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碩士論文

晶圓代工研究與未來發展分析

IC Foundry Business Research and Future

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晶圓代工研究與未來發展分析

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摘　　要

我國半導體產業結構與其他國家之最大不同點為我國之專業分工體系，在該專業分工模式下，我國之半導體產業在全球擁有強勁之競爭力。台灣的晶圓代工在半導體的產業鏈中，上下游廠商間的垂直分工是半導體產業結構之一大特色，也是建構台灣高科技產業的技術進步與專業化能力提升之成功關鍵因素。

但是面對全球化晶圓代工，現今晶圓代工廠將採取如何之因應之道，將為本篇論文之探討。所以將從晶圓代工廠之崛起，發展，成功模式，目前所遇到的挑戰，與未來可能的走向，來說明之。面對大陸強而有力的山寨文化，成功模式的複製與發揚光大，是否有機會超越現今的晶圓代工廠，是否可能轉型，來加以探討。

目前成功之晶圓代工廠，其獨特之成功之道，來自於兩個層面：創新的經營模式與領先的製程技術。 在創新的經營模式方面：客戶服務導向與技術領先。在客戶服務導向方面，採取獨特的服務模式，與客戶建立夥伴的關係，如”你泥中有我，我泥中有你”，這樣的經營模式，搭配 IT 技術，不進入 IC 設計，以建立合作之夥伴的關係模式。在領先的製程技術方面：引用海外歸國學人所帶來的技術，良率的提升，研發部門精英團隊對製程技術的投入，以及製程探索部門對未來製程的掌握度，是先進製程技術保持領先的關鍵原因之一。因此有了創新的經營模式，客戶的信任在加上領先製程，可確定客戶並不會流失，且願意下單。

目前，Global Foundry, 韓系公司, 大陸廠的市占率並不高，有別於目前的現今晶圓代代工廠有成熟的 12 吋晶圓廠技術，大陸仍是以 8 吋晶圓廠為主。而大陸晶圓代工，仍是以海外訂單為主，所以將造成與現今晶圓代工互相競爭的狀態。同樣的，晶圓代工與晶圓設計的緊密關係，製程技術的成熟度，是否具備高良率生產的條件，是決定自身的競爭力條件。

面對 Global Foundry, 韓系公司, 大陸廠代工之衝擊，可採取保守與突破的兩個方式。例如增加新事業，轉型，抑或將現今經營模式做進一步的創新。對於大陸晶圓製程仍落後現今晶圓代工廠的技術，如何不消弭這層技術上的差距，仍保持領先的姿態 ，牽涉到對於自身技術的保護。半導體產業， 40 年的發展，已屬於夕陽產業，新事業的發展，將對於已發展純熟的半導體產業，注入一盞強心

劑。

本篇論文將研究晶圓代工之成功之道，對目前晶圓代工廠所造成的衝擊，做分析與探討。分析的角度分為是否對於晶圓代工的市占率，排名與布局有所改變。而探討的部分則包括因應之道及採取的策略。總結為晶圓代工廠之何去何從加以研究。

IC Foundry Business Research and Future

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ABSTRACT

Taiwan semiconductor foundries led the way in the worldwide semiconductor history by their business models. The top two companies, the Taiwan semiconductor manufacturing company and United microelectronics have driven the vigorous development of scientific parks and owns 80% of the global foundry business.

Many new companies; however, are growing worldwide. The relaxation of the cross-strait policy is threat to shift in the current wafer manufacturing industry. Many factors including the relationship between the wafer foundry and IC design, supply chain, and customer partnerships can determine the success of failure of a wafer manufacture. The technology process breakthrough and goods delivery times also determine customers order volume.

Currently, successful foundries are descried on two levels; innovative business orientation and process technology leadership. TSMC uses a unique service model to establish a partnership relationship with customers, such as "you have my back and I have yours."The foundry business creates a cooperation partnership model by manufacturing the customers' designer request and staying away from independent IC design.

Several factors are necessary to maintain the leading process technology in IC areas, including technology competiveness, superior product yield, an elite R & D team, a process exploration sector for the future process, and advanced process technology. Building up customer trust and a innovative business model are the keys to winning customer orders.

Today's foundry market is still dominated by Taiwan, the worldwide foundry companies such as Global Foundries, Korean companies, and mainland companies

share the remainder of the market share. The mainland companies still produce 8-inch wafers and their order book is dominated by overseas orders. The core competiveness of foundry business is closely related with designs, the process maturity of the technology and the availability of high-yield production.

Facing global competition, Taiwanese companies can adopt the non-conservative approach by forming an alliance with integrated device manufacturers. Taiwanese companies hold the technology leadership, and know that keeping the technology leadership important. The semiconductor industry has been developing for over 40 years like a sunset industry; a new business model development would revitalize the future semiconductor industry.

This thesis examines the successful pure-play foundries in terms of their business models. The linkage between foundry and upstream/downstream industries is reviewed. We purpose that the non-pure play foundry is a more successful model based on the close relationship between the foundry and IC design; the possibilities of transformation of pure-play foundries to meet future market changes are discussed.

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This thesis is to my lovely Family!

HuiLin Chang

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Chapter 1 Introduction

1.1 Background Information and Motivation

Taiwan's integrated circuit (IC) history has been developed for more than 40 years with strong government support and the efforts of both industry and academia. Taiwan's IC industry's maintains an important global presence and cannot be underestimated.

The rise of semiconductor foundries in Taiwan is undoubtedly a topic worth exploring. The growth of Taiwan's semiconductor foundries was not easy. Taiwan's IC industry had to overcome the problems with the semiconductor process nad the complexity of high technology in just 20 years. The question of how to maintain its current status and pursue long-term development is worthy of study.

Taiwan's IC industry is facing tremendous pressure from globalization and the recent entrance of late arriving countries. New companies are being established in mainland China, the USA and Korea.

The Taiwanese semiconductor industry exhibits the unique business model of vertical division. The vertical division of each sector involves upstream raw materials, IC design, mask design, downstream packaging and testing. Intermediate goods are defined to the professional division of production in each sector. Pure-play foundries focus on single production and do not have their own products. The profits depend upon manufacturing cost reduction and product yields. The entrance barriers of the foundry business include technology and manufacturing capability.

The foundry industry is technology and capital intensive with a high entry threshold, high fixed costs, specific assets, economies of scale and other characteristic. Therefore, the wafer foundry industry consists of a small number of firms operating in oligopolistic market structure. An oligopoly market features only few competing manufactures, so the interaction between firms has significant implications.

In this study, we first discuss the business model of a successful foundry company. Next, we examine the factors that can change the model in the future. Finally, we suggest possible future foundry business models.

1.2Research Objective

Based on the motivation discussed above, this study empirical investigation and analysis to achieve the following purposes:

First, the complication of the semiconductor industry background, foundry company study, analysis of Taiwan's integrated circuit market, marketing, technical development, market opportunities and the current business model.

Second, organizing the relevant literature, designing a business model, analysis of a foreign semiconductor company, technical development, analysis of market opportunities, and target market selection.

1.3 Research Flows

To achieve the above mentioned research, the study will be divided into several parts to carry out the following steps and processes:

Step 1: Research themes
Establishing research questions, research objectives, research scope and limitation
Step 2: Literature reviews
Search and read the relevant literature, information collection, compiling information on wafer foundries in Taiwan and overseas companies market share and operation models.
Step 3: IC foundry business model
IC foundry business model mechanism study
Step 4: IC foundry business model forecast
Design business models for wafer foundries based on cutting-edge technology.
Step 5: Conclusions and recommendations
Discuss the results and formulate recommendation for future studies.

Table 1.1 Research steps and architecture

Research steps and architecture

1	2	3	4	5
Research Themes	Literature Review	IC foundry business model	IC foundry business model forecast	Conclusions and Recommendation

1.4 Study Area

First, study semiconductor plants in Taiwan and overseas to determine the main industry operating model. Second, study semiconductor plants in Taiwan and overseas market niches; understand the entrance barriers for new companies and the purpose of a modified business model to enhance worldwide competences.

Chapter 2 Literature survey

In the Wealth of Nations, Adam Smith (1776) indicates that the country's wealth depends on its labor productivity. Labor productivity increases from the division of labor and professionalization from the perspective of industrial development and national wealth creation. The improvement in labor productivity occurs in the most profitable, fastest growing industries because these industries have access to the largest surplus through investment, which can naturally lead to further division of labor.

Stigler (1951) points out that the industry and "vertical integration of the early formation of close" because after the development of the industry and the market scale, manufactures form specialized divisions of labor. Ming Chung Chang (2001) points out that the vertical division of labor in an industry according to the upstream and downstream processes is divided into several levels, each firm performs only one level of specialized work.

Hone Xiuwan (2002) observes that in the Taiwan semiconductor industry's vertical division of labor, the family home becomes the vertically integrated upstream vendors for the IC design companies, production of intermediate products and then downstream to IC manufactures and producing final goods.

Tirole's (1988) industrial organization theory of the downstream firms states that downstream of the IC design companies is the production of intermediate products, while downstream of IC manufactures is the production of the final goods. Tirole (1988) theory of industrial organization on downstream firms is defined as follows: the type of intermediate goods is converted into final goods after they are sold in downstream firms. Huang MingFeng (2003) observed high-tech industries in Hsin-Chu Science park, the vertical division of labor, and the main products of companies outsourcing the production process required raw materials and components of its unit costs and other expenditures to measure the proportion of manufactures of vertical disintegration. Because the outsourcing model enables companies to engage in small-scale competition in the market, while also lowering market entry barriers, it will attract new entrants into the market.

Kuang-Cheng (2000) indicates that vertically integrated firms exhibit four characteristics. First, they eliminate completion in the market caused by finished products, "combined elements of inefficiency", "double marginalization", "adapting to different customers", "price discrimination", and "vertical integration". Second, the instruction is not complete for vendors with specific asset resulting in high transaction costs and incomplete contracts, although vertical integration can reduce transaction costs to correct production of externalities. Third, vertical integration enables the expansion of production systems, and increase production costs, forming barriers to entry for potential competitors. Forth, vertical integration is a means of increasing competitors' costs to create their own competitive advantage, resulting in the market foreclosure phenomenon.

Taiwan's semiconductor industry is different from those of Europe, the United States, Japan, and Korea in using the semiconductor vertical integration model; in that it adopts an efficient and professional model for the vertical division of labor Xu Jin Yu (2001) points out that the vertical division of labor and vertical integration system is the biggest difference. The former is an open system, accepting different foundry technologies, products, customer orders and focusing on R & D and manufacturing production processes, while the surrounding support of upstream and downstream industries and the supply chain is quite complete, while as far as technology is concerned involves two issues: first, technological security and the second, payment for the rights, patents, and intellectual property. The foundry, TSMC sued SMIC 1992-1993 because of a number of patent infringements and thefts of trade secrets. Tirole (1988) notes the individual industries' development in the economic fields relative to the entrance barriers and incubation time.

Greenhut and Ohta (1979) study the access of upstream and downstream by Cournot competition. Downstream firms face a negative slope of the demand function of both final products and intermediate foods, when negotiating with customers. In this assumption, vertical integration is beneficial for manufactures of intermediate goods, and final good price variation, compared to non-vertical integration.

Salinger's (1988) model is based on the continuous development of upstream and downstream profits. If the intermediate goods and final goods are homogeneous, the vertical integration degree increase, causing an increase of intermediate goods and final products.

Wu, Ren and Wu ICP (1999) propose the theory of vertical restraints in trading restriction in different downstream behaviors. Based on their theory, the industrialization behavior of vertical restraints is based on the resources of the largest profits difference between the socially optimal choices are crucial.

Vertical restraints and vertical integration have similar behavior in an industry where manufactures are expanding the market in their territory. The biggest differences are in the vertical limits upstream and downstream firms create through market forces to restrain each other's behavior, such as price and manufacturer restrictions. The price competition can be divided into two forms: vertical price restraints and vertical flight price limit.

2.1 Market Development Strategy and Technology Innovation

Paul Miller presents two possible marketing strategies, including new scientific developments and high technology business. The first one creates a proprietary technology for niche strategy that includes preventing competitors from entering the new niche market the company has created. The second is a broad technology innovation strategy through a solution that meets consumer needs.

2.2 Global Trend in Semiconductor Industry Development

2.2.1 Vertical Specialization

In recent years, the semiconductor industry has experienced rapid transformation in the complexity of product functions including precision in the fabrication process and rising costs for production. Therefore, many international integrated Device Manufactures (IDMs) are increasingly outsourcing as the logical alternative. Based on the analysis by the industrial Economics and Knowledge Center (IEK) of the Industrial Technology Research Institute of Electronics (ITRI), packaging and testing companies subcontracted half of their production volume in 2009. The dramatic change has caused IDM to develop specialized "Fabless" and "IDM-light" production models.

After a long development period, Taiwan's semiconductor industry has distinguished itself from other industry clusters by integrating process from IC design to manufacturing, to packaging and testing companies. The global industry companies are located primarily in HsinChu and Great Taipei. Most IC fabrication is scattered through Taoyuan, HsinChu, TaiChung, and Tainan, while the first-tier packaging and testing companies are in the central and southern parts of Taiwan. An analysis of the potential business of the semiconductor industry with its complete industry chain and strong technology indicates that Taiwan has many powerful global clients and networks DRAM companies. Samsung has set up its procurement hub and sales center in Taiwan. Some companies joint venture with other companies, such as Hynix and ProMosm Elpidia, PSC, Qimonda and Nanya Technology and Inotera Technology and Winbond.

