible response to the market changes. As a smart follower, the Taiwanese companies can provide product delivery fast and with lower cost; thus it can have the opportunity to have a competitive position in the world semiconductor market.



Source : Dataquest 2001

Figure 1-4 World semiconductor market share by countries 2000

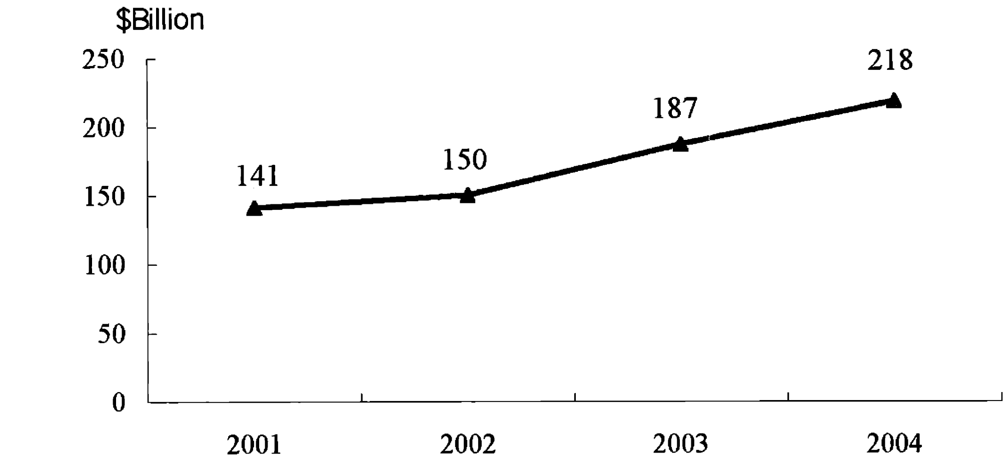
1.4 The world's semiconductor market status

Taking an overview of current world economy situation, after the events of September 11, the global recession is steeper and deeper than originally anticipated, but on the positive side, the ensuing recovery anticipated by second half of 2002, could also be stronger than originally thought. Since the U.S. economy had been sponsoring global economic expansion in recent years, the challenging economic environment of 2001 failed to provide fertile ground for the semiconductor industry's attempts to sow new demand through new technology innovation and product applications.

Following the economic recession in 2001, the electronic equipment demand in 2001 was estimated to have about 12% contraction, For 2002, an economic recovery should provide the foundation of growth again; the forecast shows the slow expansion of the electronics industry at 5%. Such a growth will still be driven by PC and mobile communication applications; the wired related applications will come later. The industry believes that the enterprises spending will ramp first, then consumers could follow later, especially in light of the US stimulus packages.

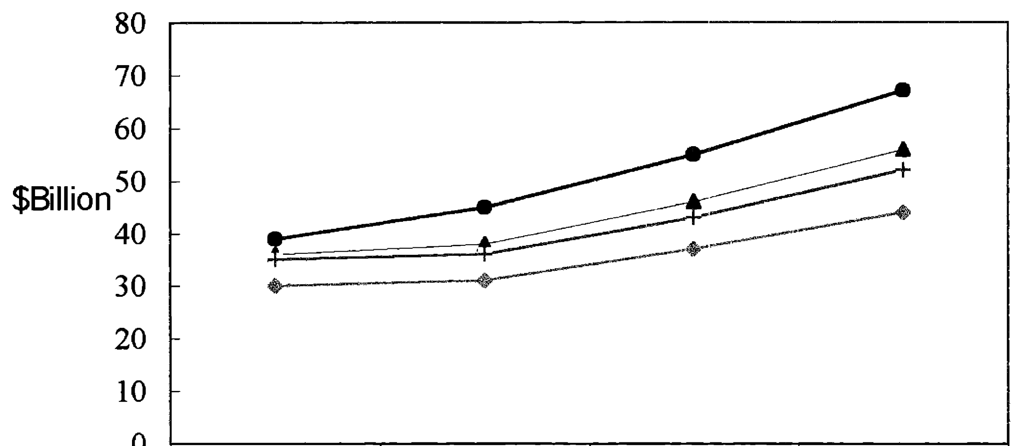
In the semiconductor market, the bottom appears to be in sight as excess inventories are coming under control. The market of year 2002 is anticipated to grow slowly again, but the market recovery will be driven by unit demand increasing, while the average selling price will remain under pressure.

SIA (Semiconductor Industry Association) announced a latest worldwide semiconductor market forecast November 2001. (See Figure 1-5). The report disclosed an optimistic prospect of the world market in the next three years; it seems that the new wave of prosperity is coming. The report forecasted that the recession of the semiconductor industry will be recovered by the 4^{th} quarter of 2001; the new prosperity cycle will gradually come up from 2002, with the highest peak in 2004. If we analyze the product lines, as the same as most of the industry analysts and research institutions, the next wave of growth will be telecommunication application related product needs, especially DSP (digital signal processing), Flash memory, microprocessor, micro-controller, analog IC, etc.. But if we look into the market growth territory, according to SIA information, the Asian Pacific region will still be the major driving force of the growth. (See Figure 1-6).



Source: SIA 2001; Topology 2001/11

Figure 1-5 2001-2004 World semiconductor market forecast

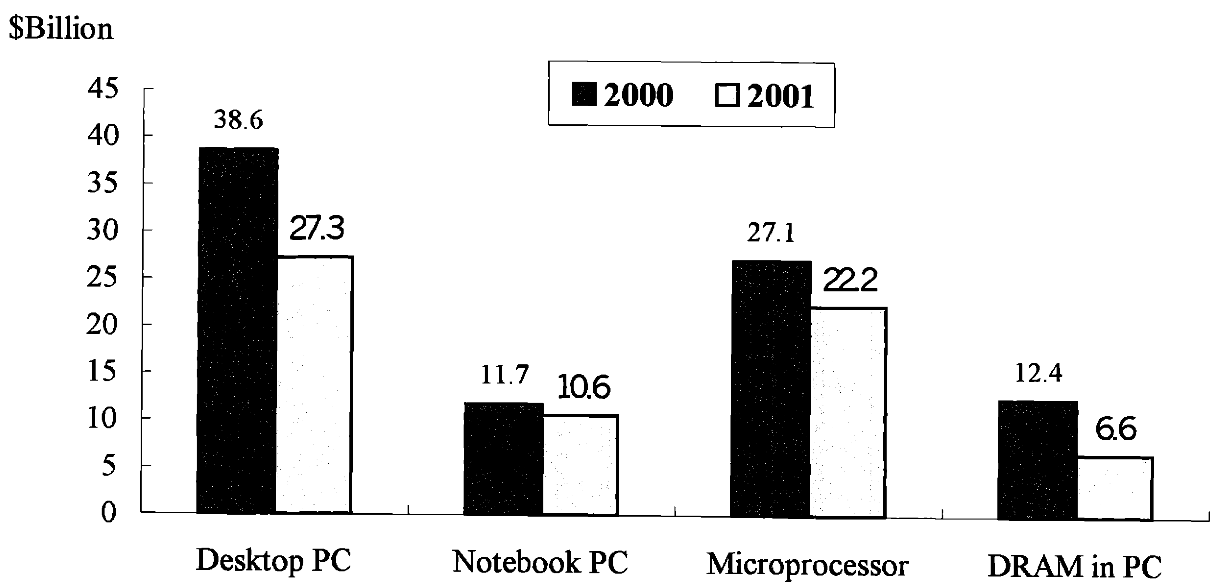


	2001	2002	2003	2004
U.S.	36	38	46	56
Europe	30	31	37	44
Japan	35	36	43	52
Asia-Pacific	39	45	55	67

Source: SIA 2001; Topology 2001/11

Figure 1-6 2001-2004 World semiconductor market forecast by region

According to WSTS (World Semiconductor Trade Statistics) announced in the fall of 2001, the semiconductor market growth rate of 2002 would only be 2.5%. Because this figure is collected from all the major companies in the industry, this is the standard figure which most of the industry market analysts base on. As the PC industry was in the mature stage of its product life cycle, from the PC market update, it seemed that it did not have any surprising story which could happen in the coming year. (See Figure 1-7). In any case, the worst was already there; with the market demand climbing up, there is no reason it can be worse again.



Source: IDC; Topology Tech. Inc. 2001/08

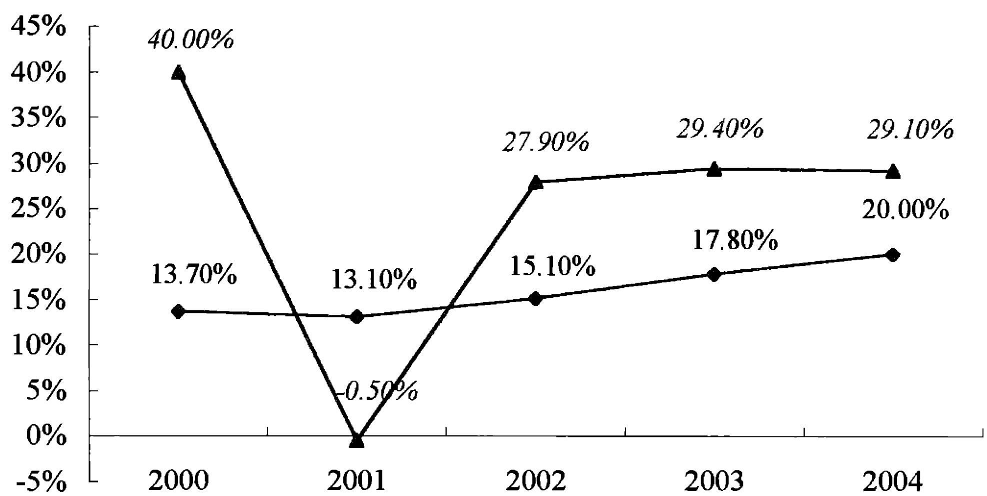
Figure 1-7 World PC market sales estimation 2001-2002

The semiconductor industry has experienced a fast evolution and significant increase in competitive intensity. While Intel has dominated the personal computer segment of the market, the remaining segments still do not have dominant players; in that respect, there are still enormous opportunities for filling the void of each segment's leading players. The industry evolution is following the trend of technology innovation which combined with the business globalization; how to boost the productivity is becoming the major challenge of the industry.

Since the world semiconductor business cycle was around 4-5 years per silicon cycle and the world semiconductor business is in the cycle of 1999-2002 now, the predicted compound annual growth rate was 15.6%. 2000 was the higher side of the growth at 30.6%; 2001 is at the lower side with negative growth – 32% .

Starting from 2001, there are additional twenty-four 8 inch fabs in place and 12 inch fabs are also significantly increasing. Due to the process technology improvements and the new capacity coming up, the demand and supply situation changed at the beginning of year 2001. The major causes were the slower PC industry growth and the world economy recession; both factors triggered the negative growth of semiconductor consumption in year 2001.

IC product design capability, process technology investment and the capital requirement of new facility construction are the three cost factors which are getting higher and higher. They have forced the IDM (integrated device manufacturer) to seek wafer manufacturing outsourcing gradually. Therefore, the industry tends to outsource to foundry manufacturing rather than build its own facility. The foundry manufacturing sector is expected to have the growth rate 23% in the next 5-7 years. (See Figure F1-8).



Source: Semico Research Co.; Topology Tech. Inc. 2001

Figure 1-8 Foundry share in world semiconductor market forecast

1.5 The future semiconductor market forecast

PC related applications were the major driving force for the semiconductor industry in the past decade's growth, but from recent developments in the trend of semiconductor applications, the total consumption of year 2000 semiconductor market reached $204.4B, a 36.8% of increase from US$149.4B in 1999. PC growth achieved a 100 million sets record in 1999, following a good growth in 2000, but the PC growth rate turned into a negative percentage in 2001. It seems that the overall PC industry stepped into a slow growth path in the "post PC era ".

The industry experts further pointed out that some demand side could drive the growth of future world market:

- The faster speed and higher performance PCs should still remain a driving force for the semiconductor industry, as PCs are still assumed to be the core equipment for the multimedia era, especially in the areas of computer-aided design and data base development, given the strong requests from internet users for more video, audio and graphic sophistication in applications.
- The explosion in internet usage and the mass electronic commerce will underscore the long run semiconductor market growth.
- Telecommunications is a surging consumer of semiconductor chips. As wireless communication continues to expand, a drop in price and the increasing usage will follow.
- The portable computing sector is another formidable buyer of semiconductor devices as PDAs and personal electronics goods for entertainment, such as digital cameras and digital audio recorders, grow in popularity.
- The developing economy regions represent large potential markets for semiconductor devices. Communication and information infrastructures need lots of investment during the development process. As both areas are rich in semiconductor content, this is truly an opportunity of large dimensions for the industry growth continuously.

Demand will be geographically spotty in the short term. The Asian region is strengthening, even though European demand is somewhat fragile. In long term, automotive electronics, personal computers, consumer electronics and communication appliances will be the key strong drivers for the future growth of semiconductor industry.