In the mid-stream semiconductor foundry industry, we can take TSMC, the leading global company, as our example, more than half of the top 20% global semiconductor companies which are TSMC clients, including Intel, the leading foreign business. Eight of the 10 leading global IC design companies order from TSMC, demonstrating TSMC's significantly presence in the global semiconductor industry. Even the other two potential foreign businesses in IC design, Xilinx and Sandisk, also order from IC manufactures in Taiwan. These facts show that the Taiwan semiconductor industry has a widespread range of clients from IC manufacture in Taiwan. These facts show that the Taiwan semiconductor industry has a widespread range of clients from IC manufactures in Taiwan.

To address the gaps of the supply chain, the recommended foreign businesses fall into several categories: facility manufactures, like Applied Materials, Tokyo Electron, ASMI, KLA-Tencor, Lam Research, Advantest, Nikon, Novellus System, and Cannon; IC design companies, like Qualcomm, Broadcom, Nvidia, SanDisk, ATI, Xlins, Marvell. Altera, Conexant, Qligic, CSR, Silicon lab, SST and Solomon systems; IC manufactures, like intel, Samsung, TI, Toshiba, STM, Renesas, Hynix, NXP, Freescake, NEC, Micro, AMD, Infineon, Qimonda, Elpida and IC packaging and testing companies, like Amkor, Stats-ChipPAC, UTAC, Caresem, Shinko and ASAT.

The output value of Taiwan's semiconductor industry had reached the goal of NTD 1 trillion in 2005 and the output value is estimated to hit NTD 2 trillion by 2010. Taiwan is the second largest IC design center, behind only the United States. Taiwan's IC fabrication continues to grow rapidly with its outstanding performance in profitability and production capability. The silicon foundry service pioneer model, Taiwan Semiconductor Manufacture Company, provides fifty percent of the global market demand with the 65 nanometer (nm) process, and it advancing to the cutting-edge 45 nm and 28 nm process technology. Other than TSMC, United Microelectronics Corporation (UMC) is the second major foundry player in the market, and Powerchip Semiconductor Corp (PSC), ProMos technologies Corp, and Nanya technology Corp. are engaged in DRAM manufacturing production. In line with its very strong IC foundry industry, Taiwan has also risen into a leading position in the world's IC packaging and assembly arena. ASE (Advanced Semiconductor Engineering Inc.) group, the world's largest provider of semiconductor packaging and assembly services, develops and offers a wide portfolio of technology and solutions including BGA; and flip chip to wafer level packaging. Siliconware Precision Industries Co, (SPIL) holds the third position worldwide in semiconductor packaging and assembly business. The main clients include ATI, Qualcomm International, and Freecale. In IC design, Media Tek has performed impressively in China and is expected to replace Trident TO as a leading IC manufacturer in North America. Their clients include Samsung, LG and Phillips.

In conjunction with design and fabrication segments, upstream silicon-proven IPs, service and EDA tool technology are expanding into Taiwan's semiconductor supply chain. Global Unichip Corp. (GUC) which has a close investment partnership with TSMC. Fareday technology Corp., a member of the UMC group, SpringSoft Corp., and Integrated Service Technology Inc. are companies pursuing advanced technology development. In the masking and IC substrate business, Taiwan Mask Corp., Nanya Technology Corp and Phoenix Precision Technology Corp., are conducting business with outstanding performance.

2.2.2 Development of Taiwan's IC Industry

1. Infancy (1964~1974)

National Chiao Tung University established a semiconductor fabrication (hereafter. fab) curriculum in 1964 and identified as primary academic focus. Semiconductor knowledge cultivation in schools is the key to the success of Taiwan's IC industry.

General instrument set up factories in KaoHsing in 1966 for transistor packaging, the first packaging industry in Taiwan, opening the door for foreign investors, such as Texas instruments, Philips, and other factories in Taiwan. The General instrument facility thus laid the foundries for IC packaging, testing, quality control for IC packaging and downstream IC business.

2. Technology introduction (1974~1979)

In 1974, the government begins the development of the domestic electronics industry and continued to gradually transition toward technology-intensive and multi-evaluation businesses. The research center (formerly ITRI electronics research institute) established the IC demonstration plant. RCA technology was introduced from US companies and mask technology was introduced from US IMR (International Materials Research) companies to establish a 7.0 micron CMOS technology, expanding the IC manufacturing capability.

In 1976, the Executive Mr. Li Gounding promotes the science and technology development progress in the HsinChu Science Park, which serves as the "Silicon Valley" in Taiwan IC industry.

3. Technological self-reliance and expansion (1979 to now)

Following the ITRI, the electronics industry established the first demonstration plant for IC projects in 1975~1979, revealing the second phase of the development plan in 1979 – 1983 and the final VLSI development project in 1983-1988. Industrial technology applied the Taiwan semiconductor technology to the stage of VLSI in 1980. UMC derived from ITRI became the first IC manufacturer and began four-inch IC manufacturing. Successful IC production was achieved after five manufacturers officially crossed over into technology development. In 1987, TSMC derived from ITRI began manufacturing six inch IC products. TSMC collaborated with Taiwan Mask Corporation in making the IC products prototype. The Taiwan IC industry in the first 15 years was focus on IC packaging and testing. The following 15 years, 4-inch plants had begun operations and the domestic IC industry began to flourish. From 1993 to 1995, the rise of 8-inch plants stimulated huge investment in IC business. In 2000, investment began in 12-inch plants, initiating the current period of the Taiwan IC industry's unprecedented success.

The significant difference between Taiwan and the overseas IC industry is Taiwan's adopting the vertical division of labor. In the rapidly changing industrial environment, this unique division of labor model aligns with the trend of rapid development to meet industry demands. The international factories operate in vertical integration models to make the most efficient use of labor has achieved good results based on effective management between upstream and downstream levels. Our business model includes specialized resources and technology orientation.

The wafer fabrication industry has been part of the semiconductor for some time. Before 1995, integrated device manufactures (IDM), such as IBM, Toshiba and others dominated the IC industry. These manufactures controlled the entire value barrier for outsiders existed due to technology and capital concerns, and so the leading IDM vendors dominated the IC business until 1987, when the professional foundry production model emerged. Our country's professional status foundries achieved the top position in the world after the establishment of TSMC and UMC, which expended the production capacity substantially through factory expansion and thus dramatically increased the scale of the Taiwan IC industry.

The riser of professional foundries leads the division of the structure of the semiconductor industry. The foundry masters the key technology, which enables fables IC design and fab light IDM to flourish. The success of structure division highlights the traditional integrated device manufactures' lack of flexibility in production design. After the economics depression of 1996, the IDMs reconsidered the pure-play foundry as collaboration partners. Then, in the 2001 global recession, the stagnant demand for the semiconductor industry highlighted the cost pressures of IC wafer manufacturing. To respond to market fluctuations, the professional foundry model is important and the pure-play foundry and fables IDMs are crucial structure in the IC industry.

Table 2.1 indicates the Taiwan IC industry value net

Value Net Co-opetition	EDA	IC Manufacturing (Foundry)	IC Design	IDM	SIP	IC Design Service
EDA	Industry Internal Co-opetition	Customer-Supplier、Complementor、Competition	Customer-Supplier、Complementor	Customer-Supplier	Customer-Supplier、Complementor、Competition	Customer-Supplier、Competition
IC Manufacturing (Foundry)	Customer-Supplier、Complementor、Competition	Industry Internal Co-opetition	Customer-Supplier、Complementor	Competition	Complementor、Competition	Customer-Supplier、Complementor
IC Design	Customer-Supplier、Complementor	Customer-Supplier、Complementor	Industry Internal Co-opetition	Customer-Supplier、Competition	Customer-Supplier、Complementor	Customer-Supplier、Complementor
IDM	Customer-Supplier	Competition	Customer-Supplier、Competition	Industry Internal Co-opetition	Customer-Supplier、Complementor	Customer-Supplier、Complementor、Competition
SIP	Customer-Supplier、Complementor、Competition	Complementor、Competition	Customer-Supplier、Complementor	Customer-Supplier、Complementor	Industry Internal Co-opetition	Customer-Supplier
IC Design Service	Customer-Supplier、Competition	Customer-Supplier、Complementor	Customer-Supplier、Complementor	Customer-Supplier、Complementor、Competition	Customer-Supplier	Industry Internal Co-opetition

Taiwan wafer foundries have relied on IC designers in the past. Manufacturing IC chips carrier not only a large capital burden but also market risks. Since Taiwan foundries, in contrast, have high yield and low cost advantages, they can have endless business opportunities. Taiwan's two leading foundry companies, TSMC and UMC, use different business models. TSMC has a professional dedicated IC foundry, in a specific location, providing customers a full set of products and services with a single development strategy. TSMC adopts the strategy of creating all aspects of the virtual wafer plant, while spreading the investment risks, and sharing the benefits of its operation with the alliance. President Chang asserts that their IC manufacturing grows continuously but with two major challenges, how to continue to grow and how to sustain profitability. UMC adopts the symbiotic relationship of IC design and foundry by setting the design element for its own products, controlling the testing departments and adopting a market segmentation strategy. UMC does not accept customers' design and commissions.

2.3 Advantages and Disadvantages of Foundries

1. Professional OEM advantages: (a) The OEM is not responsible for bearing the cost of product sales and R&D. Since OEMs do not have their own products, the customers are not concerned with technology loss. It is very unlikely that an OEM would become a competitor. (b) Virtual factory: the OEM can maintain a complete foundry plant for manufacturing their products supported by the commission of OEM customers. Their customers can take full advantage of the quality assurance and production status of orders. On behalf of the factory, the foundry can share the operation benefits by joint or co-investment strategies to diversify investment risks.

2. Professional OEM disadvantages: because the OEM does not have listed products, it relies on close cooperation with customers for survival. The semiconductor process is highly complex, and its high entry barriers are also concerns. To achieve Moore's law criteria becomes challenging, which limits the foundry profit boundary and business expansion.

3. China foundry: The China foundry includes advanced semiconductor, Grace Semiconductor, Chip Technology, Shanghai Hua Hong NEC, SMIC and others. The mainland China semiconductor industry has achieved success in a very short time. Today, with rise of mainland China semiconductor companies, many firms have begun considering the impacts of global IC supply on the foundry business in the next five years. The semiconductor industry trends are toward specialization. The successful of Taiwan IC industry indicates that the foundry is still the model of the semiconductor industry. The China semiconductor industry has a unique division of labor structure with a strict division lines, the individual sector includes design, manufacture, packaging and testing divisions.

2.4 Factors Affecting Supply and Demand of the Foundry Industry

The main demand for foundry applications from the downstream market include information products, consumer electronics and communication products as shown below. The factors affecting the supply chain and demands upon the foundry industry can be classified into the downstream markets. Table 2.1 lists the demand for IC applications. As shown in Table 2.1, PC and communication products are the major demand, consisting primarily of cell phones, PDAs, NTC, WLAMs, and other digital products.

Table 2.2 The demand of IC application

		2001		2002		2003		2004		2005	
Main application	PC(DT+NB)	132	-4%	136	3%	144	6%	157	9%	171	8%
Emerging application	Cell phone	392	-5%	400	2%	475	19%	509	7%	543	7%
	DVD player	34	77%	50	47%	63	25%	75	18%	79	6%
	Digital camera	22	39%	26	19%	32	20%	38	19%	43	14%
	Games	35	67%	41	16%	41	1%	29	-30%	21	-26%
	PDA	13	48%	16	24%	20	30%	26	29%	33	25%
	WLAN NTC	6.4	N/A	12.4	94%	18.2	47%	24.2	33%	31	28%

2.4.1. IT in the IC Market

Information technology has always been the most important semiconductor application. With the popularity of the Internet and other information communication media, the development of related IT products is the main focus of the IC market. PCs and other IT products have provided the greatest growth momentum for the foundry industry in recent years, and most such items use foundries.

2.4.2 Communication with the IC Market

According to MIC statistics, communication applications using semiconductor manufacturing accounts for about 24 % of the global market, which is second only to IT applications. Communication products using semiconductor application include mobile phones, base stations, wireless transmission equipment, LAN, and broadband transmission and switching equipment.

The PC phone is the largest application consumer in the semiconductor market with the cumulative shipment of mobile PCs tripling in 2009. Mobile phones are a far different market from PCs considering PC peripheral equipment’s volume of semiconductor consumption, including mobile phones and other functions. Although PC product marketing is shorter, it has a longer life cycle for operational maturity, since the process sectors include the parts suppliers, handset manufacturers, cognition, and the product inventory. PC phones can involve very complex factors including the progress of national/regional infrastructure and regional differences in customs and laws. The service providers or the service subsides can affect the demand for mobile phones. Before an acute hit on the expiration of the first wave of demand for fashion phones occurs, the industry has been waiting for so-called “replacement wave” representation. The highly demand for phones stimulates the foundry phone business. Absent another economic depression, the IC foundry application in fashion or smart phones is crucial to increase profits.