World Top 20 Semiconductor Companies 2001

$ Million

2001 Ranking	2000 Ranking	Company	2001e Revenue	2001e/2000 Growth(%)
1	1	Intel	23,499	-22.4%
2	2	Toshiba	7,136	-34.3%
3	6	STM	6,360	-19.4%
4	4	Samsung	6,320	-40.3%
5	5	TI	6,000	-34.8%
6	3	NEC	5,389	-49.4%
7	7	Motorola	5,000	-34.9%
8	8	Hitachi	4,724	-35.2%
9	9	Infineon Tech.	4,538	-32.4%
10	12	Phillips Semi.	4,440	-29.2%
11	17	IBM Micro.	3,993	-7.7%
12	14	Fujitsu	3,872	-34.6%
13	13	Mitsubishi	3,868	-38.3%
14	16	AMD	3,650	-16.3%
15	15	Agere Systems(Lucent)	3,260	-36.1%
16	18	Matsushita	2,885	-27.7%
17	19	Sony	2,630	-27.8%
18	20	Sharp	2,513	-30.2%
19	10	Micron Tech.	2,450	-61.2%
20	21	SANYO	2,396	-29.8%

Source: Dataquest (2001/12); IEK/ITRI (2002/01)

Table 1-1 World Top 20 semiconductor company 2001

World Top 20 Semiconductor Capital Investment Companies 2001

$Million

2001Rank	Company	Headquarters	1999	2000	2001	2001/2000GR
1	Intel	U.S.	3,403	6,674	7,500	12.4%
2	TSMC	Taiwan	1,846	5,000	2,200	-56.0%
3	Infineon	Europe	889	1,650	1,900	15.2%
4	Samsung	S. Korea	1,800	3,100	1,800	-41.9%
5	TI	U.S.	1,398	2,762	1,800	-34.8%
6	STMicro	Europe	1,348	3,300	1,700	-48.5%
7	Micron	U.S.	885	1,415	1,400	-1.1%
8	IBM	U.S.	950	1,350	1,350	0.0%
9	UMC	Taiwan	1,720	2,800	1,200	-57.1%
10	Atmel	U.S.	172	975	975	0.0%
11	Matsushita	Japan	410	1,095	900	-17.8%
12	Philips	Europe	662	1,510	850	-43.7%
13	AMD	U.S.	620	800	800	0.0%
14	Motorola	U.S.	1,540	2,500	700	-72.0%
15	Fujitsu	Japan	792	1,870	675	-63.9%
16	NEC	Japan	1,315	1,985	670	-66.2%
17	Sony	Japan	405	1,400	600	-57.1%
18	Agere	U.S.	660	675	550	-18.5%
19	Mitsubishi	Japan	500	1,390	500	-64.0%
20	Sanyo	Japan	195	450	435	-3.3%
	Others		11,290	17,999	9,395	
	Total		32,800	60,700	37,900	-37.6%

Source: IC Insights (2002/01); IEK/ITRI (2002/02)

Table 1-2 World Top 20 semiconductor capital investment company 2001

Chapter 2

The development of Taiwan's semiconductor industry

2.1 Introduction

As the world enters into the twenty-first century, technology is now, more than ever, the key factor in the promotion of industrial development and economic growth. This presents an enormous but unavoidable challenge for developing countries; they must carry out their industrial technology development in such a way as to create strong high-tech industries that can successfully compete in the global markets, while moving their national economies in the direction of prosperity. In light of these challenges, an overall technology development strategy has became the critical success factor for an industry in terms of technology acquisition, diffusion and application.

Over the course of the past three decades, Taiwan has regarded the semiconductor industry as one of the most strategically important sectors of the high-tech industries. (See Figure 2-1 for the geographical perspective of Taiwan).

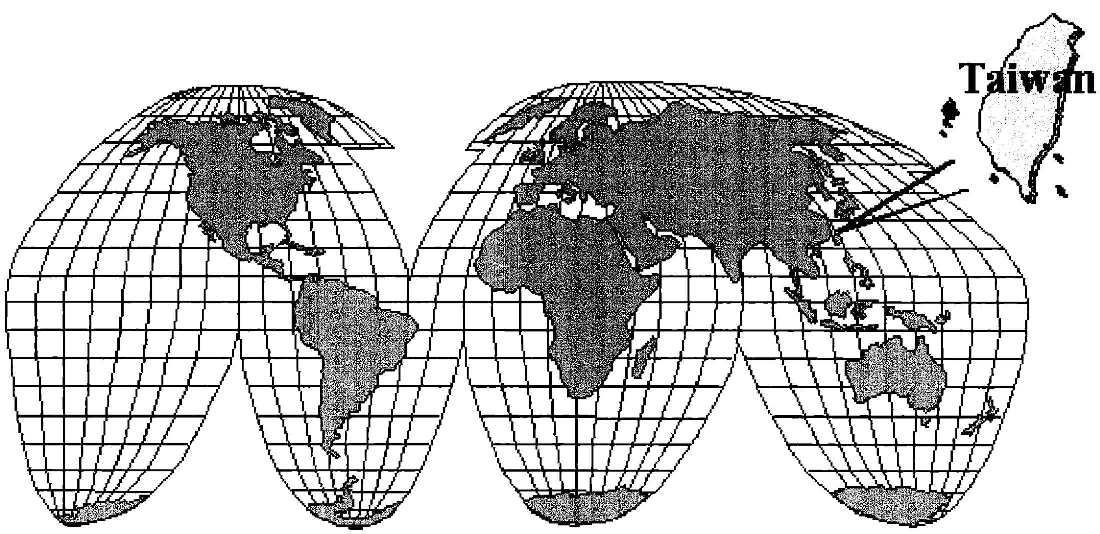


Figure 2-1 Geographical perspective of Taiwan

In the early 1960s, Taiwan's electronics industry was virtually nonexistent. Since starting with a few downstream assembly plants in the mid 1960s, the industry has developed into a comprehensive industrial system with vertical and horizontal dimensions of infrastructure and labor. It has gone through various growth stages, involving foreign-capital-based assembly, manufacturing technology transfer, growth of local companies, industrial system expansion and upgrading. Today, Taiwan's integrated circuit design industry is ranked second in the world, second only to the United States. The total output value of Taiwan's semiconductor industry in design, wafer manufacturing, and packaging in 1999 was over US$15.4 billion; it grew to US$22.7 billion in 2000. As the semiconductor industry is capital-intensive, the investment in capacity is enormous and important to the global market competition. In 1998, Taiwan's semiconductor investment was ranked as the third of the world; the world total investment in semiconductor industry was around US$21.8 billion, 15% of the amount was in Taiwan, second only U.S. and Japan.

2.2 An overview of its development stages

In 1966, when the worldwide IC market reached a high level of sales, a US company, General Instrument Microelectronics, established a semiconductor packaging company in Kaohsiung, the biggest city in south of Taiwan. The company, Kaohsiung Electronics, focused its main business on assembling transistors; this was the start of Taiwan's semiconductor industry.

With Taiwan's semiconductor industrial structure ranging across the full spectrum of IC manufacturing activities: blank wafer production, IC design, photomask making, wafer manufacturing, packaging and testing, many researchers have analyzed Taiwan's semiconductor industry by dividing its development history into specific stages. I would like to deploy a framework that divides the industrial development into four stages, based on the perspective of the acquisition and enhancement of the industrial competitive capabilities.

(1) The initiation stage (1966-1973): Building the cradle and germinating the bud

In order to survive and achieve economic prosperity, the Taiwanese government sensed the importance of electronics technology at around early of 1960s. There was a consensus among academic scholars and government leaders that the semiconductor would be the key to Taiwan's economic development. But developing the semiconductor industry required a plentiful of competent professionals, including technicians, scholars, researchers and engineers. To realize this need, the government established National Chiao Tung University (NCTU) at Hsinchu in 1958, which started to offered the courses related to electronics and semiconductors in 1963. NCTU began to conduct research on producing semiconductors and established a semiconductor lab in 1964. The establishment of the Semiconductor Lab was a major event in Taiwan's semiconductor research and development. It was where the silicon planar technologies were developed, which is considered the cornerstone of today's Taiwanese IC manufacturing technologies.

With the aim of training more high-tech manpower, it then participated in research projects coordinated by the National Science Council (NSC). It set a strategy for mutual cooperation between government units and universities and laid a solid foundation for the semiconductor industry in terms of basic research and human resource development and creating an environment for the germination of the semiconductor industry.

The industry first started with General Instrument establishing an assembly plant in Kaohsiung in 1966, followed by other plants built by Philips, Texas Instruments, RCA and Mitsubishi Electric. These companies focused on labor-intensive downstream assembly business, even so, the development of the IC packaging industry was encouraged as they brought in technology for IC packaging, testing and quality control. This stage was based on foreign capital and focus on IC packaging.

(2) The burgeoning stage (1974-1982): Building the initiator of IC power house

During the early of 1970s, Taiwan's agricultural sector was in decline, though the manufacturing sector had grown and was a major contributor of the economy Taiwan's overall exports were badly hit by the rise in inflation due the global oil crisis at 1973. The government sought to find the new ways of stimulating the economy by increasing public spending on major transportation projects. In addition, a ten-year national development plan was formulated to improve infrastructures and facilities, to speed up the industrial modernization, and build heavy industries such as steel, shipbuilding, automobiles, machinery and petrochemicals. But the development of semiconductor industry was virtually not started till the ERSO (Electronics Research and Service Organization) founded in ITRI (Industrial Technology Research Institute) in 1974. Before this time, Taiwan's IC-related industry was mostly assembly-oriented, except for the NCTU's lab and a transistor manufacturer, Fine Product Micro Electronics Corporation, the first silicon-based transistor manufacturing company in Taiwan. The company was established by the NCTU's graduates. It did not work very successfully because it lacked the right product implementation strategy; however, it did train and produce a number of engineers and technicians.

In order to accelerate the growth of Taiwan's electronics industry, the government decided that importing available technologies from the U.S. was the best way to develop the semiconductor industry quickly. To execute the decision, the government formed the Technical Advisory Committee (TAC) in the United States, and established the Electronics Industrial Research Development Center (EIRDC) in 1974. The TAC provided easier access to these highly trained technical professionals and recruited them in TAC and later ERSO projects. ERSO was the successor of EIRDC; with TAC's assistance, ERSO successfully recruited researchers and engineers locally and abroad. Many of these professionals became the important leaders of Taiwan's semiconductor industry.

The main goal of ERSO was to nurture and build the semiconductor industry and to acquire and transfer advanced IC design and manufacturing technologies from the United State. The TAC and evaluation committee of ITRI chose the CMOS (Complementary Metal Oxide Silicon) technology transfer from RCA to be the main candidate. The decision to bet on CMOS proved critical for Taiwan's ability to synchronize the development of semiconductor technology and its PC-base information technology. ERSO started the project for the building of an "IC Demonstration Plant" in 1975; the project cost NT$400 million (US$11.43 million) and 38 engineers were sent to RCA for one year training. ERSO also successfully completed its first IC design for electronic watch in 1976; the first chip was made in 1978 in IC demonstration plant successfully. This event made the success of the introduction of the IC manufacturing process in Taiwan.

This stage was led by the government laboratory (ERSO) which expedited technology acquisition and minimized possible risks by pursuing a strategy of technology introduction through government-sponsored research organization. The RCA technology transfer project was not only a IC production process transfer but also trained the engineers and managers in the overall industrial technology of engineering and operation management. This was the preliminary building block for the future development of Taiwan's semiconductor industry.

The IC demonstration plant successfully operated as the main support and development center of the entire semiconductor industry; it also began transferred its technology to local business. The Hsinchu Science Park was established in 1979 to provide high-tech industry with a complete infrastructure and to give administrative support.

United Microelectronics Corporation (UMC) was the first company to be set up in the park; it was a spin-off company from the ERSO's IC demonstration plant. It was also an initiative of ITRI, which transferred to it all the resources needed to start up, including product technology, process technology and trained personnel. UMC started operation in 1982 as Taiwan's first IC manufacturing company.
This stage featured strong governmental guidance and opened up a new era for local high-tech industry.

(3)The diffusion stage (1983-1989): Planting and nurturing the successful industry

In the early 1980s, Taiwan was affected by the global recession, resulting in falling demand for Taiwan's local manufactured products and thus a decrease in private investments. With government supporting, UMC was founded and represented the first step towards moving the electronics industry from IC packaging into IC manufacturing. The spin-off UMC also played a very important role in transferring human resources and technology from the government institution to the private sector. Thus developing a local high-tech industry. It also had the effect of building confidence into the private investors when the semiconductor industry had yet to bloom.

In the following years, the industry did grow with the founding of many successful IC design and manufacturing companies. ERSO remained the major source of technology development for the semiconductor industry during the stage. Besides the success of developing ICs for telephone, voice synthesizer, microprocessor, and many others, ERSO started the Multi-Project Chip program with NSC in 1983 to help the build-up of IC design capability of major universities. The first IC design company, Syntek, was founded in 1982 , and by 1987, there were 30 IC design companies in the industry already. In the same year, ERSO set up it a second spin-off company, Taiwan semiconductor Manufacturing Company (TSMC). The formation of TSMC, now the biggest semiconductor contract manufacturing (foundry) company in the world, created a situation where manufacturing capacity is no longer a pre-requisite for an IC design company.

In 1989, the total number of IC design companies reached 55 with a total annual sales of US$ 154 million. TSMC positioned itself as a specialized wafer manufacturer, not only providing adequate manufacturing capacity for IC design companies, but also creating a new business model of independent companies with cooperating in design and manufacturing (foundry business). This model significantly promoted industrial growth, with six more wafer manufacturers and more IC design companies established by the end of 1980s. While semiconductor manufacturing companies bloomed, the industry did not have a complete system of vertical division. The missing link, photomask manufacturing, was created in 1989, by the creation of Taiwan Mask Company, a spin-off company of ERSO's photo mask operation.

Since then, Taiwan has had a complete semiconductor industry system, including IC design, photomask manufacturing, wafer fabrication, IC packaging and testing, with each sub-industry specializing in their own areas of expertise; most of the companies are located around Hsinchu Science Park. The intensive interaction between them has created a highly efficient industrial value chain in terms of goods, material, and information flow; it also accumulated human resources and capital. At this stage, the government continued and diffused technology development into local private sectors through spin-off companies and stimulated private investments in related industries to build up the complete system of Taiwan's semiconductor industry.

(4) The growth stage (1990-present): the flourishing growth of the value chains

Since the 1990's, the government gradually switched into the role of a supporting partner rather than a guiding coach. At this time, the industry developed competitive capabilities in technology and operation. The goal of technology development has focused on catching up-to-date, sub-micron technologies. ERSO continued to undertake the Very Large Scale Integration (VLSI) project. This project allowed industrial players to participate in the "sub-micro working/user alliance" by contributing partial funds and human resources for the sub-micro technology, from which the technology can be easily transferred. By the end of 1994, 16M DRAM and 4M SRAM had been successfully developed with a 0.5um process in 8 inch wafers, which was transferred to the industry later.