2.5 Consumer Electronics in the IC Market

The semiconductor industry development over the past years has worked hard to create strong demand for mobile phones and other consumer products in order to create another view of the semiconductor. The demand for IC foundries can be considered a consequence of the continuously growth of electronic devices, such TV games, consoles, digital cameras, PDAs, and boost the foundry business.

In considering customer demands and other factors affecting demand for foundries, we can categorize foundry customers into direct IC design companies (fables IC design house), integrated device manufactures develop IC products for others as their main business. However, most business have to sell their own brand, usually designed by the foundry on behalf of their customers' IC production, such as who are major foundry customers. This type of company must rely on foundries for production. A few companies, such as Cirrus Logic, Altera, Xilinx, and other foundries can handle larger orders, but most of the IC design firms are small compared to single IDM vendors who handle a large number of small orders. In other words, IDM and similar manufactures have their own fabs, and very good process technology, dependent on the flexibility of the foundry's IC fables design, which is better than that of larger companies. Therefore, IC design companies can use foundries in order to provide a more stable source of transaction and more bargaining chips.

IC Insights' new report show 2009 integrated circuit sales declining the most for cellular-phone base station (-30%) and automotive applications (-26%), while IC revenues grew the most in non-telephony handheld system (+6%), thanks to an estimated 129 % increase in chip sales for electronic book readers. IC sales for personal computers and cell phone handsets- the two largest chip applications in the systems market – declined 9% and 3 % IN 2009, respectively.

The 2010 IC market drivers report shows e-book readers to be one of the fastest growing product categories in the coming years, with IC sales for e-reader systems rising at a 60% in the 2008-2013 periods. Among other major chip applications, the 2008-2013 compound annual growth rate for IC sales are: 26 % for RFID systems, 21% for non-technology handheld computing devices and 6% for PCs. Figure 2 compares the five-year IC sales for 13 key end-user equipment segments as well as their 2009 market sizes. Figure 2.1 indicates the IC application market growth rate comparisons.

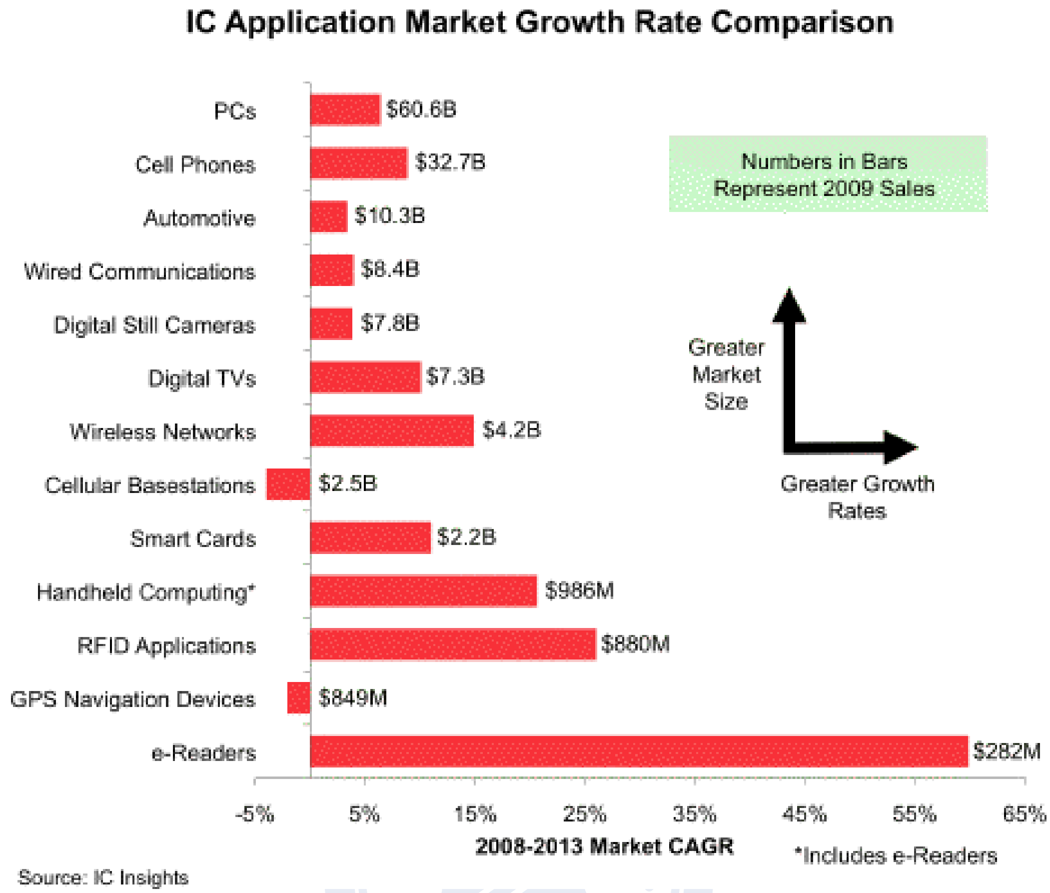

Fig. 2.1 IC application market growth rate comparison http://www.icinsights.com/news/bulletins/bulletins2009/bulletin20091217.html

2.6 IDM Companies

IDM firms in this business have a wafer fabrication facility (fab) well as the design, production, and marketing of its own brand of IC, which is their main business, these include the domestic companies Wombond, Macronix, Mosel Vitelic, etc., and foreign companies like Intel, NEC, IBM, and others. These plants have their own gab for production, and most also have a design capacity for the product, so these IDM foundry outsourcing vendors can not control orders, compared to the much lower bargaining chip design companies. Although orders more difficult for the IDM maker, their output accounts for the global semiconductor market value of Jiucheng described above, and with the future necessitating professional foundries specialized foundry revenues will have a huge impact.

IDM manufactures face risks, including R&D, design, manufacturing, IC packaging and testing, marketing, and others. One of the heaviest burdens on manufactures is the equipment risk. Building a 12-inch plant requires spending $ 3 billion US, and if sufficient orders do not produce the necessary ROI, the companies' finances will suffer irreparable harm, therefore, IDM outsourcing has become the dominant current trend.

2.7 System Companies

System operators include personal computers, peripheral systems, a variety of add-in cards, and other products in the information technology industry, or wired and wireless communication products, manufactures, or general consumer electronics like televisions, stereos, video games, and other manufactures. These operators as used in the IC industry may be designed or imposed by the IC design company for the design, then by the foundry industry for mass production, but for now, these operators are not professional foundry manufactures or the main sources of orders. However, demand continues to request in internet communication.

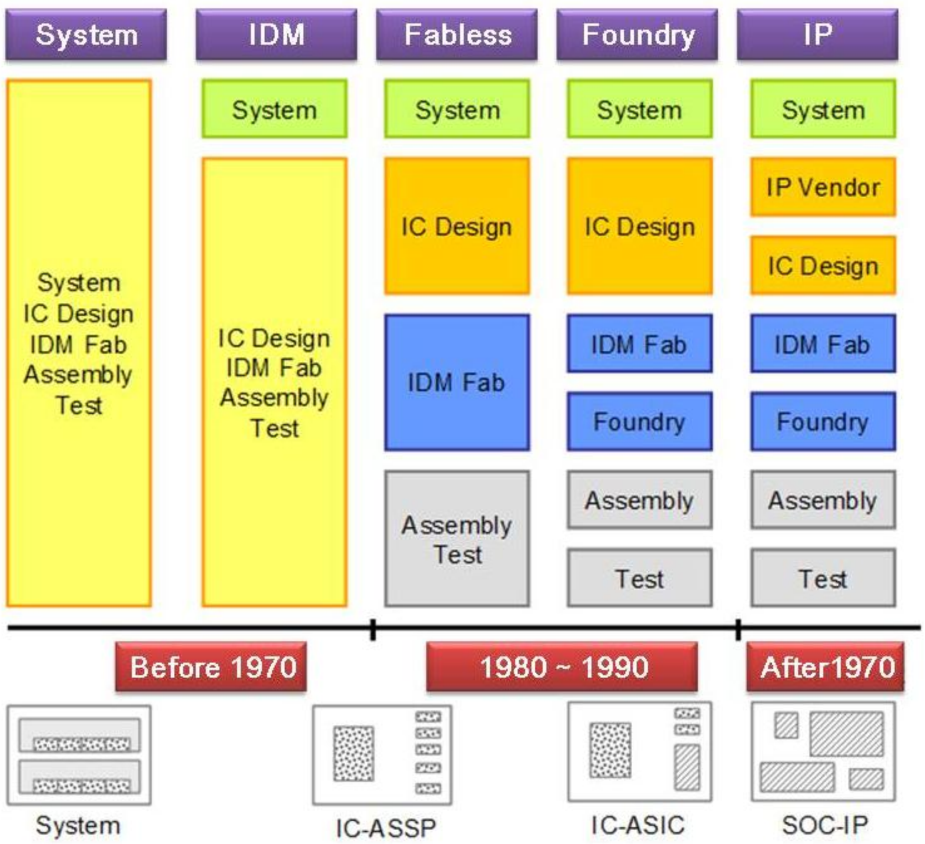

Fig. 2.2 IC industry evolution in the time period of 1970 to 1990

2.8 IDM and Pure Foundry Growth Rate

Figure 2.3 shows the 2003-2013 foundry sales forecast. Pure-play foundries dominated the IC foundry. In 2010, the pure-play foundry and IDM are expected to take 21.7 billions and 3.8 billions, respectively. The growth rate of pure-play foundries is estimated to be 25 % in 2010. The revenue of pure-play foundries is seven times that of the IDM foundry.

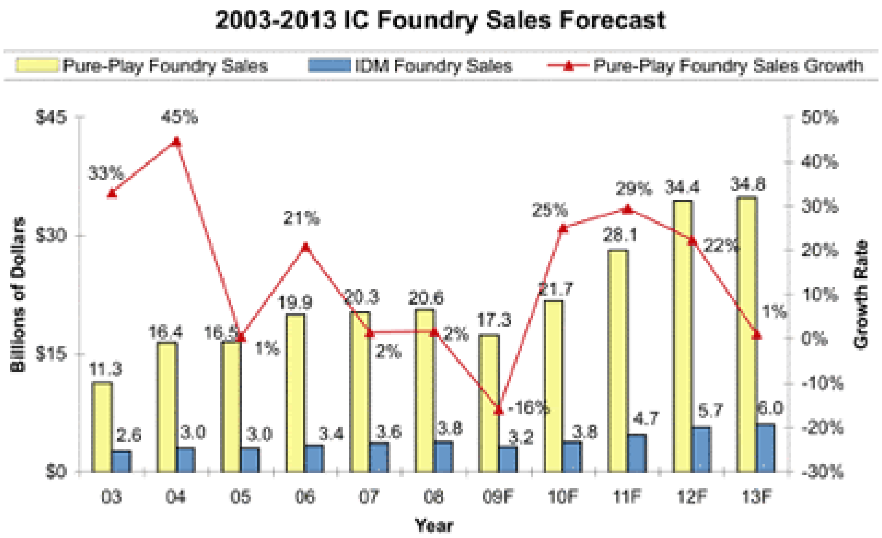

Fig. 2.3 2003-2013 IC foundry & IDM sales forecast (IC insight, http://74.125.153.132/)

According to recent IC insights, there is vague news, South Korea's Samsung Electronics is expanding its foundries annual production, with plans to increase investment to compete with TSMC. Time will tell whether Samsung's foundry can beat TSMC.

In Taiwan, the IC foundry industry is progressing smoothly over a period of time. TSMC continues to lead the foundry industry, but suffered yield problems when introducing 40 nm technologies. The company promised a solution in early 2010. In June 2009, TSMC chairman Morris Chang ran for country commissioner, and then returned to the CEO position of TSMC. The problem of advanced technology reflects the company's management problems and the change in its organization ensures TSMC's remaining at the top of the foundry industry.

However, TSMC also achieved an important victory in 2009, winning the long and intense IP infringement lawsuits against SMIC. SMIC agreed to pay $200 million US in compensation to TSMC, plus stock and warrants in SMIC, even that causes SMIC Founder and CEO Richard Chang to resign.

In China, OEM companies that have reunited to form one company include Shanghai Hua Hong NEC (HHNEC) and Grace semiconductor manufacturing corporation (GSMC).

With the integration of multi-function electronics products, the analog/mixed –signal and RF components are positioned as the next generation growth engine. Only few logic devices companies can continuously fulfill the Moore's law pace. Looking to the future, the IC foundry is more concerned about the mainstream market segments other than logic elements. The IC foundry business needs to follow the products trends because innovative technology can return the highest profit in the IC market.

2.9 Evolution of the Semiconductor Industry

The Taiwan semiconductor industry began in 1956, with the establishment of Institute of Electronic Engineering of National Chiao Tung University. Important events include HsinChu Scientific Park being built in 1980, TSMC's establishment in 1987 and Taiwan's foundry output accounting for 73 % of global production in 2003.