With the great success of sub-micro project, the "sub-micron lab" was spun off as a new business, Vanguard International Semiconductor Corporation (VISC). The whole industry was also inspired by the success of the project and became vigorously involved in building or expanding the 8 inch wafer fabs. These companies included Ti-Acer, Winbond, Mosel, Nanya, Powerchip, Macronix,UMC and TSMC; the total investment amount exceeded US$ 7.2 billion in that three years (1995-1997). The industrial technology capability was greatly enhanced during this stage with a significant increase in the human resource, especially due to the return or recruiting of professional experts from U.S. major semiconductor companies.

The major players of the industry were not only participating in the technology development alliance with ERSO, but they also started to build up strong internal research teams. In addition, they also were trying to form strategic alliances with globally renowned companies to further strengthen their technologies and management competence, such as TSMC with HP and TI, UMC with IBM and

Hitachi, Winbond with Toshiba and Sharp, Mosel with Infineon, etc.. (See Table 2.1 for a detailed alliance relationship).

With full support from the government, the entire industry sought to form strategic alliance with foreign leaders to maintain the momentum for technology development. This period has been blooming with great expansion: 6 fabs in 1989 increased to more than 20 fabs in 2000; 55 IC design companies in 1989, increased to more than 150 companies in 2000. At the same time there were also more than 25 domestically capitalized packaging companies. In addition, three more players entered into the photomask manufacturing arena and several players of raw wafer material, fine chemicals, quartzware and other design tools and equipment have appeared to make the whole industry into a more comprehensive operation. This stage started with government project stimulating the industry blooming and followed with the global strategic alliance to enhance the overall industrial growth.

Taiwanese Semiconductor Companies' International Alliances

Company	International Alliance Partner
TSMC	Philips , ST Micro , HP , TI
UMC	IBM , Hitachi , AMD , Infineon
Winbond	Toshiba , Fujitsu , Sharp , Infineon
Macronix	Matsushita , Philips , Tower
Mosel	Infineon , Sharp
Nanya	IBM , Infineon
PowerChip	Mitsubishi

Table 2-1 Taiwanese semiconductor companies' international alliances

Chapter 3

The competitive strategies of Taiwan's semiconductor industry

The growing diversification of the industrial infrastructure has led to a strong base for global operations. Although Taiwan's semiconductor industry started off with the labor-intensive IC packaging, the balanced portfolio of wafer manufacturing, circuit design, photomask making, raw material–wafers and chemicals companies had emerged. The industry has been able to attract investments from foreign companies as well as local enterprises; the companies have also leveraged educational and cultural ties with the United States and Japan to form alliances and build joint ventures with global microelectronics firms.

Three unique competitive strategies of Taiwan's semiconductor industry will be analyzed: specialized segment-focus value chain of semiconductor industry, virtual integration of all segments into a complete semiconductor supply chain, and profit sharing system attracts the best talent in the world.

3.1 Specialized segment-focus value chain

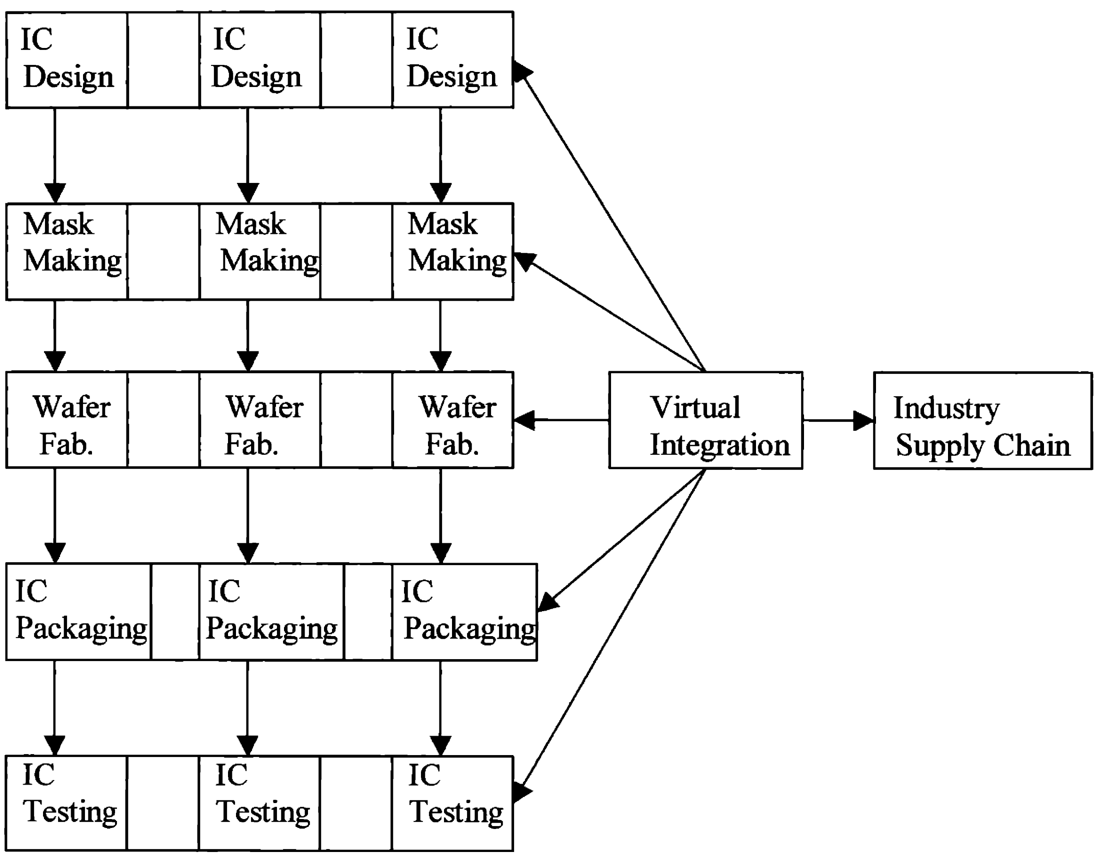
Taiwan's semiconductor industry has a unique infrastructure of vertical disintegration. It means the industry is divided into several segments, from upstream IC design companies to downstream IC packaging companies, with each firm concentrating on certain functions of each segment. The firms in the sequence of segments comprised the whole industry supply chains.

Since the industry began with IC packaging in 1960s, Taiwan's semiconductor industry has been characterized by a disintegration network. This characteristics also enable the Taiwanese semiconductor companies to adapt more rapidly than others to the stresses caused by the market changes.

Historically, Taiwan's government discouraged concentrations of Taiwanese business development and relied on the state-owned enterprises. As a result, the development of the industrial organization was less concentrated, with fewer big conglomerate groups; thus most the firms are small and medium-sized enterprises.

This situation contrasts sharply with the status of major world semiconductor companies, which have their own internal vertically integrated systems. But after 1980, the rapid growth of personal computers and the break-up of giant telecommunication enterprises, such as AT&T, the small Taiwanese semiconductor companies confronted a whole new frontier of business opportunities. Since no single Taiwanese company had the resources to establish internal integration on a massive scale; the small and medium-sized enterprises have divided the workload and developed close cooperation to compete with the market rivals.

The Taiwan's semiconductor industry comprises five segments of the whole supply chain: IC design, photomask making, wafer manufacturing, IC packaging and IC testing. The specialized segment value chain structure has resulted in three competitive effects: intensified technical proficiency, improved capacity utilization and reduced manufacturing cycle time.



Source : Made by Taiwan – Booming in the Information Technology Era

Figure 3-1 Taiwan's vertical disintegrated semiconductor supply chain

Intensified technical proficiency

The semiconductor industry is divided into the five specialized segments in Taiwan; IC design houses, photomask companies, wafer manufacturers, packaging houses and testing firms. Each company in the specialized segment of the value chain operates independently; therefore, it can concentrate on its specialized business and resources can focus solely on its core competencies, resulting in intensified proficiency and efficient management with simplicity.

Improved capacity utilization

An important factor which influences productivity in the semiconductor industry significantly is the manufacturing capacity utilization. With the vertically integrated system in traditional IC companies, each sector of the supply chain has only one end user internally; it becomes inflexible and difficult to adjust to change in demand. In contrast, the vertically disintegrated system of Taiwan's semiconductor industry has multiple outside users; it allows flexibility in response to changes in demand. Because each segment of the value chain in the vertically disintegrated system operates independently, management of each segment can easily focus on the production efficiency and simplify the operation targets, so the yield of product and capacity utilization can be managed much better.

Reduced manufacturing cycle time

Time to market is a critical success factor to compete in the highly competitive electronics industry, especially semiconductor products. With shortened product life cycle, timing is always critical to the market; early entry earns the premium. Additional pressure of competitive supply chains make the manufacturing flexibility and turn-around time even critical. Taiwan's semiconductor industry, under the disintegrated industry cluster, increased efficiency in each segment of the value chain resulting in the shortest possible cycle time.

Another important factor which contributes to the cycle time reduction is the aggregation of the semiconductor companies in Hsinchu Science Base Industrial Park (HSIP). The gathering of IC-related companies reduced the cost of communication, information exchange, and cost of transportation. As the government supports HSIP;

there is efficient administrative support for the firms in the park, which leads to the reduction at cost of bureaucracy as well. With such advantages, the park attracted up, middle and down stream companies located in the same area to form a complete industry supply chain system within the park.

Since technical disintegration contributes to the value of productivity, quality, cycle time and higher utilization, the result will lead to a competitiveness in the market and higher profits. As each segment developed its strong competitive capability, the industry as a whole becomes strong competitive in the market.

3.2 Virtual integration of all segments into a complete supply chain

An important factor affecting the success of Taiwan's semiconductor industry is its virtual integration into a global IC supply chain. Taiwanese companies have integrated all of the semiconductor options of the industry in the island.

(1) The construction of a manufacturing plant – includes: facility architectural design, construction engineering, mechanical, electrical, water, gas purification and supplies, and the clean room installation.

(2) The implementation of a manufacturing line – integrates all the process equipment into a complete process line including: photolithography systems, ion implanters, diffusion furnaces, thin film depositions, cleaning equipment, etching machines and many different types of instruments in the clean room.

(3) The leverage of IC process equipment manufacturers – needs a complex chain of integration because the equipment is produced by a variety of specialized companies around the world. Taiwan does not have any tool suppliers.

(4) The supply of an IC component – integrates all the segments of the semiconductor manufacturing value chain, including: design, mask making, wafer manufacturing, packaging and testing.

(5) The assembly of an electronic system – needs a huge number of downstream companies to provide the various sources of electronic components, the integration of these activities to make the computer systems, the communication systems and the industrial application systems.

Taiwan's semiconductor industry has been able to virtually integrate these options into a global supply chain and manage these integration options in a competitive position. The major driving force is technical specialization and knowledge management. With the virtual integration of the industry, three significant effects has resulted: a competitive global supply chain, accumulated professional knowledge and competitiveness of capital market.

A competitive global supply chain

Since the semiconductor industry is a global competitive industry, different countries enter at different stages of the product life cycle. The entry point depends on the capability and competitive position which the countries possess. As each segment of the Taiwanese companies in the virtual integration system is exposed to the severe realities of global competition, each company need to find its way to continuously improve its core competence in order to survive and be integrated into the global semiconductor supply chain.

Accumulated professional knowledge

As a high level of proficiency was developed in each sector of the virtual integration system, it is more efficient to accumulate the professional knowledge in the focused area of semiconductor industry technologies and management.

Competitiveness in capital market

Since the semiconductor industry is a capital intensive industry, with the continuous improvement of IC design and manufacturing process, existing process equipment need to be replaced to meet the new technology and product design requirements. Thus, a continuous large amount of capital is always needed to upgrade the facility and process equipment to maintain competitive advantages. Because each company in the disintegrated value chain was about the adequate size of the market, it is easier to reach the necessary scale capital than the traditional vertical integrated semiconductor companies where the capital scale is huge. The competitive scale of firm size appeals strongly to the investors.

3.3 Profit sharing system attracts the best talent

One of the significant factors that contributes to the success of Taiwan's semiconductor industry in the past decade is the employee profit sharing system. The employees receive their annual profit sharing bonus in the form of company's stocks, which are created from the company's retained earnings converted into capital. The system had helped the industry attract excellent talent worldwide and create an aggressive and active attitude toward the entrepreneurship type of hard work. Such a system in the industry leads to three positive effects; it reduce conflicts between employees and managements, creates active working attitude and attracts global talent. These advantages enhanced the competitiveness of the Taiwan's semiconductor industry in the global human resource competition.

Reduces conflicts between employees and managements

Although the labor initiative issue has not been as important in Taiwan as western countries, the labor priority has gradually increased in Taiwan as well. As employees become company's shareholders, many issues or problems between employees and managements are eliminated. As the employees in this type of system are highly motivated and productive, the result turns out to be a win-win situation for the companies. Up to the moment, there are not any labor problems in these employee profit-sharing companies, such as TSMC, UMC and Winbond. These firms shared around 4%-11% of their annual profits with employees in the form of companies' stocks in the past ten years and created many young and rich millionaires in the HSIP, similar to Silicon Valley in the United States.

Creates active working attitude as the entrepreneurship

Since employee profit sharing is a common practice in the industry, the labor force understands definitely the best way to receive a bonus is to make company as profitable as possible, so employees usually work actively and do the best they can to make the company more profitable. If the performance of company is good, the stock price of the company will rise and employees will enjoy the profit sharing bonus through high stock price margin. This is also similar to Silicon Valley's start-up firms' entrepreneurial working attitude.

Attract global talent to join the industry

The base salary of Taiwanese companies is relatively low compared to the U.S. or Japanese competitors due to the income level of social structure, but the actual annual income of Taiwan's semiconductor companies' employees could be much higher than those of U.S. or Japan because of the stock bonus of profit sharing. The amount of bonus can be equivalent to more than three times the annual salary in terms of cash. Because the total annual incomes of employees could surpasses those of the U.S. or Japan, Taiwan's semiconductor companies are in a very strong position to attract global professional talent.

The professionals attracted by the system are highly active as well as highly skilled. The employee profit sharing bonus is different from the stock option system which is commonly used in the United State. Profit sharing is distributed only when the company makes a profit; it is not a cost of operation, but a dividend to employees. The stock option allows employees to purchase shares of company stock with certain price discounts, as compared to market price. In order to keep employees within the company, this option can be exercised within certain period, such as 3 years or 5 years. Employees work hard for the future stock price raise and could stay longer for the full option. In the stock option, companies need to pay for the price difference as a cost of operation to retain the good talent in companies. The profit sharing bonus system contributed a lot of the Taiwan's semiconductor industry's growth and prosperity; more and more companies adopted the system in order to compete in the global human resource market.

Chapter 4

The competitive advantages and industry value chain

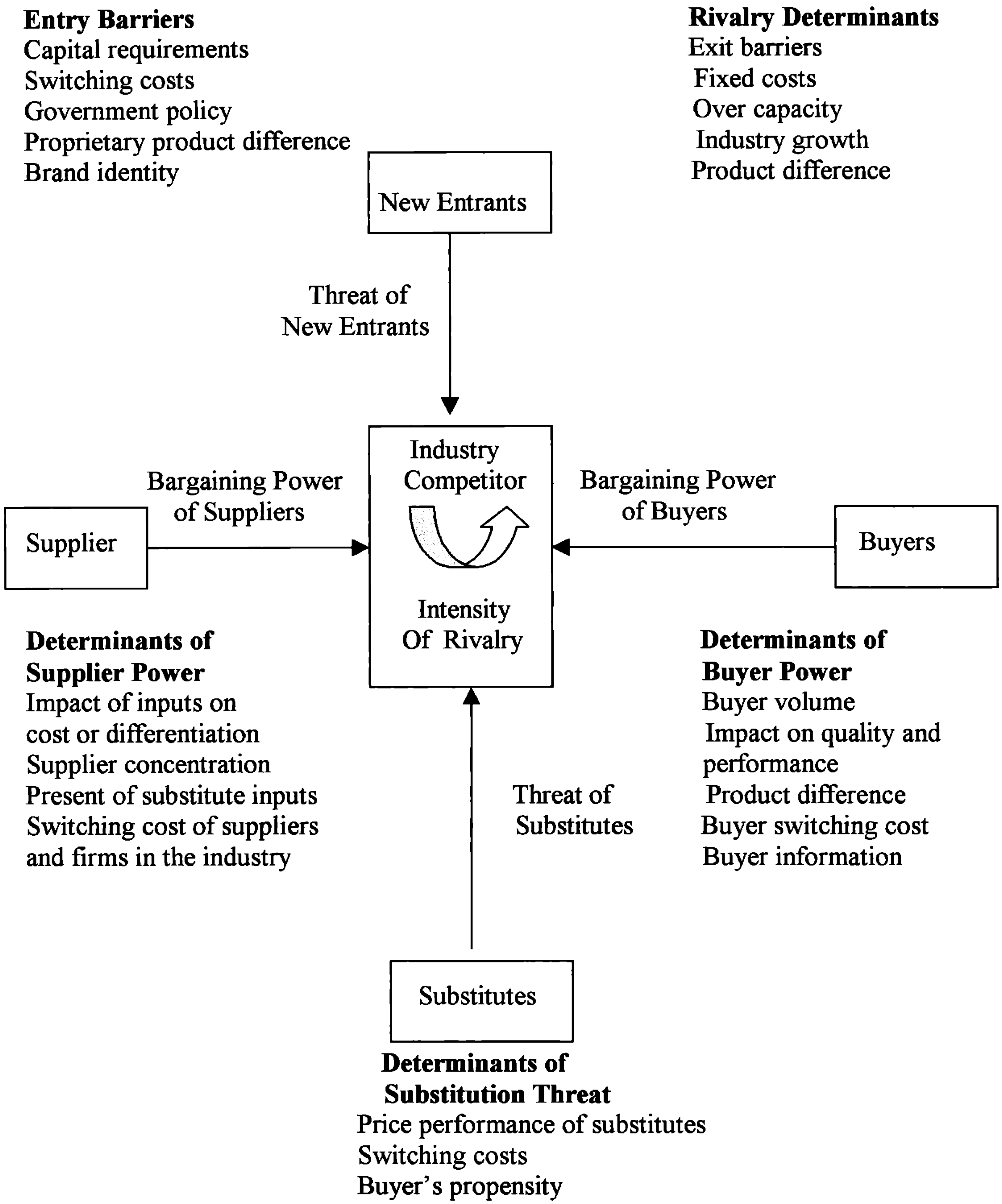
With its unique competitive strategies, Taiwan's semiconductor industry could have advantages in its industry value chain competitiveness. The important elements of the industry value chain analysis will be evaluated through Porter's five forces analysis, to realize the industry competitiveness. (See Figure 4-1). We will then look at Taiwan's industry structure in terms of the value chain and apply the Delta model of competitive positioning to Taiwanese companies' strategies.

4.1 Porter's competitive strategy analysis:

Porter's competitive strategies analysis indicated that industry profitability is not a function of what the product looks like or whether it involves high or low technology, but what the industry structure is. Some very mundane industries such as postage meter and grain trading are extremely profitable while other, more glamorous, high-technology industries are not profitable for many participants.

The strength of the five forces varies from industry to industry. In industries where the five forces are favorable, such as pharmaceuticals, soft drinks, and data base publishing, many competitors earn attractive returns. In industries where pressure from one or more of the forces is intense, such as rubber, steel and video games, few firms command attractive returns despite the best efforts of management.

The strength of each of the five forces is a function of industry structure or the underlying economic and technical characteristics of an industry. The semiconductor industry structure is relatively stable as a whole in its past history, but it also changes over time due to the industrial innovation of new technologies in each segment of the supply chain.



Source: Competitive Advantage – Michael E. Porter, 1985

Figure 4-1 Taiwanese semiconductor companies – Porter's five forces

The structural change shifts the overall and relative strength of the competitive forces, thus positively or negatively influencing industrial and an individual company's profitability. The industry trends that are the most important for the companies' strategy are those that affect industry structure. In the 1990s, the personal computer industry affected the semiconductor industry a lot. The microprocessor and memory are the two key elements of personal computer; the huge demand in the fast growing PC market made Intel and few Japanese DRAM companies the most significant players in the semiconductor industry at that time. Personal computer end users are compelled to buy these proprietary products because they have the relatively better performance and higher quality. Not only end users of PCs, but other logic IC components, the system board design and related peripheral components have to make their products compatible with Intel standards to reach the most customers and compete in the market. This is the example of how a firm can shape the industry structure and fundamentally change the industry's attractiveness for better or for worse.

Positioning determines whether a firm's profitability is above or below the industry average. A firm that can position itself well can earn a high rate of return even though the industry structure is unfavorable. The fundamental basis of the above average performance in the long run is sustainable competitive advantage. There are two basic types of competitive advantage a firm can possess: low cost or differentiation. The strategies a firm seeks to achieve the competitive advantage in an industry are: cost leadership, differentiation and focus, the generic strategies. (See Figure 4-2). The cost leadership and differentiation strategies seek competitive advantage in a broad range of industry segments, while focus strategies aim at cost advantage (cost focus) or differentiation (differentiation focus) in a narrow segment. Achieving competitive advantage requires a firm to make a choice. It is because achieving cost leadership and differentiation are usually inconsistent that differentiation is usually costly.

Competitive scope		
Broad Target	**Cost Leadership** (Taiwanese)	**Differentiation** (Japanese)
Narrow target	**Cost Focus** (Korean)	**Differentiation Focus** (U.S. & European)

Source: Competitive Advantage – Michael Porter 1985

Figure 4-2 Three generic competitive strategies

Taiwan's semiconductor industry was positioned at a low cost strategy for its entry to the competitive market. In starting its business, low cost competition was the driving force of Taiwan's semiconductor industry growth. It started from the low-end consumer products with relatively old technology, but its higher productivity kept Taiwan's semiconductor industry still in a good position in those low-end consumer markets. We can compare the different strategies in different semiconductor industries in countries. Taiwan's semiconductor industry has had the cost leadership strategies for the past two decades; Korean's semiconductor industry focused on narrow product segment–memories, especially the DRAM. They focused on high volume and driving the cost lower to compete and acquire the market share. The Japanese semiconductor industry was more focused on product differentiation. Though they were started with low cost, high volume competition with American companies in memory business at the early stage, they gradually moved their strategies into specialty product needs due to their domestic market's growth.

Thus the Japanese semiconductor industry has many companies which are dedicated to different products specialty and work very hard on quality image and perception. The United State's semiconductor industry has more differentiation focus. Intel and AMD focus on CPUs and flash products; Motorola and TI focus more on DSP chips and mobile communication applications. Micron Tech focuses on DRAMs. Due to the creation and leading position, American companies can differentiate their products from their competitors and take competitive positions in the global semiconductor markets. (See Figure 4-2 for the different strategies mapping).

Taiwanese semiconductor companies grew with appropriate investments and management efforts; the industry gradually caught up with the technology trend and carried the leading manufacturing capability in recent years. The companies in the industry gradually changed their strategies into product focus and provided relatively lower cost products to the markets, such as memory ICs (DRAM). Korean companies focus on personal computer chip sets competed with American companies in the recent years. The strategies also changed over time because the industry product and technology trends changed as well.

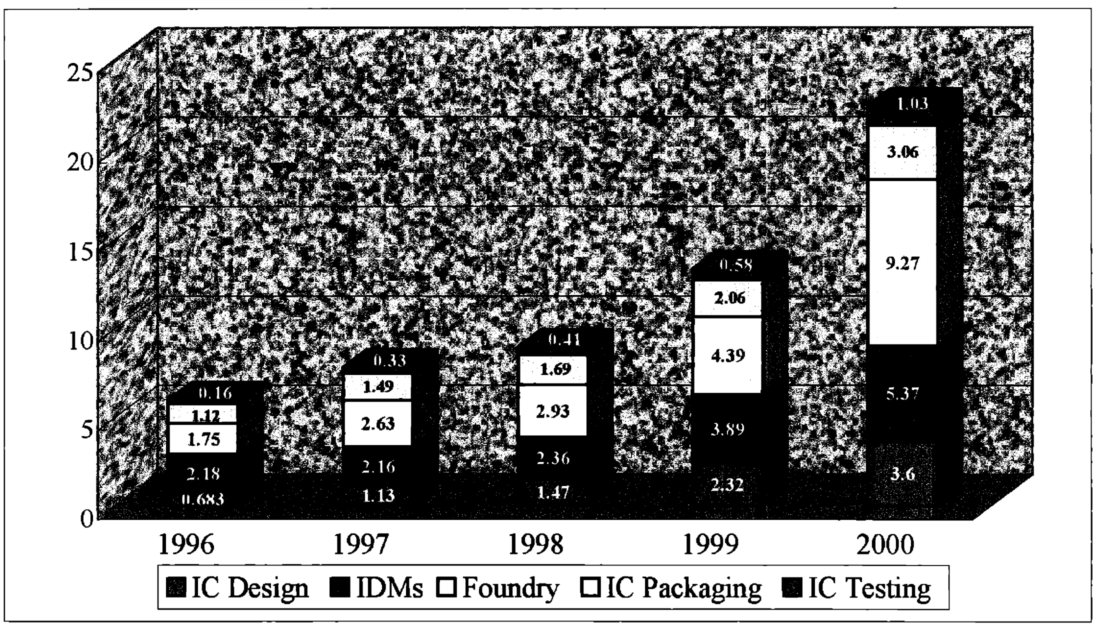
4.2 The structure analysis of industrial value chain

Taiwan's semiconductor industry can be divided into six categories: chip design companies, photomask manufacturing companies, integrated device manufacturers, wafer foundry companies, packaging and testing companies.

- **Chip design companies**: merchant semiconductor suppliers that design and market, but do not manufacture its own products.
- **Photomask manufacturing companies**: photomask providers which perform the mask-making service under contract from chip design companies or integrated device manufacturers.
- **Integrated device manufacturers**: semiconductor suppliers, merchants or captives which manufacture their own products.
- **Wafer foundry companies**: service providers which perform wafer manufacturing operations under contracts from customers.

- **Packaging companies**: service providers which perform semiconductor packaging operations under contracts from customers.
- **Testing companies**: service providers which perform semiconductor testing operations under contracts from customers.

Taiwan was ranked as the world fourth-largest semiconductor manufacturing country at 2000. Among all business segments, IC fabrication business reported the highest growth rate, at 76.9%, while foundry grew 111.3%. Business segments such as chip design, packaging and testing also reported high growths of 55.3%, 48.4% and 52.6 % respectively. (See Figure 4-3).



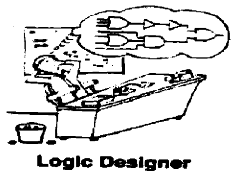
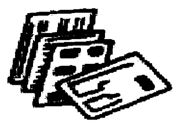
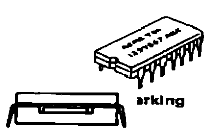
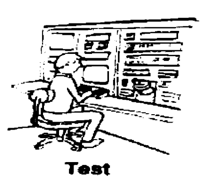
Source: IEK/ITRI, ITIS Project (March, 2001)

Figure 4-3 The growth of Taiwan's IC industry

Up to 2000, the unique disintegrated industry infrastructure of Taiwan semiconductor industry consisted of 140 IC design houses, 8 wafer suppliers, 5 mask houses, 16 wafer manufacturers, 47 packaging suppliers, and 37 testing houses.

Although most vendors are small or medium-sized companies, their dedication to core business and entrepreneurship supports the growth to expand the industry into an even larger scale domestic consumption in 2000. Foundries and IDMs are the two major wafer manufacturing segments in Taiwan's semiconductor industry. (See Figure 4-4).

Taiwan's Disintegrated Semiconductor Industry

	Number of Company	Number of Employee
Chip Design 	140	9800
Mask Making 	5	1000
Wafer Manufacturing 	16	50700
IC packaging 	47	25000
IC Testing 	37	11500

Source : IEK/ITRI 2001

Figure 4-4 Taiwan's disintegrated semiconductor industry

Chip design companies

Due to product varieties and the diversification of semiconductor applications, 140 chip design companies' business does not fluctuate much along the semiconductor business cycles. Chipsets, networking ICs, consumer ICs, memories and CD-ROM vendors all reported excellent business performance. In 2000, Taiwan chip design business reached US$3.6B, 55.3% growth from the previous year. (See Table 4-1).