Taiwan's semiconductor industry has transitioned through three main stages of growth. The preparatory and seeding stage began in the 1960s when Taiwan positioned its economy for export-led growth, mainly through small and medium private firms involved in contract manufacturing relationships with US and European manufacturing firms. Through the establishment of an export processing zone in 1965, Taiwan attacted contracts from US electrons and semiconductor firms seeking to invest in low-cost manufacturing in Asia as worldwide IC market sales soared. In 1966, US based general instrument microelectronics established a semiconductor packaging business in Taiwan and became the first semiconductor company there. By the 1970S, the seeding phase had taken roots as Taiwan was successfully transferring global technologies into capabilities in its semiconductor industry. The ITRI played significant roles in technology developments. The ERSO was subsequently formed out of the ITRI and charged by the government to promote technology from the world's best resources into Taiwan. The government enacted Phase 1 of the electronic industry development project in this area, which closed with ITRI/ERSO spinning off its pilot plant into the private sector, resulting in the creation of UMC in 1980.

Taiwan's semiconductor industry went through the diffusion phase from 1981 to 1990. With government sponsorship technologies and new products were diffused to private firms that took on an increasing role in growing the domestic industry. Phase II of the electronic industry development project was enacted in this period to promote the strategic growth of the industry. Various companies including TSMC were spun off from ITRI/ERSO during this era. By the end of this phase, an immature industry cluster had emerged with firms engaged in design, masking, fabrication, and assembly.

The semiconductor industry experienced the burgeoning phase over the subsequent decade following the diffusion phase. Competitiveness in the industry greatly increased along with a rise in prominence of Taiwan's semiconductor industry at the global level. An increased partnership between government and industry increased the role of private firms in the industry. By 1995 the cluster was fully developed with over 180 firms and had a large share of the world market. By 1999, Taiwan's semiconductor output exceeded $5 billion US, making it the fourth largest producer in the world ahead of industrial giants such as France and the UK. The private firms became more collaborative even as competition among them increased.

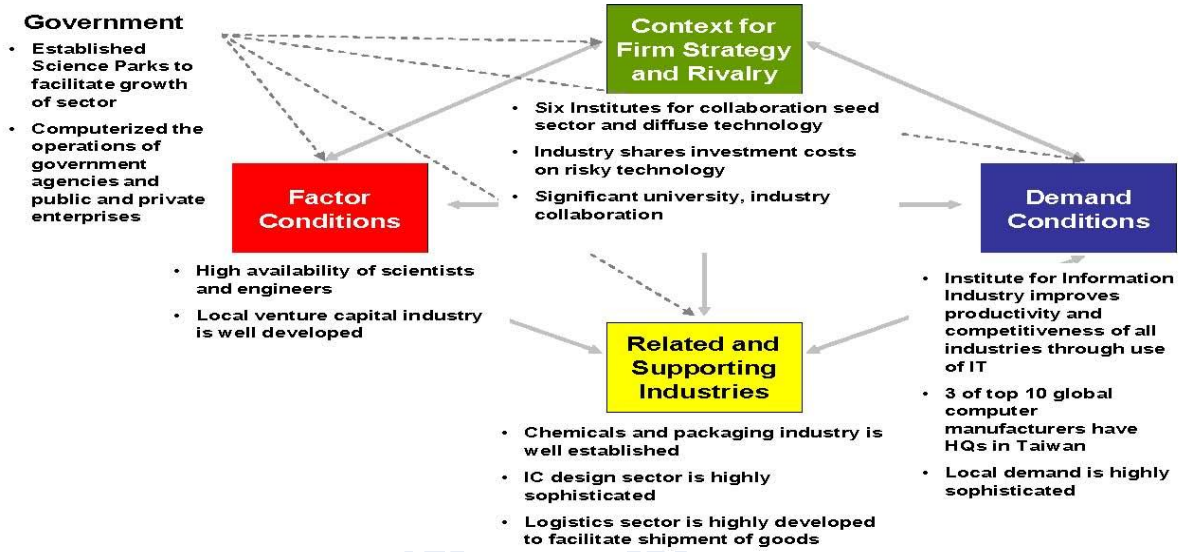

Fig. 2.4 Taiwan semiconductor industry schematic diagram

Source: John A. Matthews "A Silicon Valley of the East: Creating Taiwan's Semiconductor Industry", California Management Review (1997); Pao-Long Chang and Chiung-Wen Hsu, "The Development Strategies for Taiwan's Semiconductor Industry", IEEE Transactions on Engineering Management, Nov 1998 .

Chapter 3 Research Theory

3.1 Document Analysis

The evaluation of the semiconductor industry's development history covers its beginnings in Asian and globally and continues through its current status and future projection. The literature analysis includes relevant topics in journal articles, conferences, seminars information, books, and statistical reports to collect, organize and summarize the analysis.

3.2 Research Method

The background and development history of IC factories in mainland China and Asia are selected. The competitive advantages and future of Taiwan foundries are researched. The global foundry layout is discussed. Finally, we propose the business model for the future IC foundry business.

3.3 Taiwan's Foundry Industry and the Current Situation

The structure-conduction-performance is used to describe the effect of market structure on firm performance and behavior. The vertical division of labor is the main operational model in the Taiwan semiconductor IC manufacturing industry. Figure 3.1 indicates the structure-conduction-performance of the Taiwan foundry industry.

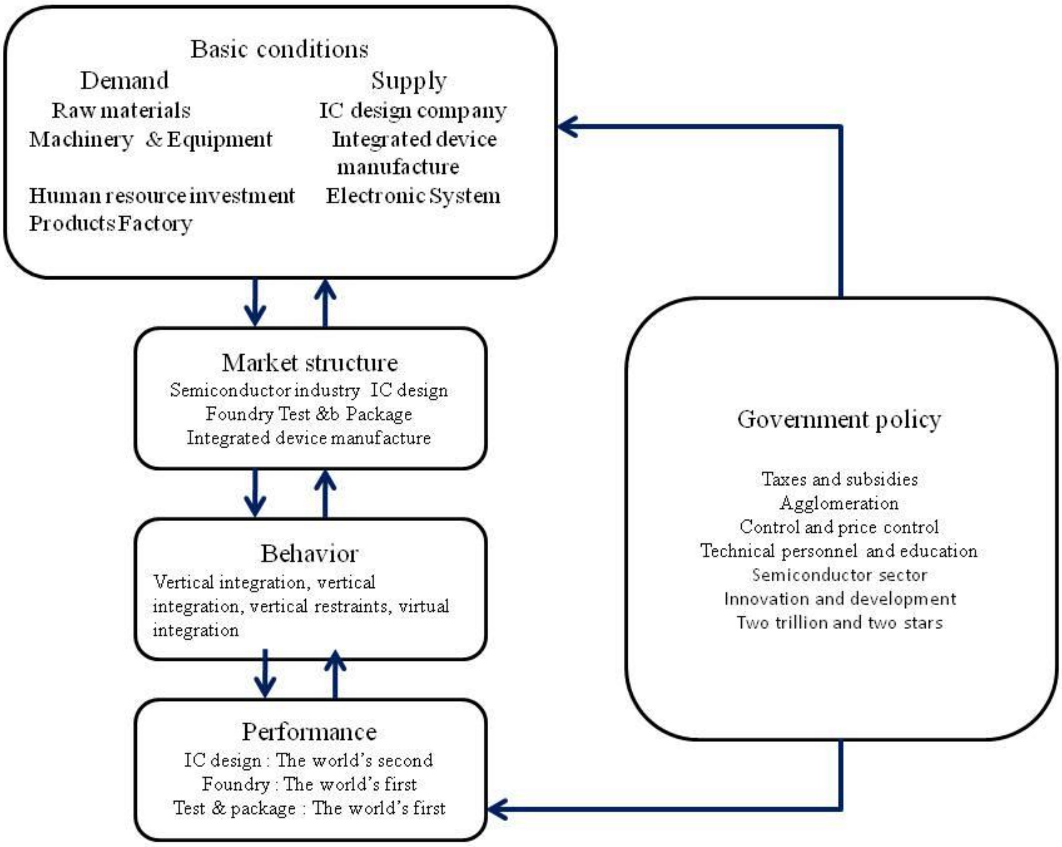

Fig. 3.1 Taiwan foundry structure-Conduction-Performance

TSMC and UMC are noted models of the Taiwan IC foundry industry, representing Taiwan high technology companies. TSMC was established in the HsinChu Science Park in 1987, and is the world's first professional integrated circuit manufacturing company. The company is service oriented and provides the most advanced manufacturing technology. TSMC offers full services to its customers, the most complete component data libraries, intellectual property, design tools and design flows.

UMC was established in 1970 and headquartered in HsinChu science industrial park. UMC is currently a world-class foundry and plays an important role in Taiwan's semiconductor industry. UMC is the second foundry company and first publicly traded semiconductor company. The 2009 IC insights report, ranks TSMC and UMC first and second place, respectively in the foundry business.

According to the 2009 IC insight for market research, the growth rate declined 15 % because of the financial crisis. IC Insights indicates that Taiwanese companies plays an important role in the foundry business, among the manufactures throughout the Asia-Pacific IC market. The top 17 pure-play foundry rankings in the 2009 global foundry market-to-date are followed by TSMC, UMC, Chartered Semiconductor, Global Foundries, SMIC, East, Advanced, IBM, Samsung, Grace. TSMC remains the most eye-catching with 2009 revenues of nearly $90 billion U.S. reported in IC insight statistics. Global Foundries (GF) divided from AMD shows brilliant performance and it is noteworthy that GF revenue is $1.1 billion U.S. IC insights also indicates that only four integrated device manufactures' (IDM) foundries are rank in the top 17 wafer in the top 17 wafer foundries. IBM is the world largest IDM, but its revenue is only about 4 % of TSMC's.

Table 3.1 Year 2009 IC foundry ranks from IC insights

2009	Company	Foundry type	Location	2007 sales ($M)	2008 sales ($M)	2009 sales ($M)
1	Tsmc	Pure-play	Taiwan	9813	10556	8989
2	UMC	Pure-play	Taiwan	3430	3070	2815
3	Chartered	Pure-play	US	1458	1743	1540
4	Global Foundries	Pure-play	US	0	0	1101
5	SMIC	Pure-play	China	1550	1353	1075
6	Dongbu	Pure-play	South Korea	510	490	395
7	Vanguard	Pure-play	Taiwan	486	511	382
8	IBM	IDM	US	570	400	335
9	Samsung	IDM	South Korea	335	370	325
10	Grace	Pure-play	China	310	335	310
11	He Jian	Pure-play	China	330	345	305
12	Tower	Pure-play	Europe	231	252	292
13	HHNEC	Pure-play	China	335	350	290
14	SSMC	Pure-play	Singapore	350	340	280
15	TI	IDM	US	450	315	250
16	X-Fab	Pure-play	Europe	410	368	223
17	MagnaChip	IDM	South Korea	322	290	220

3.4 Development of Taiwan’s Integrated Circuit

Dr. Shen Rongqin has divided the Taiwan integrated circuit industry development into the following four stages.

(A) Government Policy

In the classical point of view, the government policy is the most important factor in demining the success of new business in developing countries. The international division of labor is the first stage for developing countries to explore international business. Wade (1990) proposed that the government should use a series of economic policies such as rewards, incentives, management, and a variety of mechanisms to spread risk, together with guidance and resource allocation to promote economic in developing countries. The semiconductor business was a new technology for Taiwan in 1964. The Taiwan government played a vital and unique role in promoting the IC development process. Government set up the semiconductor technology center, technology transfer center, factory building, staff training and technology exploration. The government’s economic policies dominated the success of high technology business in this stage.

(B) HsinChu Science Park

UMC was established in the HsinChu Science Park in May 1980. The company set up the first factory in the production of electronic devices, computers and a variety of chip used in television and music IC. In order to develop advanced technology, the R & D center was established. The semiconductor business enlarged Taiwan’s industrial economic scale and foreign purchasers began to order their products from Taiwan.

(C) DRAM Development

In June 1986, there was insufficient production capacity of equipment for developing 1M DRAM, so this technology was sold to South Korea. The state Administration for the VLS project set up R&D results obtained from TSMC, through the state's ability to raise the domestic product circuit design and manufacturing capacity.

(D) IT Domination Country

The Taiwan IC industry was developed very quickly in the 1990s and became the business hub in the IC market. IC was Taiwan's core technology and its most value-added business. Taiwan manufacturing has come to dominate IC production, with its IC foundry, packaging and design businesses ranked as the top one and two worldwide.

3.5 Semiconductor

A semiconductor is a material that has an electrical conductivity between that of a conductor and an insulator, that is, generally in the range 103 Siemen/cm to 10-8 S/cm. Devices made from semiconductor materials are the foundation of modern electronics, including radio, computers, telephones, and many other devices. Semiconductor devices include the various types of transistor, solar cells, many kinds of diodes including the light-emitting diode, the silicon controlled rectifier, and digital and analog integrated circuits. Solar photovoltaic panels are large semiconductor devices that directly convert light energy into electrical energy. An external electrical field may change a semiconductor's resistivity. In a metallic conductor, current is carried by the flow of electrons. In semiconductors, current can be carried either by the flow of electrons or by the flow of positively-charged "hole" in the electron structure of the material.

Common semiconducting materials are crystalline solids but amorphous and liquid semiconductors are known, such as mixtures of arsenic, selenium and tellurium in a variety of proportions. They share with better known semiconductors intermediate conductivity and a rapid variation of conductivity with temperature but lack the rigid crystalline structure of conventional semiconductor such as silicon and so are relatively insensitive to impurities and radiation damage.

Silicon is used to create most semiconductors commercially. Dozens of other materials are used, including germanium, gallium arsenide, and silicon carbide. A pure semiconductor is often called an "intrinsic" semiconductor. The conductivity, or ability to conduct, of common semiconductor materials can be drastically changed by adding other elements, called “impurities” to the melted intrinsic material and then allowing the melt to solidify into a new and different crystal. This process is called “doping”.

Semiconductor devices are electronic components that exploit the electronic properties of semiconductor materials, principally silicon, germanium and gallium arsenide. Semiconductor devices have replaced thermionic devices (vacuum tubes) in most applications. They use electronic conduction in the solid state as opposed to the gaseous state or thermionic emission in a high vacuum.

Semiconductor devices are manufactured both as single discrete devices and as integrated circuits (ICs), which consist of a number—from a few to millions – of devices manufactured and interconnects on a single semiconductor substrate [1].

3.6 Semiconductor Fabrication

Semiconductor device fabrication is the process used to create the integrated circuits (silicon chips) that are present in everyday electrical and electronic devices. It is a multiple-step sequence of photographic and chemical processing steps during which electronic circuit are gradually created on a wafer made of pure semiconducting material. Silicon is the most commonly used semiconductor material today, along with various compound semiconductors.

The entire manufacturing process from start to packaged chips ready for shipment takes six to eight weeks and is performed in highly specialized facilities called “fabs”.

Table 3.2 Process flows and description for semiconductor fabrication

	Classification	Description
1	Front-end processing	Front-end processing refers to the formation of the transistors directly on the silicon. The raw wafer is engineering by the growth of an ultrapure, virtually defect-free silicon layer through epitaxy. In the most advanced logic devices, prior to the silicon epitaxy step, tricks are performed to improve the performance of the transistors to be built. One method involves introducing a straining step wherein a silicon variant such as silicon-germanium (SiGe) is deposited. Once the epitaxial silicon is deposited, the crystal lattice becomes stretched somewhat, resulting in improved electronic mobility. Another method, called silicon on insulator technology involves the insertion of an insulating layer between the raw silicon wafer and the thin layer of subsequent silicon epitaxy. This method results in the creation of transistors with reduced parasitic effect.
		Front-end surface engineering is following by: growth of the gate dielectric, traditionally silicon dioxide (SiO_2), patterning of the gate, patterning of the source and drain regions, and subsequent implantation or diffusion of dopants to obtain the desired complementary electrical properties. In memory devices, storage cells, conventionally capacitors, are also fabricated at this time, either into the silicon surface or stacked above the transistor.
2	Back end processing	Once the various semiconductor devices have been created they must be interconnected to form the desired electrical circuits. This back end of line (BEOL, the latter portion of the wafer fabrication, not to be confused

		with back end of chip fabrication which refers to the package and test stages) Involves creating metal interconnecting wires that are isolated by insulating dielectrics. The insulating material was traditionally a form of SiO_2 or a silicate glass, but recently new low dielectric constant materials are being used. These dielectrics presently take the form of SiOC and have dielectric constants around 2.7 (compared to 3.9 for SiO_2), although materials with constants as low as 2.2 are being offered to chipmakers.
3	Modules	Historically, the metal wires consisted of aluminum. In this approach to wiring often called subtractive aluminum, blanket films of aluminum are deposited first, patterned, and then etched, leaving isolated wires. Dielectric material is then deposited over the exposed wires. The various metal layers are interconnected by etching holes, called vias, in the insulating material and depositing tungsten in them with a CVD technique. This approach is still used in the fabrication of many memory chips such as dynamic random access memory (DRAM) as the number of interconnect levels is small, currently no more than four. More recently, as the number of interconnect levels for logic has substantially increased due to the large number of transistors that are now interconnected in a modern microprocessor, the timing delay in the wiring has become significant prompting a change in wiring material from aluminium to copper and from the silicon dioxides to newer low-K material. This performance enhancement also comes at a reduced cost via damascene processing that eliminates processing steps. In damascene processing, in contrast to subtractive aluminium technology, the dielectric material is deposited first as a blanket film, and is patterned and etched leaving holes or trenches. In single damascene

		processing, copper is then deposited in the holes or trenches surrounded by a thin barrier film resulting in filled vias or wire lines respectively. In dual damascene technology, both the trench and via are fabricated before the deposition of copper resulting in formation of both the via and line simultaneously, further reducing the number of processing steps. The thin barrier film, called copper barrier seed (CBS), is necessary to prevent copper diffusion into the dielectric. The ideal barrier film is as thin as possible. As the presence of excessive barrier film competes with the available copper wire cross section, formation of the thinnest continuous barrier represents one of the greatest ongoing challenges in copper processing today. As the number of interconnect levels increases, planarization of the previous layers is required to ensure a flat surface prior to subsequent lithography. Without it, the levels would become increasingly crooked and extend outside the depth of focus of available lithography, interfering with the ability to pattern. CMP (chemical mechanical planarization) is the primary processing method to achieve such planarization although dry *etch back* is still sometimes employed if the number of interconnect levels is no more than three.
4	Wafer test	The highly serialized nature of wafer processing has increased the demand for metrology in between the various processing steps. Wafer test metrology equipment is used to verify that the wafers haven't been damaged by previous processing steps up until testing. If the number of dies—the integrated circuits that will eventually become chips— etched on a wafer exceeds a failure threshold (ie. too many failed dies on one wafer), the wafer is scrapped rather than investing in further processing.
5	Device test	Once the front-end process has been completed, the

		semiconductor devices are subjected to a variety of electrical tests to determine if they function properly. The proportion of devices on the wafer found to perform properly is referred to as the yield. The fab test the chips on the wafer with an electronic tester that presses tiny probes against the chip. The machine marks each bad chip with a drop of dye. The fab charges for test time; the prices are on the order of cents per second. Chips are often designed with “testability features” such as "built-in self test" to speed testing, and reduce test costs. Good designs try to test and statistically manage corners: extremes of silicon behavior caused by operating temperature combined with the extremes of fab processing steps. Most designs cope with more than 64 corners.
6	Packaging	Plastic or ceramic packaging involves mounting the die, connecting the die pads to the pins on the package, and sealing the die. Tiny wires are used to connect pads to the pins. In the old days, wires were attached by hand, but now purpose-built machines perform the task. Traditionally, the wires to the chips were gold, leading to a “lead frame” (pronounced “leed frame”) of copper, that had been plated with solder, a mixture of tin and lead. Lead is poisonous, so lead-free “lead frames” are now mandated by ROHS. Chip-scale package (CSP) is another packaging technology. A plastic dual in-line package, like most packages, is many times larger than the actual die hidden inside, whereas CSP chips are nearly the size of the die. CSP can be constructed for each die *before* the wafer is diced. The packaged chips are retested to ensure that they were

		not damaged during packaging and that the die-to-pin interconnect operation was performed correctly. A laser etches the chip's name and numbers on the package.

Table 3.3 Semiconductor industry from upstream to downstream

<table>
<tr><td>Upstream</td><td>Equipment
1. Wafer cutting equipment
2. Wafer surface grindingequipment
3. Cleaning equipment
4. Thin film equipment
5. Photoresist coating equipment
6. Lithography equipment
7. Etching equipment
8. Ion Miscellaneous equipment
9. Photoresist stripping equipment</td><td colspan="2">Materials
1. Wafers
2. Special gas
3. Process of chemical raw materials
4. Photoresist</td><td>Ordering customer types
1. Fabless (IC desgn)
2. IDM
3. System</td></tr>
<tr><td>Midstream</td><td>Design automation factory</td><td>Intellectual property suppliers</td><td>Design component vendors</td><td>Design servicevendors</td></tr>
<tr><td rowspan="2">Downstream</td><td colspan="4">Packaging and testing</td></tr>
<tr><td>Information product</td><td>Consumer electronics</td><td>Communication products</td><td>Others</td></tr>
</table>

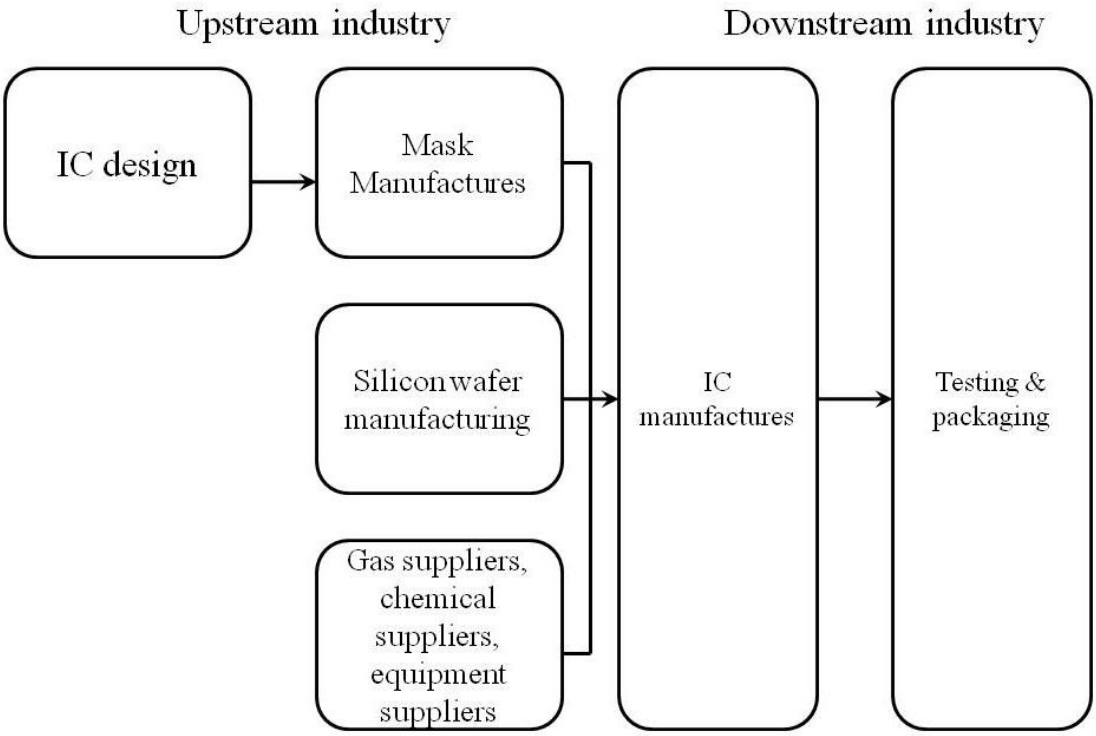

Fig. 3.2 Semiconductor upstream and downstream diagram

3.6.1 Electronic Device Technology

Electronics is that branch of science and technology that uses the controlled motion of electrons through different media and vacuums The ability to control electron flow is usually applied to information handing or device control. Electronics is distinct from electrical science and technology, which deals with the generation, distribution, control and application of electrical power. This distinction stated around 1906 with the Lee De Forest's invention of the triode, which made electrical amplification possible with a non-mechanical device. Until 1950, this field was called "radio technology" because its principal application was the theory and design of radio transmitters, receivers and vacuum tubes. Most electronic devices today uses semiconductor components to control electron flow. The study of semiconductor devices and related technology is considered a branch of physics, whereas the design and construction of electronic circuits to solve practical come under electronics engineering.

3.6.3 The Revolution in Electronic Devices

The emergence of the IC semiconductor stems from the electronic devices revolution, people started to use semiconductors in marking complex chips. Table 3.3 lists the events in the resolution of electronic devices.

Table 3.3 The events of electronic devices revolution

1874	Braun invents the solid-state rectifier
1906	DeForest invents triode vacuum tube
1907~ 1927	First radio circuit developed from diodes and triodes
1925	Lilienfeld field-effect device patent filed
1947	Bardeen and Brattain at Bell laboratories invent bipolar transistors
1952	Commercial bipolar transistor production at Texas Instruments
1956	Bardeen, Brattain and Shockley receive Nobel Price
1958	Integrated circuit developed by Kilby and Noyce
1961	First commercial IC from Fairchild Semiconductor
1963	IEEE formed from merger or IRE and AIEE
1968	First commercial IC opamp
1970	One transistor DRAM cell invented by Dennard at IBM
1971	4004 Intel microprocessor introduced
1974	First commercial 1-kilobit memory
1978	8080 microprocessor introduced
1984	Megabit memory chip introduced
2000	Alferov, Kilby, and Kromer share Nobel price

3.7 Semiconductor Industry

3.7.1 Integrated Device Manufacturer

An integrated device manufacture (IDM) is a semiconductor company that designs, manufactures, and sells integrated circuit (IC) products. As a classification, IDM is often used to differentiate between a company that handles semiconductor manufacturing in-house and a fables semiconductor company, which outsources production to a third-party. Due to the dynamic nature of the semiconductor industry, the term IDM has become less specific than when it was coined.

3.7.2 IC Foundry

An IC foundry is a company that manufactures ICs (Integrated Circuits) for IC design houses. Being regarded as a profitable and promising area, many new IC foundries have recently been established and the area is becoming increasingly competitive. In this highly competitive environment, the quality of service provided by an IC foundry has been widely regarded as the critical factors for establishing a competitive advantage.