Photomask manufacturing companies

Taiwan photomask manufacturers include Taiwan Mask Corporation (TMC), Precision Semiconductor Mask Corporation (PSMC), Dupont Photomask Taiwan, Ltd-(DPT) and two additional mask manufacturing suppliers. These mask companies supply more than 80% of the Taiwanese semiconductor industry demand; their businesses expanded into the LCD industry recently.

Integrated device manufacturers

Taiwan IC fabrication companies include foundry companies such as TSMC and UMC. (See Table 4-2). IDM (Integrated Device Manufacturers) such as Winbond, MXIC and SiS produce broad IC products including Flash memories, DRAMs, SRAMs, Mask ROMs and logic Chip sets, etc.. Memory manufacturers such as Powerchip, ProMOS, and Nanya focus on DRAMs products. The total number of IDM companies in Taiwan was 14 by the end of 2000.

Foundry companies

TSMC and UMC are the two big foundry companies; the two companies together controlled total 71% of the world's foundry market, their shares are 43% and 28% respectively. North America is the largest geographic market for Taiwanese foundry companies. Due to increased outsourcing from U.S. IDM, 56% of Taiwan's foundry sales came from North America in 2000. The foundry sales share in the European and Japanese markets also expanded as telecommunication applications IC gained momentum in 2000. Foundry business demonstrated astonishing growth in 2000; it reached 111 %. (See Table 4-3 for the top10 foundry companies).

IC Packaging companies

Large IC packaging companies continued to merge and acquire medium- and small-sized packaging houses; advanced packaging technology got market potential in 2000. Japan and China were the major geographic markets to explore in 2000.

Total packaging revenue (including captive packaging business from global companies) in 2000 reached US$3.0B, a 48.4% growth from the previous year. Domestic packaging industry revenue reached US$2.58B, up 52.6% compared to 1999. The major business contribution to domestic packaging companies are overseas customers.

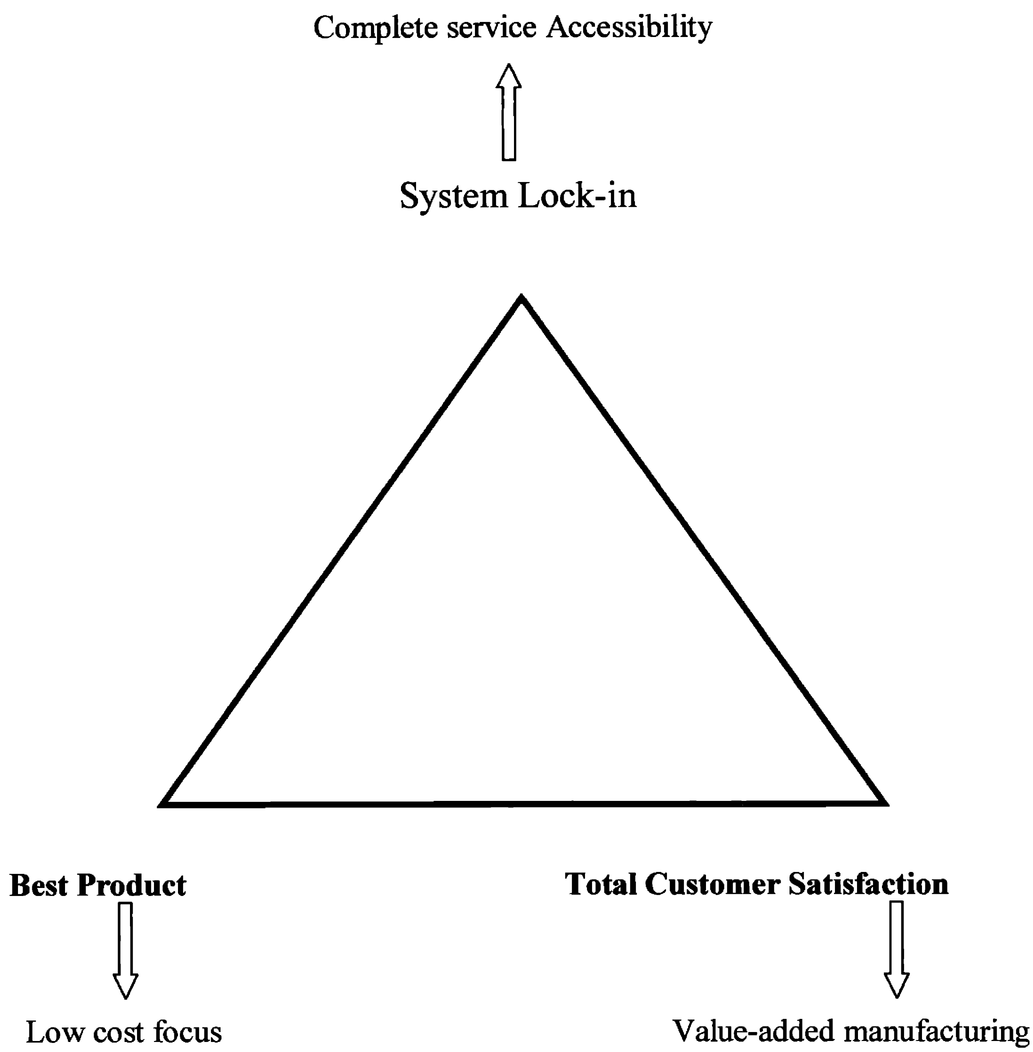
IC Testing companies

The IC testing industry in Taiwan marked the highest annual growth rate in history in 2000. Remarkable domestic design, IDM, foundry business growth, and the higher testing prices during the fourth quarter of 2000 resulted in a testing capacity shortage; testing revenue grew 77.3% in 2000 to US$0.73B. The testing industry consisted of 37 companies in 2000.

The most significant characteristic of Taiwan's semiconductor industry lays in its vertical disintegration structure. This unique way of specialization in each industrial segment distinguishes Taiwan from its international competitors, most of which operate in vertical integration with up- and down stream sectors covering design, manufacturing, packaging, and testing, which function together in the company. Taiwan's unique industrial structure of concentrating resources on one single industrial segment proved its competitive advantages under a rapid and dramatic changes in industrial environment.

4.3 The strategic model in competitive market

Taiwanese semiconductor companies' strategies can also be analyzed using the Arnoldo Hax's Delta model; it fits perfectly with the best product, total customer satisfaction and the system lock-in mechanism. (See Figure 4-5).



Source: The Delta Project – Arnoldo C. Hax & Dean L. Wilde II, 2001

Figure 4-5 Taiwanese semiconductor companies – Delta model strategy

The best product with low cost to attract customers

The best product positioning builds upon the competition of product itself; the Taiwanese semiconductor companies used a low cost strategy for the entry to the markets. They continuously provided relatively low cost products to the markets during early 1990s, but the strategy is different from previous classical form of low cost. It provides the markets and its customers the best productive solutions for semiconductor product manufacturing.

The dedicated manufacturing service with compatible technologies and appropriate quality level provides a best alternative solution for market's needs. (See Table 4-4). The reason why Taiwanese companies can position well in the market is due to three factors:

- The higher and higher entry and exit barriers of investing and operating a new semiconductor manufacturing plant, preventing too many new entrants.
- The infrastructure to support the plant operation, including utility, human resources, material supply and support equipment, is very important to success.
- The productivity of the plant operation, including production tool utilization, process optimization and yield improvements, are the core competitive factors which are critical to cost consideration.

In the past decade, Taiwanese semiconductor companies proved they have the best performance for these measures; they can continuously provide better productivity with lower cost. Moving from a continuous low cost focus, the industry tried to acquire the leading edge manufacturing technology for better service to high-end product requirements and tried to differentiate the product offer in the world market. It is significant that the industry's best product strategy was moving from a low-cost focus to a differentiation in service focus as the technology innovation changed in the mid 1990s.

Total customer satisfaction to fulfill customers' special requests

Instead of providing only products or goods to customers, the way to seek a deeper customer relationship is to develop a better value-added proposition which is adaptive to customers and helps them to be more competitive and make higher profits. The Taiwanese semiconductor companies work hard and try to set up better value-added service for the value chain to the whole electronics related industry. They try to provide not only the manufacturing products but also the total system solutions including the component design, chip production and system board implementation to their customers. The industry as a whole is trying to do as much as they can in the value added service of their focus segments for the customers.

As we know, if you provide customers with superior quality products or services with less cost, then they do not need to spend their own internal resources for such activities. They can gain extra benefits when they seek the available outsourcing for these desired products or services. Taiwanese semiconductor companies do their best to give such dedicated services with higher value-added to their customers as they can in the competitive markets. The reason why they can achieve and prove to be successful is due to three factors:

- The effective returns on investment management through productivity driven operations.
- The significantly hard working forces through good quality engineering education and discipline.
- The good incentive systems for innovation and creative thinking for the technology development and leading manufacturing skills.

Taiwan's electronics industry has many examples of value-added services, such as the whole product design and manufacturing cycle done by outsourcing contractors. In the PC industry, with companies such as Dell, Compaq and HP, most of the brand desktop and notebook computers were made from ODM contract manufacturers; they only had to do their own brand marketing/sales and product distribution. They gained much more value from outsourcing supply than their own manufacturing plants. The Taiwanese semiconductor industry also provides similar capability to catch its customers' needs with their value-added services. Turn-key service from foundry companies for IC chips and ASIC contract service provided by IDM companies are good examples for the total customer satisfaction strategies.

System Lock-in for the further growth opportunities

The system lock-in strategy identifies the complementors, either internally or externally, and tries to lock your product into customer's system and lock-out competitors. Normally, establishing the proprietary standards is the most effective way to achieve system lock-in; Intel microprocessor and Microsoft Windows OS are the two well known examples. PC users are compelled to buy the WIN-TEL proprietary products because it has the best performance and widest selection of software application available. Actually, the users do not have other better choices for the solution, since this is the proprietary standards in the market.

Taiwanese semiconductor companies did not have sufficient resources and good enough research ability to create new industrial proprietary standards with either product specifications or system architectures. So they are trying to create their innovations in the value-added services, such as fast turn around of ASIC services, as the key success factor of the new product for time to market. The foundry company's microchip turn-key service is the key success tool of new start-up chip design semiconductor companies. While the Taiwanese semiconductor industry can continuously provide the competitive value-added service and make special efforts in their proprietary manufacturing and service know-how, the product and service keep the best price/value ratio. It certainly has the chance to lock-in the customers and lock-out the competitors. Three major factors which make it possible to the success:

- Proprietary know-how in manufacturing service, fast turnaround delivery and completed service portfolios to customers.
- Dedicated and focused business strategies, high customer service and market-driven orientation to the competition.
- Adequate value chain management, created value in any possible business segment of the competitive industry to lock in customers.

(See Figure 4-6 for an illustration of the value upgrade through the Delta model).

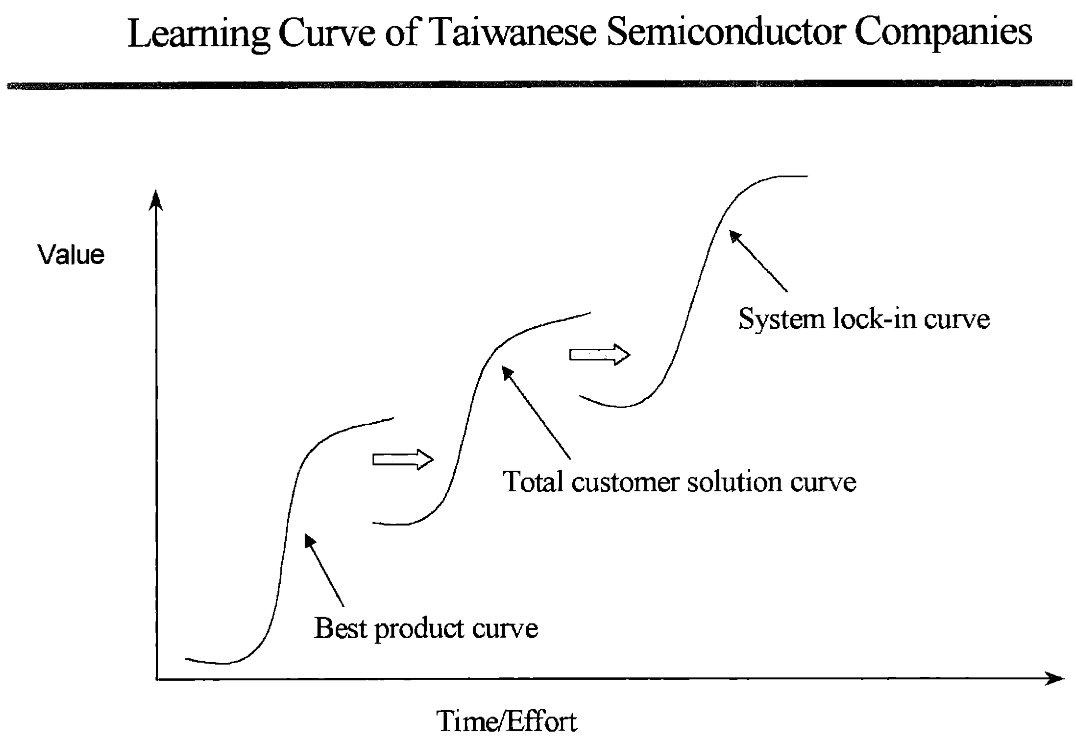


Figure 4-6 Learning curve of Taiwanese semiconductor companies

Major Indices of Taiwanese IC Design Business

US$ billion

Year / Item	1992	1993	1994	1995	1996	1997	1998	1999	2000
# of Companies	59	64	65	66	72	81	115	127	140
Revenue(in US$B)	0.27	0.37	0.39	0.60	0.68	1.13	1.47	2.32	3.6
Growth rate(%)	30	36	6	56	13	67	29	58	55
Domestic : Export ratio	50:50	46:54	65:35	61:39	64:36	52:48	57:43	62:38	59:41
Investment/Revenue(%)	10.0	23.5	15.5	15.9	15.5	17.3	13.5	15.4	15.3
R&D/Revenue(%)	10.1	9.5	10.0	12.2	9.5	8.8	9.4	8.9	9.3