Opinion leaders in the Taiwan IC foundry industry proposed the “virtual fab” as the way to establish a leading IC foundry. A virtual fab is an IC foundry whose service is so good that customers would virtually take the foundry as their own factory. Thus, a vertical fab, is virtually owned, monitored or controlled by its customers. If such a virtual fab is available, customers would rather place orders with IC foundries that establish a virtually customer owned IC factory.

Although many companies continue to both design and manufacture integrated circuit (achieving efficiency through vertical integration), theses integrated device manufactures (IDMs) are not alone in the marketplace. Economic forces have led to the existence of many companies that only design devices, known as fables semiconductor companies, as well as merchant foundries that only manufacture devices under contract to other companies without designing them.

IC production facilities are expensive to build and maintain. Unless they can be kept at nearly full utilization, they will become a drain on the finances of the company, so companies avoid costs by not owning such facilities. Merchant foundries, on the other hand, find work from the worldwide pool of fabless companies, and by careful scheduling, pricing and contracting keep their plants at full utilization.

Originally, microelectronic devices were manufactured by companies that both designed and produced the devices. This was necessary because manufacturing involved tweaking parameters, having a precise understanding of the manufacturing processes, and the occasional need to redesign. These manufactures were involved in both the research and development of manufacturing process and the research and development of microcircuit design.

However, as manufacturing technology developed, microelectronic devices became more standardized, allowing them to be used by more than a single manufactures. This standardization allowed design to be spit from manufacturing. A design that obeyed the appropriate design rules could be manufactured by different companies that had compatible methods. An instrumental development that allowed this standardization was the introduction of advances in electronic design automation (EDA), which allowed circuit designers to exchange design data with other designer using different foundries. Because of the separation of manufacture and design, new types of companies were created. One type of company is called a fables semiconductor company. Such companies have no semiconductor manufacturing capability but rather contracted production from a manufacturer. This manufacturer is called a merchant foundry. The fables company concentrations on the research and development of an IC-product, the foundry concentrates on fabricating and testing the physical product. If the foundry has no semiconductor design capability, it is called a pure-play semiconductor foundry.

An absolute separation into fables and foundry companies is not necessary. Some companies continue to perform both operation and benefit from the close coupling of their skills. Some companies manufacture some of their own design and contract out the manufacturing or design of others, in case where they see value or seek special skills. The foundry model is a business vision that seeks to optimize productivity.

After the 2009, dip in the semiconductor market, in March 2010, the Taiwan semiconductor manufacturing company chairman Morris Chang predicted a strong recovery in the semiconductor market economy, with “the global revenue for the semiconductor market to rise at an annual rate of 22 % this year, better than the 18% he estimated in late January. He concluded the growth of the market would stay on course this year and maintain at quite high space.

Through the end of the 2008 finical crisis, the global semiconductor plant inventory was controlled for more sensitive and cautious growth, so during 2009, in the largest semiconductor market, he structure change was in the large fab capacity of the IDM facilities, which would not only halt investment in expanding production, but also, in its own fab capacity utilization, wait until the actual receipt of the order, and increase the amount of cast films.

Thus, when IDM facilities had a sudden increase, in customers' order volume, they met it by ordering the extra production from the foundries in an attack and retreat that kept the potential negative factors and their risk to a minimum.

In this kind of logical thinking, the entire semiconductor manufacturing chain becomes very sensitive to the inventory adjustment, the change in LCD driver IC orders last year, is a good example. During two quarters of last year, in the U.S. and China, plan to stimulate the economy, driven by LCD driver IC panel plant on demand, the customer also increased wafer foundry orders per year, but the market in last September's panel felt only slight demand for a flat down had less that three months time to complete the inventory adjustment.

Low inventory is becoming the normal, as sales and shipments of computers, mobile phone, and other electronic products continue to increase, so the chip supply is always lower than the demand. If past experience is an indicator, the industry should soon enter a large semiconductor plant expansion phase, but we look at capital, only foundries and memory plant boost the capital.

3.7.3 IDM Outsourcing

In year 2001, the semiconductor is in the economy downturn stage. The international IDM industry has been thinking about a new business strategy. The IDMs cannot afford the hyge manufacturing cost for the technology beyond 65 nm, the profit gain is not attractive due to the minimum investment return for the largest business interest. Therefore, the IDM plants need to be fab-lite for more benefits. IDM outsourcing becomes a new business when IC technology goes to the 65 nm process. Many IDMs including NXP, Free-scale, Crolles, Alliance, IBM, Ti announced they were ceasing their advanced research and process development. The IDMs choose to collaborate with pure-foundry companies. Some IDMs announced the closing of their half-factory and expanded their outsourcing portion. The foundry model has swept through Asia, Japan and the global giant NEC.

IDMs plan to reduce their investment in the fab and move off the large factory model. The IDM facilities have chosen to cooperate with foundries. The implantation the fab-lite IDM strategy will inevitably increase the proportion of outsourcing and foundry orders volume will increase.

When IDM facilities are intended to be fab-lite, the foundry can not only get low-priced equipment but also use this equipment to create more valuable products. Similarity, the domestic foundry business can also benefit downstream industries including packaging and testing companies, especially in IC packaging. The IC packaging technology is now focused on the ball gate array package (BGA) and flip chip package (Flip Chip). IDM outsourcing can release orders and leverage their investment, thus, the fab-lite strategy affects the business model of the IC industry. The IC market pie is divided by function, and the division of labor can decrease the market risks of integrated businesses. The fab-lite IDMs thus becomes the future trend for current IC technology nodes.

In the long run, the fab-lite IDM can also promote the products' cycling time since a closer relationship between the IDM and the foundry is necessary. The chip design tesm actively interacts with the foundry in the beginning, which can ensure that the foundry delivers a process that required shorter time. The foundry's ability to seize the business and shorten production time makes the collaboration between foundry and IDM win-win situation. Table 3.4 summarizes the reasons why fabless works

Table 3.4 Main reasons to support fabless business model

Reason	Description
Technology	➢ Gain the benefits of process technology ownership with minimal investment ➢ Fab Independence: Able to migrate quickly to the most effective process technologies
Supply	➢ Multiple sourcing improves response to volatile changes in demand ➢ Access best in class supply chain advances
Capital	➢ Effective use of capital for R&D ➢ High return on assets (ROA)
Effectiveness	➢ Enables increased focus driving improved business execution ➢ Fabless business model benefits from more effective capacity utilization

3.8 Taiwan Semiconductor Manufacturing Company

TSMC created dedicated semiconductor foundry industry when it was found in 1987, and is the world's largest specialized IC manufacturing services company. It continues as the market leader by steadily increasing its capital spending and by outperforming all other market competitors. TSMC posted annual sales $9.83 billion U.S. in 2007 and currently employs over 20,000 people worldwide. TSMC's headquarters are located in the HsinChu science park with account management and engineering service offices in China, India, Japan, Korea the Netherland, Taiwan and United States. The company is listed on the Taiwan stock exchange (TSE) and on the New York Stock Exchange (NYSE) under the trading symbol TSM, Table 3.4 illustrates the history of TSMC.

To serve and support their customers' manufacturing needs, TSMC has consistently experienced strong growth by building solid partnerships with its customers. IC suppliers from around the world trust TSMC with their manufacturing needs, due to its unique integration of cutting-edge process technologies, pioneering design services, manufacturing productivity and product quality.

As the founder and leader of this industry, TSMC has built its reputation on offering advanced wafer production processes and unparalleled manufacturing efficiency. From its inception, TSMC has consistently offered the foundry industry's leading technologies to its customers. The company's manufacturing capacity exceeded 8 million 8-inch equivalent wafers in 2007, while its revenues represent some 50% of the dedicated foundry segment in the semiconductor industry.

In 2002, TSMC became the first semiconductor foundry to enter the ranks of the top 10 IC companies in worldwide sales. It continues to move up and ranked sixth in 2007 according to the IC insight report in March 2008.

TSMC operates two advanced 300 nm fabs, four 8-inch wafer fabs, and one 6-inch wafer fab. Fab operations are centralized in Taiwan, primarily in HsinChu Park and Tainan Science Park. TSMC fabs are also located in Camas, Washington (WaferTech), Singapore (SSMC, a joint venture with NXP semiconductor) and Shanghai, China.

Its 2008 consolidated revenue of NT 3,332 million yielded a profit of about 99.9 billion yuan, placing it recenue among the world's top ten semiconductor companies. Its whole wafer shipments in 2008 were about 8.5 million eight-inch Jorden wafers, about 8% of worldwide integrated circuit wafer shipments from the previous year's 7.5 %

Table 3.5 The history of TSMC

	History of TSMC
1	Founded in 1986, TSMC
2	The world's first professional and specialized IC foundry company
3	Revenue accounts for about 48% of the global foundry market
4	2002, first entered the top ten semiconductor foundry company
5	In 2000, TSMC merge WSMC and Ti –Acer
6	TSMC currently has two 12-inch wafer fabs (Hsinchu and Tainan), five eight-inch fabs and one Six-inch wafer fab
7	Also from its wholly owned subsidiaries American Wafer Tech Corporation, Taiwan Semiconductor Manufacturing Company (Shanghai Co., Ltd.), and SSMC Singapore joint venture production company support
8	TSMC currently employs more than 20,000 worldwide
9	Chang Morris, general manager of the 2005 resignation, is still chairman. The post of general manager and replaced by CEO Rick Tsai
10	Chang Morris CEO and Chairman in 2009

3.8.1 TSMC Pushes Foundry 2.0

TSMC has made a series of high profile moves recently. During the 2010 VLSI week seminar, TSMC Chairman, Morris Chang, unveiled the Open Innovation Platform (OIP), a new business model for the foundry, whose purpose is to shorten client's time to market and reduce their development and manufacturing costs. Some people also called the new OIP model "Foundry 2.0" , signifying the second generation of the fables-foundry model. Based on the OIP or Foundry 2.0 model, the foundry will offer vertically integrated services to customers, from designing (design tools and IP) establish more extensive and deeper technical cooperation with its customers.

Besides the ambitious OIP imitative, TSMC is also aggressively developing its own silicon-proven embedded IPs, such as flash, DRAM, and CPU, as well as pushing the envelope on process technology. According to TSMC's 40G process will be in risk production at year 2009, while 32LP process is expected to ready by the end of year 2010. TSMC also announced that its 28HP will offer a high K/metal gate option.

With access to advanced process technology, TSMC's foundry is increasing market share, and TSMC will play the "winner-take-all" role to dominate standard foundry and technology platform development. It is understood that TSMC is atctively developing a new platform expected to replace the traditional foundry, what the press has called "Foundry 2.0". TSMC expected that through this platform, the future will see a broadening of its technical cooperation with the industry and enhance its competitive position, as the foundry industry standard against Intel. The foundry model popular for the past 10 years, with the creation of numerous fables IC design companies, may now be in transition from what TSMC chairman Morris Chang has previously called "The innovative business model" to integrating the entire fab based IDM semiconductor structure. TSMC is creating Foundry 2.0, which will re-interpret and give new meaning to the term "Foundry". In the past, foundry was limited to OEM, but is now beyond the original foundry manufacturing area, integrating the entire production process including design, design service platform, back-bump packaging, and testing processes. Increasingly involved in the technological trend toward integration, the foundry industry can play a leading role in linking customers and manufactures, as well as in the development of standards for the upstream and downstream industries to follow. This requires a strong technology platform for support, open to manufactures for use so they can also apply the new Foundry 2.0 platform. It is noteworthy that TSMC's Foundry 2.0 will promote a new platform for its global market share of more than 5 percent. TSMC licenses its platform to competitors. In the current foundry industry, the Singapore foundry Chartered Semiconductor has the main-purpose platform.

Morris Chang has described TSMC's combined competition-Chartered and IBM, Infineon, Samsung Electronics, etc.. as a awesome competitor. TSMC's new Foundry 2.0 is an attempt to expand it influence with a broad technology platform that could replace the foundry and establish a new milestone in the semiconductor industry.

3.9 UMC Rank 2nd in the Foundry Industry

UMC is a leading global semiconductor foundry that provides advanced technology and manufacturing services for applications spanning every major sector of the IC industry. Founded in 1980 as Taiwan's first semiconductor company, UMC is the world's foundry technology leader, consistently first-to-market on advanced processes and possessing the highest number of semiconductor patents in the industry. UMC's customer-driven foundry solutions enable chip designers to leverage the strength of the company's leading-edge processes, which include production-proven 65 nm, 45/40 nm, mixed signal/FRCMOS, and a wide range of specialty technologies. The company employs approximately 12,000 people worldwide and has an extensive network of service offices in Taiwan, Japan, Singapore, Europe and the United States to meet the needs of its global clientele.

As a global industry pioneer, UMC was the first foundry to ship wafers using copper materials, to produce chip 300 mm wafers, to deliver functional 65 nm ICs to its customers, and to produce chips using 28 nm process technologies. UMC's leading-edge foundry technologies enable the creation of faster and more powerful chips to meet today's demanding application, including high k/metal gate, low-k dielectrics, immersion lithography and mixed RFCMOS.

UMC led the development of the commercial semiconductor industry in Taiwan. It was the first local company to offer foundry service as well as the first semiconductor company to get listed on the Taiwan Stock Exchange (1985). UMC is responsible for many local industry innovations including the introduction of the employee share bonus system, often credited as a primary factor in the development of a prominent electronics industry in Taiwan. UMC also enables customers to access complete supply chain information online through the website. This shortens the ordering time.

UMC is committed to the timely delivery of leading-edge solutions that serve the specific and unique requirements of their customers in the face of today's advanced application. UMC collaborates closely with customers as well as partners throughout the entire supply chain, including equipment, EDA tools, and IP vendors to work synergistically towards each customer's system-on-chip silicon success. The company also possesses the required knowledge in system design and architecture necessary to a greater change of first-pass silicon success for today's SOC designs.

UMC's customer-driven foundry solutions start from a common logic-based platform, where designers can choose the process technology and transistor options that best fit their application. From there, technologies such as RFCMOS and embedded Flash can be used to further fine-tune the process for customers for individual needs. Furthermore, as IP has become a critical resource for today's SoCs, UMC have worked to provide basic design building blocks as well as more complex IP that are optimized for portability and cost, developed both internally and from third-party partners.

With advanced technology, a broad IP portfolio, system knowledge, and advanced 300 nm manufacturing, UMC offers comprehensive solution that help customers deliver successful results in a timely fashion.

3.10 Intel Corporation

Intel Corporation was founded in 1968 and is based in Santa Clara California , manufactures, and sells integrated circuits for computing and communications industries worldwide. It offers microprocessor products used in notebooks, netbooks, desktops, servers, workstations, storage products, embedded applications, communications products, consumer electronics devices, and handhelds. The company also offers system on chip products that integrate its core processing functionalities with other system components, such as graphics, audio, and video, onto a single chip. It also provides chipset products that send data between the microprocessor and input, display, and storage devices, such as keyboard, mouse, monitor, hard drive, and CD or DVD drives; motherboards that have connectors for attaching devices to the bus, and products designed for desktop, server, and workstation platforms; and wired and wireless connectivity products, including network adapters and embedded wireless cards used to translate and transmit data across networks. In addition, Intel offers NAND flash memory products primarily used in portable memory storage devices, digital camera memory cards, and solid-state drives; network processors used in networking equipment to manage and direct data moving across networks and the Internet; software products, including operating systems, middleware, and tools used to develop, run, and manage various enterprise, consumer, embedded, and handheld devices, as well as software development tools that enable the creation of applications; and healthcare products designed to connect people and information to improve patient care and safety. Further, it offers platforms that include a microprocessor, chipset, and enabling software. Intel sells its products primarily to original equipment manufacturers, original design manufacturers, PC and network communications products users, and other manufacturers of industrial and communications equipment.

3.11 Samsung Electronics

The Samsung Group is a multinational conglomerate corporation headquartered in Samsung Town, Seoul, South Korea. It is the world's largest conglomerate by with an annual revenue of $173.4 billion U.S. in 2008 and is South Korea's largest chaebol. The meaning of the Korean hanja word Samsung is "tristar" or "three stars".

The Samsung Group is composed of numerous international affiliated businesses, most of them united under the Samsung brand including Samsung Electronics, the world's largest electronics company, Samsung Heavy Industries, the world's second largest shipbuilder and Samsung C&T, a major global construction company.

Samsung has been the world's most popular consumer electronics brand since 2005 and is the best known South Korean brand in the world. Samsung Group accounts for more than 20% of South Korea's total exports and is the leader in many domestic industries, such as the financial, chemical, retail and entertainment industries. The company's strong influence in South Korea is visible throughout the nation, which has been referred to as the "Republic of Samsung".

Chapter 4 Research Methods

The semiconductor industry in Taiwan has played an important role in global IC manufacturing since 1980. The structure of Taiwan's semiconductor industry deserves study. This chapter discusses the foundation of the foundry business, the potential issues within the foundry business, and market share. The research methods are based on the IC industry's evolution and technology development trends.

4.1 Why Pure-play Foundries Face Potential Issues

In recent years, semiconductor-related industries have been the fastest growing ones in Taiwan, especially TSMC and UMC, which are considered "miracles in Taiwan's IC business'. TSMC was the first company to focus entirely on the IC foundry. TSMC's position is very precise, with its main development strategy of strengthening foundry capacity, manufacturing with the wafer process and supporting downstream businesses. TSMC mainly relies on capital investment to build factories when strategic thinking and customer joint ventures are necessary. Industries relate to foundries include IC packaging, testing, masking and semiconductor equipment and materials. Unlike TSMC, UMC's business strategy is a joint venture plant with major clients, including those in the IC design industry.

The pure-play foundry TSMC is dedicated to IC manufacturing services. The president, Morris Chang, created the original concept of the virtual fab to offer customers a full set of products and services. The purpose of the formation of the full range of virtual fabs is to achieve strategic alliance or a co-investment approach. Although the customers do not own their own foundries, they can understand and monitor their product status and stimulate the processing of the products in the virtual fab. Customers also can from this co-investment plan. In contrast to OEM products, customers can consider that they are manufacturing their own products in the virtual fab. TSMC focus on high yield and high quality products. As representative of the world's foundry industry, TSMC strives to maintain good relationship with their customers. Its business strategy can achieve great stability, maintain the company's good image even during an economics depression.

In contrast, the vertically integrated industry business model treats each sector independently. Wafer design, production, packaging, and testing are separated with each sector creating its own value. Therefore, the online products cannot be changed. Compared to pure foundries, the vertical integration process is less flexible, and requires more capital, equipment, manpower and other resources due to the dispersive resources. Its overall management efficiency and economics of scale are relative poor.

The battle of the foundry industry for the next stage has several fronts: the technical level, human resources, cost structure, product yield, and capital allocation capabilities. Since the foundry industry is capital-intensive and responds immediately to market demand, the greatest threat is investment in mainland China. Mainland China has considerable high-tech talent and lower labor costs, which will make it a strong competitor if foreign investment can benefits from its laissez-faire economics and flexible social system. In contrast to the infrastructure elements, its possession of Singapore is very expensive. In Singapore, manpower costs are very high and the foundry business began relatively late. Malaysia and the Philippines began their foundry industry before Taiwan, but their companies focus on testing and packaging and do not dominate the industry. The United States provides a free and open market, and is more suitable for creative industries and design work rather that wafer manufacturing. The Taiwan foundry industry must pay more attention to the threat from Japan and South Korea, since they have a background similar to that of Taiwan. The Japanese government also supports companies in the IC design and wafer manufacturing industries. Regardless of the worldwide threat, Taiwan foundries needs to continuously improve the technology of wafer production. Production yield, quality and cost/performance ratio should be enhanced to create the highest possible market barrier for potential entrants and enlarge the scale of Taiwan's foundry business.

Considering the vertically integrated IC, the integrated resources are bound to capital arrangements. When the government supports the integrated IC industry, the investment risks are relative low. The issues of the Japanese semiconductor industry can be identified by the lack of its own competitive process. The business profit is diluted because of wasted resources, uncontrollable investments and improper management. Therefore, Japanese companies operate in the opposite manner. They focus on high value-added activities and specialized production. In recent years, the product life cycles have become very short, so strategic alliances with Taiwan manufactures can speed the creation of completed products. In manufacturing because of the large production capital required, complex processes and short production cycles.

4.1.1 The Characteristics of the Pure play Foundry Business

1. Integrity with customers, vendors, and employees, with honesty and objective-driven approach, consistent and impartial attitude.
2. Consistent focus on core business: IC foundries must focus on their main business, the dedicated IC foundry, and not be distracted by other pursuits.
3. Globalization of business, not limiting themselves to the domestic market or any specific geographical region. The foundry business must develop capabilities to become competitive globally.
4. Continuous innovation is the wellspring of growth. It is vital to all sections of the foundry business from strategic planning to marketing, management, technology and production.

4.2 External Competition

This section describes the assessment of industry competitiveness among four nations: the United States, Japan, Korea and Taiwan. The United States has the advantage in technology leadership, large economic scale, CPU domination and intellectual property rights. Its disadvantage is the high cost of chip manufacturing. Japan has the advantage of being the consumer chips technology leader and having a good market, but its disadvantage is the increasing cost of chip manufacturing. South Korea leads in chip process technology and production volume, its disadvantages are a lack of IC design and application, and investment stagnation not favorable to support and powerful IC design and application specific integrated circuit (ASIC) technology, its only drawback is that it has not yet established its intellectual property base.

4.3 IC Industry Outlook

There are two subjects worth addressing: how to keep Taiwan's semiconductor profits growing in a challenging future and the economic flexibility of the semiconductor business.

TSMC and UMC plan to be able to lead the world's most advanced process technology. Intel, IBM and Korean companies are IDM standards. According to domestic ITRI reporting, the United States may be the leader for IC design, Japanese companies shall focus on the development of embedded memory (mainly used in consumer electronics) and South Korea can move into next generation memory development. Taiwan represents the professional IC foundry. The domestic IC industry is assumed to have a brilliant future. The international division of labor should be beneficial for the value addition. To enhance its international competitiveness and upgrade the industry, the companies in Taiwan should focus on R & D, marketing and sales and outperforming competitors in the international arena.

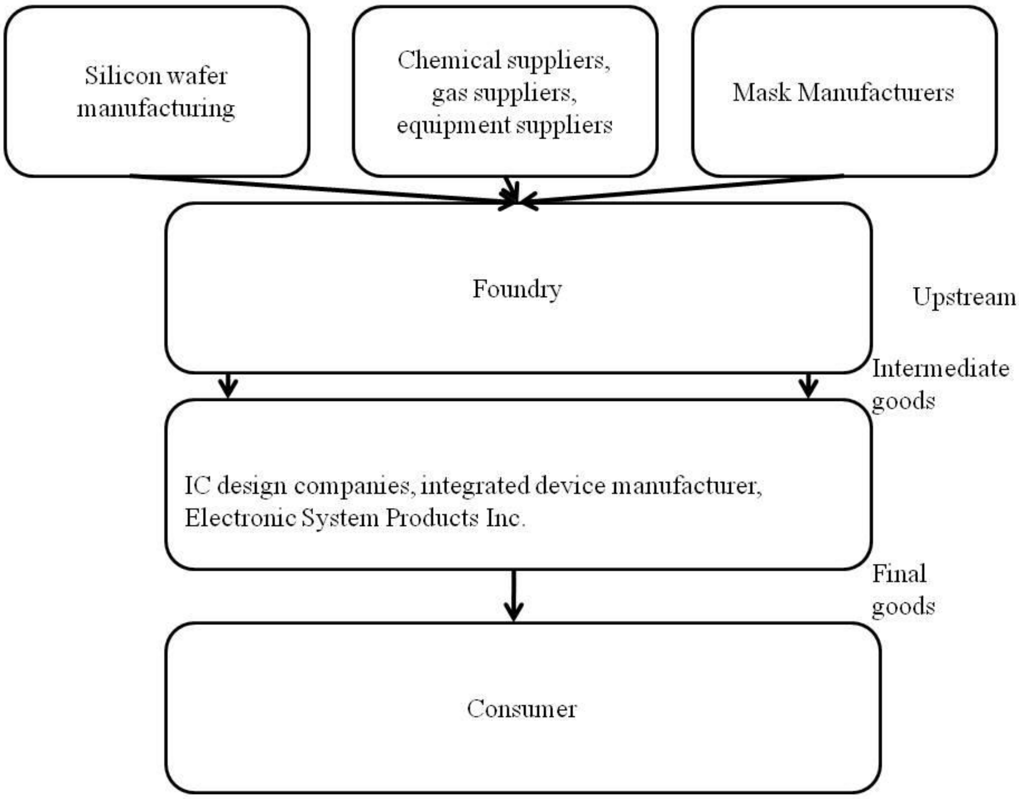

Fig. 4.1 Foundry relevance graph

4.4 Professional OEM Advantages

OEMs do not have to bear the cost of product sales and R&D. Since the OEM does not own any products, its risk from product failures is low and customers do not worry about the professional OEM market learning their technology. The disadvantage is that the OEM has no listed products, and so must rely on and cooperate with customers.

The relationship between OEMs and their customers is very close. Contractually, the foundry customers can get complete product information and manufacturing process status from the virtual fab. They can take full advantages of the production quality and status of orders. The foundry shares the operation outcomes with customers. They can use strategic alliances and joint investment to diversity investment risks for a win-win situation with customers. The professional foundry enjoys three additional advantages: (1) Each sector can excel in its own skill through the tight-knit professional division of labor. (2) When the business becomes simple and high specialized, the system can easily be integrated for spontaneously integration. (3) The trend of “anti-concentration” for semiconductor becomes more and more obvious, including the value of the depth and the breadths of vertical integration.

The principle of virtual fab is that only one company is responsible for the entire process: product order, IC design, and end packaging, testing and final product delivery. The production status of orders is offered on-demand to ensure that customers can track their products. Therefore, the factory can fully control the complete flows including products confidentiality, production flexibility, testing service, intellectual property, supply, product technology, and technical information. The Taiwan foundry industry was supported in its early stage with deep government intervention. Among its competitors in Asia, Hong Kong was slower paced, and the science park movement was not established as early as still operates in a socialist framework and laws, and its institutions are not healthy enough to support such a capital-intensive industry.

The factors affecting the competitiveness of the IC foundry business including human resource, technology level, cost structure, capital allocation, and yield stability. The industry needs to adjust related industries completeness and technology skill.