Source: IEK/ITRI, ITIS Project (March, 2001)

Table 4-1 Major indices of Taiwanese IC design business

Top 10 IC Manufacturing Companies in Taiwan 2000

US$ billion

2000 ranking	1999 ranking	Company	Revenue in 2000 (US$B)	Revenue in 1999 (US$B)	Growth (%)
1	1	TSMC	5.19	2.28	127
2	2	UMC	3.28	1.72	92
3	3	Winbond	1.50	0.97	55
4	6	MXIC	1.00	0.53	94
5	4	Mosel	0.84	0.63	36
6	5	ProMOS	0.66	0.56	13
7	7	VIS	0.59	0.41	49
8	8	Powerchip	0.59	0.34	78
9	10	NanYa	0.47	0.28	61
10	-	SiS	0.25	0.34	-28

Source: IEK/ITRI, ITIS Project (March 2001)

Table 4-2 Top 10 IC manufacturing companies in Taiwan 2000

World Top 10 Semiconductor Foundry Companies

$Million

2001Rank	Company	Country	1997	1998	1999	2000	2001
1	TSMC	Taiwan	1,544	1,503	2,270	5,318	3,705
2	UMC Group	Taiwan	1,250	1,110	1,996	3,362	1,898
3	Chartered	Singapore	380	423	694	1,134	467
4	ASMC	China	105	120	145	180	190
5	Anam	S. Korea	--	116	293	378	175
6	CSMC	China	--	10	95	130	135
7	ESM	South Wales	125	135	150	185	125
8	X-Fab	Europe	--	17	60	104	115
9	PolarFab	U.S.	--	--	--	100	110
10	Tower	Israel	126	70	70	105	55

Source: IC Insights (2002/01); IEK/ITRI (2002/02)

Table 4-3 World Top 10 semiconductor foundry company

Comparison on Mass-Production Process Technology

Technology	Taiwan	Benchmarked Regions	Technology by Benchmarked Regions
CMOS (Logic)	0.13um	US, Japan	0.13um
CMOS (RF)	0.18um	US, Europe	0.13um
BiCMOS	0.35um	US, Japan, Europe	0.25um
Bipolar	0.8um	US, Japan, Europe	0.35um
GaAs MESFET	0.7um	US, Japan	0.5um
GaAs HBT	2.0um	US, Japan	1.0um

Source: IEK/ITRI, ITIS Project (March 2001)

Table 4-4 Comparison on mass-production process technology

Chapter 5

The competitiveness of the industry value chain

After the structure analysis of Taiwan's semiconductor industry value chain, we understand the industry value chain was strongly disintegrated. Companies in each segment are dedicated to their own business; the intensified and focused management has given these companies a competitive capability in their business. We will discuss how the companies take their advantages in selecting their entry points of product life cycle and develop their own competitiveness in the industry supply chain. We will also discuss the value chain activities to evaluate the strength and weakness of the industry, then conclude with opportunities and threats. Finally, we will provide an example of the industry value chain initiative for study.

5.1 The evaluation of competitiveness

In the value chain of an industrial product different suppliers select different entry points of the product life cycle. (See Figure 5-1). The United State's semiconductor companies enter the market mostly at the introduction stage of new product to market. Due to their creativity and innovation in product development, they enter at the product burgeoning stage. With high uncertainty, risk could be higher but the higher profits can be gained at this stage. From the market aspect, an early entry in the product life cycle can have the advantage of defining the product specification and future direction of product development. The product-added value is also the highest at this time. But it does not mean any company or country can choose freely at the entry point of product life cycle; each will certainly rely on the technology capability and market size which the company or country possesses.

Taiwanese semiconductor companies do not have the competitive advantages of Silicon Valley companies at the moment because the market size is small in Taiwan and the advanced technology is still behind the leading companies in the United States. The entry point selection can only be set at the market growing stage in the product life cycle. Taiwan must act as a quick follower, then work hard at higher productivity in order to offer lower cost advantage to gain market share and grow its business. (See Figure 5-2).

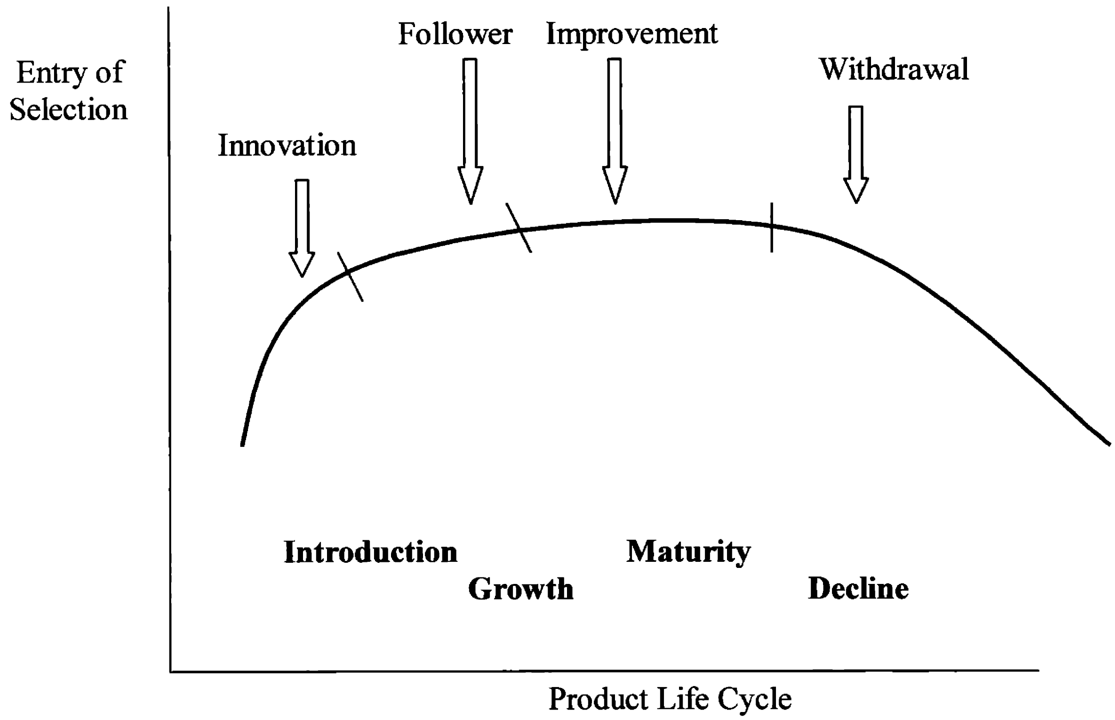


Figure 5-1 Selection of entry points in product life cycle

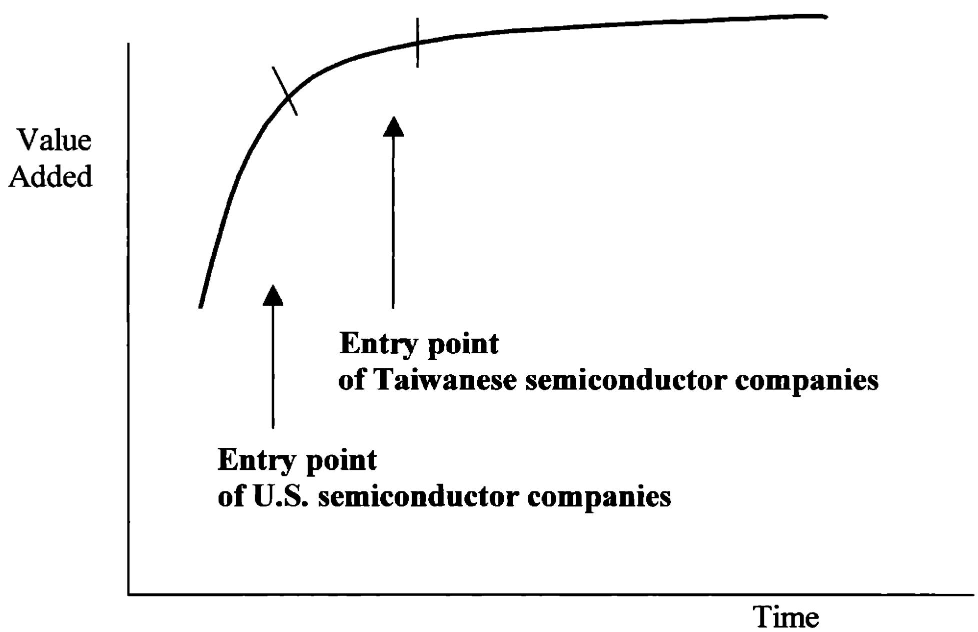


Figure 5-2 Value added in different points of product life cycle

We have assessed and concluded the industry long-term competitive capability by using the industry attractiveness analysis, now we need to know the competitive position of the industry. The evaluation of the competitive position of Taiwan's semiconductor industry includes IC product design, production, distribution, marketing, sales, service and many other supporting operations. The value chain chart to illustrate these activities. (See Figure 5-3).

Industrial Infrastructure

Adequate industry sub-groups and dedicated operation lines, each business sector can focus on its own specialty one.
Strong manufacturing operation managements in each industry sectors.

Human Resource

Good incentive plan for hiring good talent and high quality people .

Promotions and incentives are linked together with individual and group performance.

Quality and productivity are major focus in arrangement manpower and resource.

Technology Development

Alliance with leading companies for join technology development in the industry.
Investments in new tools and future technology development.

Procurement

Good purchasing negotiation bargaining power due the position of buyers'

Good discipline and practice in the cost reduction management through procurement process.

Inbound Logistics	Operations	Outbound Logistics	Marketing & Sales	Service
Experience of high-tech material and Tools handling and management .Good relationship with suppliers and With high volume of purchasing power .	Good discipline of manufacturing . Skillful and hard working force . Good talents in management .	Need to set up adequate and Competitive distribution channel - direct and indirect accounts .	Need to focus on more competitive and aggressive marketing strategies . Need to expand the business scope to Wider global territory . European and Japanese markets are the toughest ones .	Need to create more value added Service scope . Need set up adequate service logistic System globally .
(Strong)	(Strong)	(Weak)	(Weak)	(Weak)

Source : Semiconductor value chain – Porter's Competitive Advantage

Figure 5-3 The value chain activities in Taiwan's semiconductor industry

Primary activities in semiconductor industry:

- Inbound Logistics: Receiving, storing, materials handling, warehousing and inventory control. Taiwanese companies have strong position due to their investment in CIM system implementation.
- Manufacturing Operations: Transforming inputs into final product forms. Taiwanese companies have a strong position with excellent manufacturing operation practices.
- Outbound Logistics: Distributing the finished products. Taiwanese companies are in weak position and need improvements in the overseas distribution channels.
- Marketing and Sales: Advertising, sales force, channel selection, relation, and pricing. Taiwanese companies are in weak position and need to expand their scope of new business accessibility to European and Japanese markets.
- Service activities: Maintain or enhance value of product after sale. Taiwanese companies are in weak position and need to intensify their global service network.

Support Activities in semiconductor industry:

- Procurement: Purchasing material, supplies, consumables and assets. Major Taiwanese companies have a strong position with significant high volume purchasing power.
- Technology Development: Know-how, procedures and technical inputs. Taiwanese companies are in weak position because of lower investment in basic R&D activities.
- Human resource management: Selection, promotion and placement, appraisal, rewards, management development and employee relations. Taiwanese companies have a strong position because of lower incentive systems which attract global talent.

- Industry infrastructure: General management, planning, finance, accounting, legal and government affairs. The infrastructure is competitive except in the areas of semiconductor equipment and raw material industries.

With these strengths and weaknesses analysis in the industry value chain activities, the opportunities and threats are:

Opportunities:

- High industry growth opportunity through competitive manufacturing capability.
- Existing customers' relationship can be enhanced through further alliance in future technology development.
- Global market opportunity, especially in booming China, not only with cheaper labor costs but also the high quality manpower and huge market growth potential.

Threats:

- Stronger market competition in commodity product, such as DRAM, SRAM and flash memory.
- Potential challenge and competition from developing countries.
- Severe up/down cyclical business situation due to industry manufacturing capacity over expansion.

5.2 An initiative of semiconductor industrial value chain – the Taiwanese foundry companies

Taiwanese foundry companies provide the manufacturing expertise:

- Relatively lower cost to competitors in the world market.
- Good quality of product which serve customers' need and meet the customers' specification.

- Up-to-date technology choices in semiconductor manufacturing operation.
- Faster turn around time compared to competitors in the market.
- Turn-key service to customers' need with cost competitiveness.

Taiwanese foundry companies provide total solutions:

- Have sufficient capacity provided for customers' growing needs.
- Meet customers' special requests with less additional cost.
- Help customers to reduce their costs and sharing profits with them.
- Provide customers with full range choices of manufacturing operations.
- Provide stable quality and high yield product manufacturing practices.

Not only providing product manufacturing service and customer satisfaction solutions to compete in the market, the foundry companies went further by:

- Providing proprietary technology specifications and rules for customers' products design-in.
- Providing capacity planning for customers' growing business in their strategic planning.
- Making investment in compatible information systems for ease of access and communication with customers.
- Joining with customers for future technology developments.
- Growing businesses with customers' success and royalty through best service.

The foundry companies have five characteristics as their key competences:

- Advanced technology
- Manufacturing performance and capacity commitment
- Quality and consistency
- Customer service and transparency
- Integrated Design Service Alliance

- **Advanced Technology:** The technology race is really about the numbers of transistors, interconnect performance, design rules, technology offering, timing of planned developments, and overall roadmap content and completeness. It is the ability to match roadmaps against customers' specific needs.
- **Manufacturing Performance and Capacity Commitment:** This is typically viewed as the core of a foundry operation. There are 4 major indices to measure the performance: (1) productivity, (2) yield and quality, (3) cycle time and (4) cost , all of which end up associated with operation margins and profits.
- **Quality and Consistency:** Crucial to a foundry's quality and consistency is its ability to institutionalize a culture of continuous improvement. A premier foundry must develop tools and methodologies that instill quality in every facet of its operations (e.g., applications, processes, fabs, etc.). Another element of the premium foundry is that it strives for is how well it attends to the customers' needs in activities such as risk assessment and failure analysis.
- **Customer Service and Transparency:** Refers to the vital concept of foundry's virtual fab philosophy and practice. It wants each of the customers to think of foundry's fabs as their own fabs, except that the results of teaming with a foundry are more economical and efficient than those that might be achieved on their own. Committing to protecting customers' intellectual property and respecting the needs of the customers are essential elements of a foundry's companies position in the semiconductor industry.
- **Integrated Design Services Alliance:** The Alliance is the platform for easier and faster system-on-chip implementation at the very front end of the integrated circuit design process, for the purpose of easier IC manufacturing at the foundry end. The focus is on foundry's ability to simplify and integrate the design supply chain (including foundry itself, the customers, and third-party solution vendors such as Library, Intellectual Properties, Chip Implementation, and Computer Aided design).

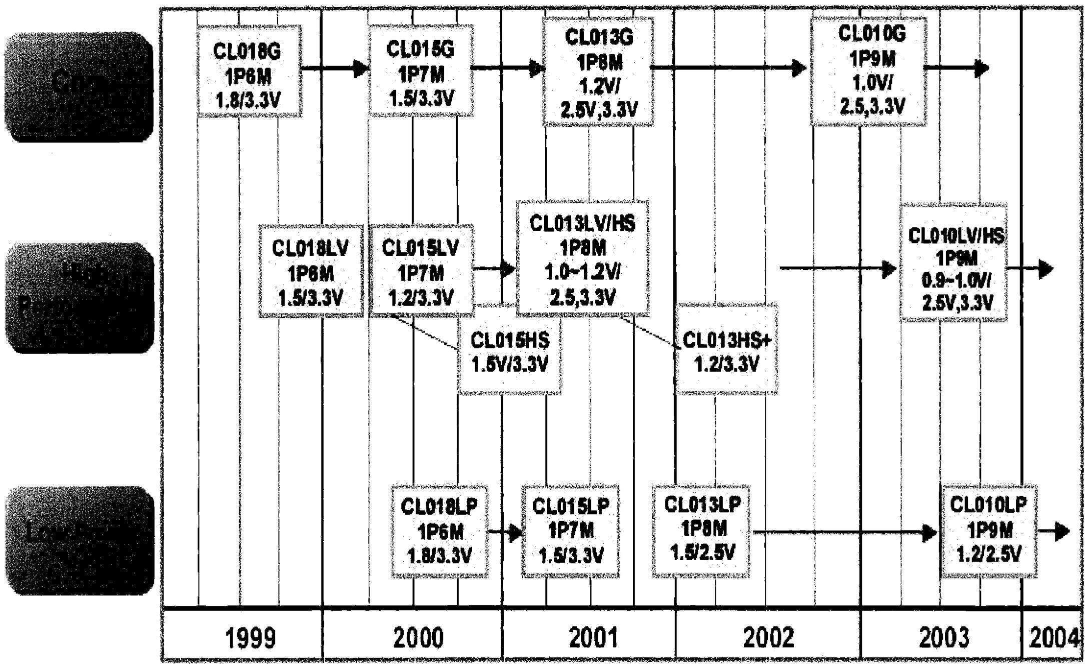
All these business strategies are followed by Taiwanese semiconductor foundry companies. It would be interesting to introduce a successful example of the case, the Taiwan Semiconductor Manufacturing Company (TSMC).

5.3 Taiwan Semiconductor Manufacturing Company - TSMC

Founded in 1987, Taiwan Semiconductor Manufacturing Company (TSMC) is a high–tech company based in the Hsinchu Science-Base Industrial Park, Taiwan. TSMC is a join venture between Philips Electronics NV's, the EYDF of Republic of China (Taiwan) and other private investors. The company is listed on the Taiwan Stock Exchange (TSE) and the New York Stock Exchange (NYSE).

This company was the first dedicated semiconductor foundry company in the world. Since it began, the company has been dedicated to providing manufacturing service for advance ICs. TSMC positions itself as a partner, not a competitor, to most of the other semiconductor companies because its charter prevents TSMC from designing or making its own brand name IC products. Its success in the foundry business has served as a model for many new entrants in the market. What was once only a concept, a dedicated foundry for semiconductors, is today a multibillion-dollar industry. As the semiconductor industry faces greater consolidation and spiraling costs for new IC fabs, dedicated foundry companies like TSMC stand to become a primary source of IC manufacturing service to meet the raising worldwide demand.

TSMC consistently provides its customers with leading technologies, including 0.15um and 0.13um logic process with copper interconnects. TSMC offers the most comprehensive set of technology processes, including CMOS logic, mixed-signal, volatile and non-volatile memory, embedded memory, and BICMOS. (See Figure 5-4 for the further technology development road map).



Source : TSMC /2001

Figure 5-4 TSMC technology roadmap

In 2000, TSMC delivered the first 300mm production wafers to its customers from its newest facility in Taiwan Science Park, in the southern part of Taiwan. TSMC is constructing two 300mm manufacturing facilities continuously, one in Hsinchu and the other in Tainan; these two fabs are expected to operate around end of 2001 and 2002 respectively. It also plans to build several additional 300mm fabs in its Tainan base in the coming five years.

TSMC's business objective is to become the customers' "Virtual Fab"; it intends to provide the customers with the benefits of an in-house fabrication plant without the associated expense or organizational complexity. TSMC tries to make the foundry services as transparent to customers as possible. It launched the industry's first "e-foundry" service in 2000, extended its service structure onto the internet, and provided its customers with a real time and personalized view of its manufacturing operations and services.

Even though the industry suffered a severe recession in 2001 with negative 32% growth, according to Dataquest analysis, the long term outlook for the semiconductor foundry industry will still remains a positive growth in the next five years. With 39% of the total foundry market share in 2000, TSMC will continue its US$15 billion investment in its Tainan SBIP base; the company will expect to be able to sustain and continue its leading position in the foundry industry for the coming decade. (See Table 5-1 for recent income statements).

TSMC 1994-2000 income statement

US$ million

Year	Y1994	Y1995	Y1996	Y1997	Y1998	Y1999	Y2000
Revenue	604	899	1,231	1,373	1,570	2,285	5,195
COGS	-283	-396	-545	-714	-934	-1,279	-2,885
G. Profit	322	503	686	659	636	1,007	2,310
O/E							
G&A	-23	-29	-50	-49	-43	-66	-166
S&M	-13	-16	-20	-47	-25	-57	-92
R&D	-17	123	-47	-78	-61	-75	-160
TOE	-53	-69	-116	-175	-129	-197	-418
Income	269	434	570	484	506	810	1,892
	0.47	-4.63	16.94	-9.44	-15.09	-24.00	78.66
	-1.53	17.69	6.13	10.28	-64.69	-32.47	24.34
EBIT	268	447	593	485	427	753	1,995
	-3.34	23.97	13.38	76.34	53.00	14.06	39.66
Net / IN	265	471	606	561	480	768	2,035
EPS	0.34	0.31	0.22	0.13	0.09	0.1	0.18

Source: TSMC/2001

Table 5-1 TSMC income statement 1994-2000

Chapter 6

The sustainability of competitive advantages of Taiwanese semiconductor companies in the coming decade

With the competitiveness analysis, we understand the opportunities and threats which lie on the road of future development of Taiwan's semiconductor industry. Overcoming the threats from new competitors and retaining the competitive advantages in the coming decade will be the most significant challenges confronting the industry and the government. In this chapter, we will discuss the threats from new entrants and fast technology migration. These two factors will force Taiwanese companies to develop new strategies to sustain their competitive positions. We will also discuss the direction of Taiwan's semiconductor industry development and its value chain integration with China's semiconductor industry growth. Finally, we conclude with the sustainable strategies of Taiwanese semiconductor companies in the coming decade.

6.1 The challenges from new entrants

The attractive returns from the semiconductor foundry service are triggering new entrants to step into the business. The competitive challenges come from different countries.

Korea: The Korean semiconductor industry is powerful in its memory products segment; it is the world largest supplier of DRAMs. In Eumsung, Dongbu Electronics Co., one of the two semiconductor foundry companies in the country, has picked up the pieces, signed a technology and outsourcing agreements with Japanese Toshiba Corporation and opened sales offices in U.S., Europe and Japan. It wants to be among the top foundries in the world. In Bucheon, another foundry company, Anam Semiconductor, has similar ambitions. It had a worse time during the Asia economy crisis; after the restructure and sold-off chip-packaging plants, it became a stand alone foundry in 1999. In 2000, Anam reported $350 million in revenues, emerged from its loss position and brought its financial report into a better status. Korean efforts to grow a foundry industry is representative of the foundry fever that seems to have caught on in Asia .

Malaysia: The semiconductor industry began in Malaysia the early 1970s, but the companies undertook only the back-end packaging business. The government realized sustainable economic growth could depend on the production of high-tech and high value-added products such as semiconductor wafer's manufacturing. The government promoted and introduced the high technology industry in its 6th Malaysia Plan (1991-1995). In the late 1990s, semiconductor industry showed some progress in moving up the technological ladder. Two new semiconductor wafer foundries, First Silicon in Kuching and Sawawak and Silterra in Kulim and Kedah, began 8 inch wafer volume productions some time 2001. They will provide turn-key service as well as Taiwanese foundry companies. These two companies are gradually making their presences in the marketplace, aiming to capture a slice in the high-tech manufacturing service.

China: China's semiconductor market grew 35% in 2000, became the leading market in the Asia-Pacific region, and expected to sustain its lead for the next five years. New foundries are also appearing in the growing market. Grace Semiconductor Manufacturing Company (GSMC) and Semiconductor Manufacturing International Corporation (SMIC) are building 8 inch 0.25um process technology. After the entry into WTO, greater investments will expect to move into China and accelerate the semiconductor market growth. The semiconductor market reached US$ 11.4 billion in 2000 and is the largest in Asia-Pacific region, but current chip production meets only less than 20 percent of demand. It presents a huge business opportunity and attracts foreign investment to the growing industry.

China's semiconductor industry development

"China's industrialization will be the information technology driven" – this principle disclosed by the "15 project" of China's economy development plan. Information technology is the major target of China's economy development in the twenty-first century. Thus, the investment and development of the information technology-related industries will be the most important direction of industry policies in the next ten years. Beijing, Shanghai and Shenzhen are all making their best effort to promote and attract its semiconductor industry investment respectively; the final goal and intention is to build up a complete semiconductor industry value chain in China. The ambition is to align with the huge domestic market demand and establish a complete integration system for China's electronic industry.

China is already the world's biggest consumer electronic products production center; its TVs, stereos and DVD players are the top of the world; it is also the major producer of the mobile phone, CRT, and PCB, these devices are the critical components of personal computer and communication industries. But more than 80 percent of the components still need to be imported from foreign countries; the gap between demand and supply of semiconductor devices is huge. As the market demand grows in China, the semiconductor industry investments and developments become more and more critical to the competitiveness of China's electronics industry.

China's current semiconductor industry development status is similar to Taiwan's semiconductor industry around of ten years ago; process equipment and raw materials are mostly from on foreign suppliers, but the basic semiconductor industry structure of supply chain is ready. Though process technology is far behind the leading countries and semiconductor product value is also far below the world market level, the gap is closing as more and more industrial products' manufacturing are moving to China. The local supply of semiconductor components will confront a big challenge and gain a great opportunity for the semiconductor industry growth and development in China. (See Figure 6-1 for China's ambitious semiconductor industry growth plan).

China Semiconductor Industry Status 2000

[illegible]	[illegible]
IC design	Revenue: $125 million, design capability - 0.35μm
IC packaging	Revenue: $1.63 billion, packaging pieces - 4.5 billion pcs
IC types	More than 300 types
IC production	Revenue: total $ 2.5 billion- 5.88 billion pcs

Source: China Electronics Report; Topology Tech. Inc., 2001/09

China Semiconductor Industry Development Plan 2005

[illegible]	[illegible]
IC design	Embedded CPU; MCU; DSP; MPEG; RF IC; IC for ICcard
IC process	8 inch wafer capability □0.18~0.25 μm process
ICpackaging	Achieve 10 billion pcs
ICproduction	Revenue $10 billion, 20 billion pcs and with more than 3 % worldwide share

Source: China Electronics Report; Topology Tech. Inc., 2001/09

Figure 6-1 China semiconductor industry growth ambition

Through government promotion and favorable industry policies, foreign capital and up-to-date technologies were invested in the growth industry. The semiconductor value chain of each segment, including IC design, wafer manufacturing, IC packaging and testing emerged as all these companies were invested in either by foreign or local capital. (See Figure 6-2). In order to ensure the semiconductor industry development and growth, the Chinese government also provided further supporting policies for the investment in China. These incentive plan including deduction of income tax, import tax and favorable interest of bank loan. In addition to the central government's policies, the local governments also provided further support, even free land offers and construction support to attract more foreign investments.

IC Design	• With more than 20 design houses, total revenue reached \$125 million, top four design companies sales achieved \$12.5 milliom each. • Design IC product more than 300 types, design capability - 0.35 μm, majority designs at 0.8~1.5 μm. • Average design of gate count is more than 10k transitors, capability can be reached 50K gate count design.
Wafer Maf.	• Majority wafer size is 5 or 6 inch with o.8um-1.0μm process. The latest update technolohy is HH-NEC 8 inch wafer fab with 0.35 μm process capability. • 8 major companies total production reached 130k pcs, 6-8 inch capacity share is around 36 □.
Packaging & Testing	• Up to Dec. 2000, there were more than 34 packaging companies, There has more than 18, their production volume exceeded 100million pcs each. • Top 10 packaging companies total sales around \$657 million, occupied around 40% of the revenues. • The major type is DIP packaging, but the new types of SOP, QFPand PLCC are all grow very fast.

Source: CSIW; Topology Tech. Inc., 2001

Figure 6-2 China semiconductor industry value chain

With these incentives from the Chinese government, many semiconductor manufacturing investment projects were launched in 2000. (See Figure 6-3). More than four 8 inch wafer fabs were planned or built in different cities; existing semiconductor companies also planned to renew or expand their facilities. Some are planning investments for new production facilities. From these emerging investments, the intention of China's semiconductor industry development is clearly to create the whole semiconductor industry supply chain with the new up-to-date 8 inch wafer manufacturing capability as its core.

SMIC (www.smics.com)	Fab 1- Q4 / 2001 Fab 2 – Q4 / 2002	8 inch 8 inch	0.18/0.25 0.13
HH-NEC (www.hhnec.com.cn)	Q1/ 1999	8 inch	0.25/0.35
Motorola (www.motorola.com.cn)	Q1/ 2002	8 inch	0.25/0.35
SBMC (www.belling.com.cn)	Q4/ 2002	6 inch	0.5~0.35
GSMC	Q4 / 2002	8 inch	0.25

Source: J. P. Morgan; Topology Tech. Inc. 2001

Figure 6-3 China 8 inch semiconductor fab projects 2001

6.2 The challenge from technology migration

Given the new technology, 300mm wafer fabrication is already in the pipe line. Even the world's largest and second-largest foundry suppliers in Taiwan both constructed their 300mm facilities, but huge capital expenditure and the slowdown of the business made the learning cost higher and the progress of high-volume production longer. The 0.13-0.10 um process technology would be more challenging in driving the overall manufacturing cost down because the new technology would need brand-new tools and materials. It needs to be investigated whether it would take a jump from 8 inch to12 inch technology in terms of wafer size to get economic scale effect or if it would be better to push further investment in current 8 inch technology to extend the existing knowledge. (See Figure 6-4 for the cost difference in wafer size).

China could be a strong potential competitor in the foundry industry to Taiwanese foundry leading companies with the current down turn, weak market demand, and the huge capital requirement of 12 inch facilities. How Taiwanese semiconductor companies can continue to the lead the foundry industry in the coming decade is a real challenge in terms of new technology investment.

6-8 inch Wafer vs. 12 inch Wafer efficiency (DRAM)

Size	Area ratio	Total gross dies with 64M DRAM	Total gross dies with 128M DRAM
6 inch	1	222/1	93/1
8 inch	1.77	404/1.82	195/2.09
12 inch	4	959/4.32	454/4.88

Source: IDC/Japan 2000

Cost Structure 8 inch Wafer vs. 12 inch Wafer

		Aluminum/SiO_2		Cu/Low-k
		0.25µm	0.18µm	0.13µm
8 inch	Wafer cost ($US)	1437	1697	2122
	$ Cost/cm2	4.58	5.40	6.76
12 inch	Wafer cost($US)	2303	2663	3328
	$Cost/ cm2	3.26	3.77	4.71
8 inch vs. 12 inch	Cost ratio/wafer	60%	57%	57%
	Cost increase / cm2	-29%	-30%	-30%

Source: Sematech, 2000

Figure 6-4 12 inch vs. 8 inch wafer cost efficiency

6.3 Take China's investment as a future source of competitive advantages

The competitive strategies in China's growing market

The labor and land cost advantages of China's production make a good contribution to the cost reduction of product manufacturing; it helps the competitiveness of their market position. Information system product manufacturing needs the assembly of all components, as well as labor intensively. Low priced personal computers indicated the PC industry's maturity; severe competition, tiny profit and large economic scale were the characteristics of the product life cycle in the industry. The production expansion of PC assembly in China is the best and only choice for Taiwanese PC companies. In addition to the cheaper cost, the huge demand of China's market is the major reason for most Taiwanese information technology related companies to move to Mainland China. As plenty of information system companies have moved production to China, the huge demand of semiconductor components is the most attractive incentive for Taiwanese semiconductor companies to follow.

The development and growth in China's semiconductor market

The strategic value chain direction

Because the market size of Taiwan is relatively small, the development of China's semiconductor market becomes the critical point of Taiwanese semiconductor companies. The continuously growing market potential makes China the world's biggest VCD player market and the second largest market of personal computers in Asia-Pacific region. The low production cost attracts major Taiwanese information system companies to invest in China. Most of the companies are focused on the low cost incentives in the beginning stage, but they also have the advantages of first mover in the market; growing market shares and the competitive advantage positions are the long run strategies.

The United State is the world largest consumer product market; the companies in Silicon Valley take advantage of the accessibility to the end consumer market. They can create and make the new product innovations continuously. They also enjoy higher added-value creation through new product ideas and make their products the industrial common standards. Taiwanese companies do not have their own big market as American companies have; yet, given China's future domestic market potential with TVs and telephones, the market demands are more than hundred million each, it is big enough for economic scale. It also provides a similar environment to high-tech companies in Silicon Valley; Taiwanese semiconductor companies can grasp the opportunities to become involved in new product standards and create new specifications for China's growing market.

Normally, semiconductor devices were sold to system companies rather than end consumers, so technical support and application services are the best way to sell products. Most of China's system companies are at the burgeoning stage of their design capabilities. If Taiwanese semiconductor companies can set up the support capability for semiconductor product applications and provide total component solutions to the growing market, this would help create new markets. With the new product innovations and new standard creations, higher added value and profitability can be expected in long run.

Taiwan's semiconductor industry is excellent in its quality manufacturing and operation management. Moving the high capital investment and relatively smaller value-added manufacturing segment in an innovation-oriented and high value-added direction seems the only way to grasp huge market opportunities, utilize talent and move towards a knowledge economy while Taiwan confronts intense challenges in the world market.

The creation of competitive advantages in China

The strategic segments of investments

Taiwanese semiconductor companies invested a lot in their manufacturing capacity of 8 inch wafer fabs. As the importance of the growing manufacturing power was acknowledged by the world market, the lack of talent in human resources and the creativity problem both emerged in the industry. The move to Mainland China seems to provide the best opportunity to compensate for the lack of human resources. If Taiwanese companies can utilize the talent in China and link it together with valuable experiences which Taiwanese professionals possess, it will certainly have the advantages of reducing risk, creating value and becoming more competitive in the market for Taiwanese semiconductor manufacturing companies in the long term.

IC design

The advantages of IC design investment in China are: 1) Lower risk due the lower capital requirement. 2) Advantage in the standard or specification creation, thus gaining bigger market share. 3) Utilizing good talent and reducing cost.

4) Solve the problem of lack of design talent in Taiwan. 5) Through utilization of China's labor, Taiwan can focus on the high value-added product research and creation, thus it will help to raise the competitiveness of Taiwanese companies. Chinese investment companies can focus on digital consumer electronics or automobile electronics which provide huge market potential and higher value opportunity. The Taiwanese semiconductor companies can work together with China's system companies to create and set new product standards. The future great market benefit can be expected, as the product life cycle is now captured by Taiwanese companies.

IC packaging and testing investment

Taiwanese packaging and testing segments already recruited a high percentage of foreign workers in the past few years in Taiwan's operation. Due to the higher labor and land cost, some Taiwanese packaging companies have already started operations either in the Philippines or Malaysia. As investment amount is relatively lower, major foreign semiconductor companies already invested and set up their packaging and testing operation in China. Thus, to help the sustainability of competitiveness for the industry, moving Taiwanese semiconductor downstream sectors, IC packaging and testing, to China must be done now.

The disadvantages of participating in China's semiconductor industry

The creation of long run competitors

The investments in China of Taiwanese semiconductor companies will certainly help to the upgrade of China's technical capability and will create the future competitors in long run. This could be the most negative effect of the course. The capability of Taiwanese semiconductor process technology, yield management and production scheduling were the critical success factors of its semiconductor manufacturing operation. These core competence could gradually transfer into China's investment, thus the competitive advantages of Taiwanese companies will eventually be lost. But it seems that no better choice which Taiwanese semiconductor companies can possess, since the semiconductor industry is a global competitive industry, the trends indicates more and more foreign companies will invest in the big potential market. The competition is already there; it seems Taiwanese companies can only choose to go or quit.

The outflow of Taiwanese talent and capital in the short term

Because the cross-straits political parties are still in opposite positions, if the main stream 8 inch wafer fabs investment is opened for Taiwanese companies because the capital investment is huge and the technology transfer intensive, the risk of openness could be too big to manage at the moment. In addition, the huge capital outflow will have an impact on the foreign exchange reserves; the exchange rate and consequent GDP growth concern will be the problems for Taiwanese government. With the globalization of industrial value chain, not only will the investment capital flow but also the human capital will flow globally as well. Due to the lack of professional and skilled talent in semiconductor manufacturing operation management in China, the companies there will certainly offer attractive packages to recruit the experts from Taiwan in order to accelerate the investment progress and bring up China's operations as soon as they can. From the point of local employment opportunities, Taiwan will lose a sizable number of job offers at the same time.

As there are only a few semiconductor 8 inch fabs investments in China at the moment, there is a process technology level and capability gap between Taiwan and China; Mainland China may not bring any threat in the short term. Yet, the impacts and concerns which it brings in the near future will certainly need the high attentions from Taiwanese semiconductor industry and its government.

6.4 The future move of Taiwan's semiconductor industry

The advantages of human resource aspect

The openness of Taiwanese semiconductor companies to invest in Mainland China seems to be the inevitable approach to sustain the competitive advantages of the industry in world market competition. It would solve the lack of land, water, electricity and concern of contamination issues in the small island. The investment in China would certainly intensify the strength of the Taiwanese semiconductor industry.

IC design, packaging and testing are the three segments; the investment itself indicates great opportunities. Taiwanese semiconductor companies can try to utilize the advantages of good talent by and gain labor cost incentives from China's low cost operation; it seems to be the best approach to enhance their competitive position in the world market.

The dilemma of Taiwanese semiconductor companies

For pure foundry wafer manufacturing operation, because the industry does not require the design of products, the move to China can only be counted as the reason for operation cost reduction. But the capital investment of 8 inch fab is relatively high; it makes the labor cost comparatively tiny in the overall cost structure of wafer production. The current process technology of China's semiconductor companies can not be upgraded to the most updated due to constraints on the export of certain high-tech equipment to China; the per wafer value produced in China will certainly be lower than the Taiwanese operations because of technology. In addition, labor discipline and skill level need a while for training to keep up with productivity in competitive indices. In such situations, operation cost will not be reduced as a whole and the overall semiconductor industry cluster effect in China will not occur, as Taiwanese companies have currently. If the investment environment does not go worse short term in Taiwan, the urgency of moving the wafer manufacturing line to Mainland China does not seem as critical as other labor-intensive industries.

From the market development point of view, Taiwanese semiconductor companies can have the advantage to provide the speedy and effective service to China's system companies because they speak the same language and because of the short cross-straits distance. In the long term, the move of Taiwanese semiconductor companies to Mainland China may not only provide huge opportunities in certain areas, but might also bring negative effects.

The future direction of Taiwan's semiconductor industry

Given the industry development trend, the disintegrated value chain of the semiconductor industry is inevitable. China's advantages are lower labor cost and a huge domestic market. Taiwanese companies could lose their competitive advantages if the structure of China's industry value chain is completed. Therefore, the most important strategy of Taiwan's semiconductor industry is to create sustainable competitive advantages through the value chain integration with China's growing semiconductor industry and develop the core competence of its operation expertise. With the advantages of same language and culture background , Taiwanese investments in China's operation can utilize the talent pool of China's great human resources and gain access to its huge potential market. How to leverage the strength of Taiwanese semiconductor operation and management and reproduce the industry value chain in China will become the most significant challenge confronting industry and government over the next few years.

Bibliography

"12 inch v.s. 6-8 inch Wafer Efficiency." IDC Report, 2000.

"12 inch v.s. 8 inch Wafer Cost Structure." Sematech Report, 2000.

Chang, Chun-Yen and Yu Po-Lung. "Made by Taiwan: Booming in the Information Technology Era." World Scientific, 2001.

Chang, P.L. and Hsu C. "The Development Strategies for Taiwan's Semiconductor Industry." IEEE Transaction on Engineering Management, 1998.

Chang P.L., Shih C. and Hsu C. "The Formation Process of Taiwan's IC Industry Method of Technology Transfer." Technovation, 1994.

"China Electronics Industry Research: Semiconductor Sector." ITIS Project, ITRI; March, 2001.

"Chip Fabrication Process." Scientific American, 2002.

Corrigan, Wilf. "IDMs and Foundries: The Changing Landscape." ISS Taiwan, 2001, LSI Logic 2001.

"Evaluation of Taiwan's Semiconductor Industry Development." China Electronics/ Information Product Market Review, 2001.

Hax, Arnoldo C. and Dean L. Wild II, "The Delta Project: Discovering New resources of Profitability in A Networked Economy." Palgrave, 2000.

Hines, James. "The Semiconductor Manufacturing Outlook." ISS Taiwan 2001, Gartner/Dataquest, 2001.

"Industrial Monitor 2000-2001." Semiconductor and Related Devices, WEFA, 2000.

Lim, Kwanghui."Introduction to Managing the Innovation Process." MIT, Fall 2001.

Liu, Chung-Yung. "Government Role in Developing A High-Tech Industry: The Case of Taiwan's Semiconductor Industry." Technovation, 1993.

Mathews, John A., "High-Technology Industrialization in East Asia: The Case of the Semiconductor Industry in Taiwan and Korea." CHI for Economic Research, 1995.

Mathews, John A., "A Silicon Valley of the East: Creating Taiwan's Semiconductor Industry." California Management Review,1997.

"An Overview of Taiwan's Semiconductor Industry." TSIA Report 2001.

Porter, Michael. "Competitive Advantage: Creating and Sustaining Superior Performance." The Free Press, 1985 .

"The Semiconductor Industry Quarterly Report Q1 2002." Topology Technology Inc., Q1 2002.

"The Semiconductor Industry Quarterly Report Q4 2001." Topology Technology Inc ., Q4 2001.

"Taiwan IC Industry Development Quarterly Report." TSIA , Q1/ 2002.

"Taiwan's Semiconductor Industry Trends." Gartner / Dataquest, Sept., 2001.

"Taiwan's Semiconductor Industry Update." IT IS project ITRI, March, 2001.

TSMC web site, www.tsmc.com.tw , accessed April, 2002.

U.S. Department of Commerce, "U.S. Industry & Trade Outlook 2000." Semiconductor and Related Devices, June 2000.

U.S. Department of Commerce, "U.S. Industry Profile:The Leading 100." Semiconductor and Related Devices, June, 1998.