Since the Taiwan business enjoys some conditional advantages, the Taiwan IC foundry industry has a unique entrepreneurial spirit, coupled with high standards and abundant human resources and a strong overall industry basis. Unlike some companies that are heavily reliant on foreign companies, foreign companies may not pose an immediate threat to Taiwan.

However, Taiwan does need to pay attention to the possible threats from mainland China. China is gradually joining the market; this attracts many world-renowned manufacturers that are eagerly to enter China. The electronic information industry is developing in China now with the advantage of China's abundant and cheaper labors. The downstream business once its technology foundation is built.

The complexities of IC manufactures come from many business units. The vertical division of labor in the Taiwan IC industry has been implemented thoroughly. The technology integration is relative simple and competitiveness can be achieved through virtual cycling. In terms of worldwide investment, Taiwan holds three of the top ten in the global market. The Taiwan IC industry offers integrated manufacturing capabilities, a high degree of flexibility and international strategies. Its IC foundry industry is gradually becoming the leader in this field and plays an important role in the international area.

TSMC's strategies for maintaining its superior positions are as follows: (1) To upgrade its human resources technology level, cost structure, capital allocation and yield enhancement (2) To continuously explore the market for opportunities. (3) To set the market entry barrier high and expand its industry investment.

Based on the existing implantation of strategy and their experience, European, United States and Japanese companies are partnering with overseas foundries. In fact, Japan has closed it foundry business and places orders with Taiwan foundries. Most of the top five Japanese companies –NEC , Hitachi, Toshiba, Mitsubishi, and Fujitsu have recently transformed to fab-lite IDM and collaborate with Taiwan foundries. Many countries' IDM adopt a conservative strategy and delegate orders to foundries because of cost consideration and Taiwan foundries mainly service theses orders.

The semiconductor industry trend is clearly toward specialization. In contrast, Japan's large financial groups integrate their business units from middle-stream to down-stream. Unlike the business specialization trend in the global semiconductor industry, Japanese companies focus on complete business units. The performance of the integrated process remains to be investigated, is competitive edge is not clear.

To summarize, the Taiwan IC foundry industry still exhibits the strength in the face of change and competition. The IC foundry remains the model for the semiconductor industry. Taiwan's semiconductor industry has a unique labor-division structure and a high degree of specialization with each individual business units performing its business independently. Furthermore, the IC industry networking integrates the business units, including design, manufacture, packaging and testing. The Taiwan IC manufacturing industry can adapt flexibility, creating international competitiveness. In contrast, Europe, the United States, and Japan are adopting vertically integration for wafer processing. The main advantages for foundries are human resources, technology level, cost structure, capital allocation, and yield stability. The IC manufacturing industry combines process technology and product design. The world's IC fabless design companies grow continuously. The fabless design companies have brought unlimited potential to the foundry business. The combination of IC design and foundries can not only cope with the variety of market demands but also benefit from new products.

Furthermore, when the economy is depressed, foundries and IC design companies can face together a "slow growth and increased investment" situation. During periods of marginal profits, the IC design companies may fear losing bargaining power when bring their new products to a dedicated foundry. However, if the IC designer chooses tow foundries, it may limit high costs since different foundries offer different technology capability. On the other hand, the foundry may also fear the loss of customer orders to competitors. There does exists that tension between IC design houses and foundries.

In order to seize the market, Samsung, IBM, and Chartered Semiconductor formed an alliance for increasing their market share. TSMC immediately struck back and signed a TI OEM orders. With the increasing entry threshold of wafer manufacturing, TSMC needs to maintain their technology leadership more carefully. IC technology drives new application, and IC manufacturing takes the new application to the market. Given the length of IC product cycling time, gaining profits in the IC design and IC foundry industry is challenging.

Taiwan foundry industry needs to consider the technology threshold to maintain continuously profit gain. Figure 4.2 indicates the revenues of IC foundry market share and revenue.

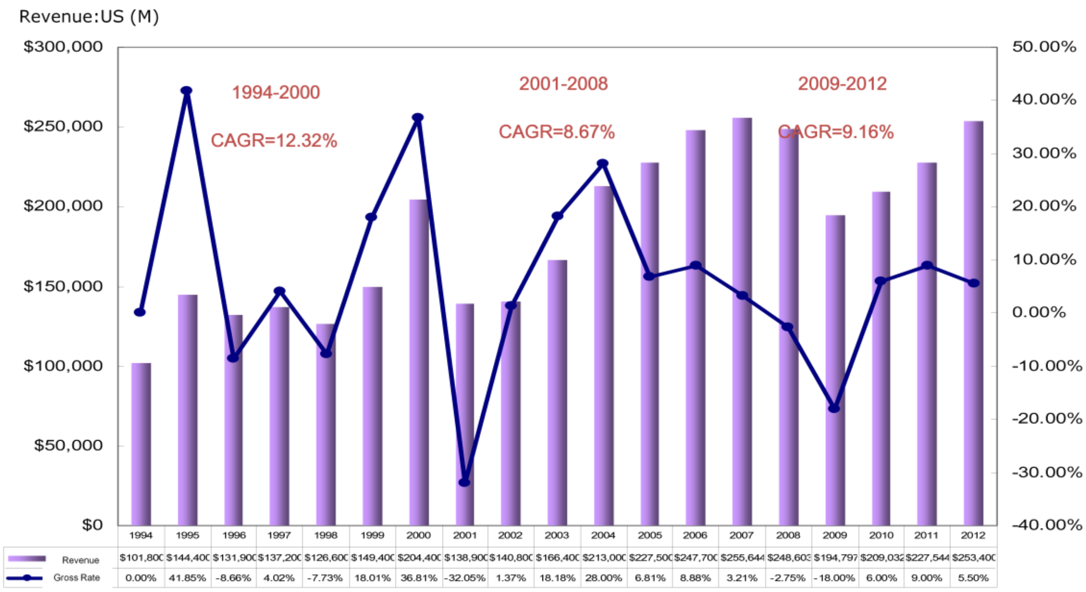

Fig 4.2 The global foundry market trends, Unit: billion /%

4.5 The IC Foundry Procedure for a New Process Delivery

Table 4.1 lists the procedures of IC foundries for delivering new technology. The IC designer designs the IC circuit based on the design rules. Then, photo masks tap out based on the layout IC chips are implanted on the Si wafers. Finally, the wafer acceptance test, yield and spice performance tests are performed to ensure the IC device quality.

Table 4.1 New process delivery for IC foundry

	Items	Objective
1	Layout	IC designer designing the circuit based on the design rules
2	Mask	Photo mask tapping out based on the layout
3	Process	To convert the layout into Si process
4	WAT	Wafer acceptance test to check electrical/device performance
5	Yield	SRAM yield performance
6	Spice	Device performance & Spice model delivery
7	Qualification	Device performance in wafer package level

4.6 Foundry and Fabless Comparison

A fabless semiconductor company specializes in the design sales of hardware devices of semiconductor chips. The company outsources the fabrication of the devices to a specialized manufacturing company called a semiconductor foundry.

Foundries are typically located in countries with lower cost of labor, so fabless companies can benefit from lower capital costs while concerning their research and development resources on the end market. Fig 4.3 compares the process development point against “low”, “average” and “high” levels of technological uncertainty for both models of organization.

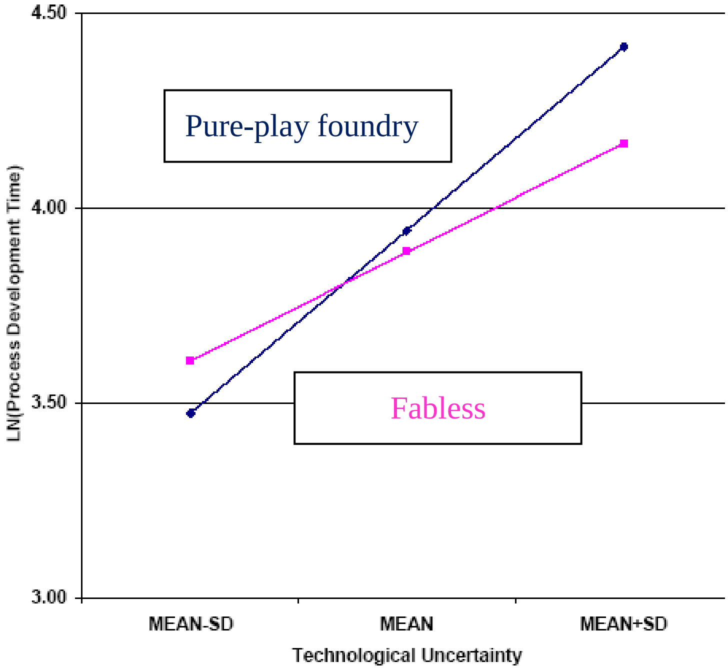

Fig. 4.3 Process development against different technological uncertainty (pure-play

foundries vs. fabless)

The credit for pioneering the fabless concepts is given to Bernie Vonderschmitt of Xilinx and Gordon A. Cambell of Chips and Technologies. The first fabless semiconductor company, the western design center, was founded in 1978. Since the early 1990s, the fabless business model has grown exponentially both in terms of net output and global presence. The top five fabless companies according to Table 4.3 are Qualcomm, AMD, Broadcom, Media Tek and Nvidia. Figure 4.4 indicates IC design industry still maintain double digital reasonable growth rate.

Table 4.2 The top 10 sales leaders for fabless companies:

Rank 2009	Company	Country of origin	Revenue (million) $USD
1	Qualcomm	USA	6,585
2	AMD	USA	5,252
3	Broadcom	USA	4,190
4	Media Tek	Taiwan	3,500
5	Nvida	USA	3,135

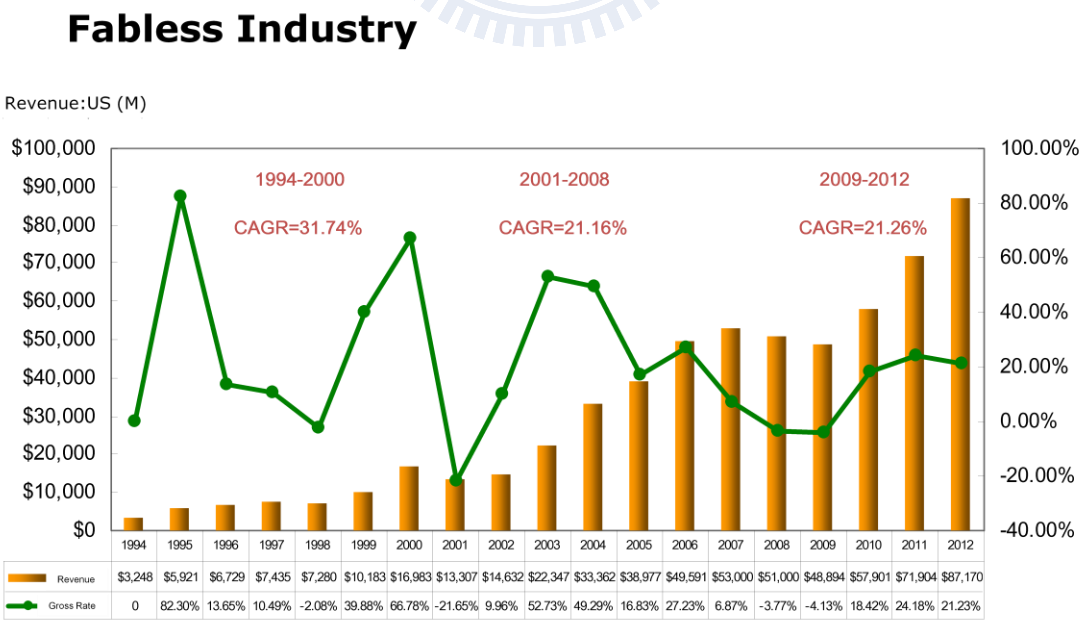

Fig 4.4 The global fabless market trends, Unit: billion /%

Chapter 5 Results and Discussion

IC production is becoming increasingly challenging with decreasing feature size and increasing chip and wafer sizes (Pfitzer et. al. 1999). Generally, an IC foundry manufactures ICs for IC design house or other semiconductor manufactures. The complexity of the business process between enterprises, including demand planning, manufacturing, and logistics, has attracted tremendous attention during the past decade. Furthermore, continuous expansion of IC foundries can be achieved by building new wafer fabs, or becoming involved in mergers or joint ventures with IC related companies, complicated business processes and operations.

This study proposes a business model for the IC foundry industry to address the issues at different levels. Based on examining first the IC design industry structure, and then the relationship between IC design and IC foundries, we propose an IC design and IC foundry business model in the future.

5.1 IC Design Business Model

There are two fundamental factors that affect IC design organization pattern: demand and supply. These two factors can change the types of organization.

The demand side changes when the market trends are mastered with a firm grasp of market demands while adjusting the organization pattern to meet them. The influential factors that affect IC design can be summarized as the ability to grasp market trends, organization pattern and the markets.

In fact, the IC design business model may be changed if the manufacture cannot match the IC design. The manufacturer and designer need to find a sweet zone that can make the IC application workable. IC design also needs to accommodate IC manufacturing speeds. Otherwise, the IC manufactures who can accommodate a wide spectrum of IC designs are the winners. Figure 5.1 shows the IC design business model and its relation with downstream industry.

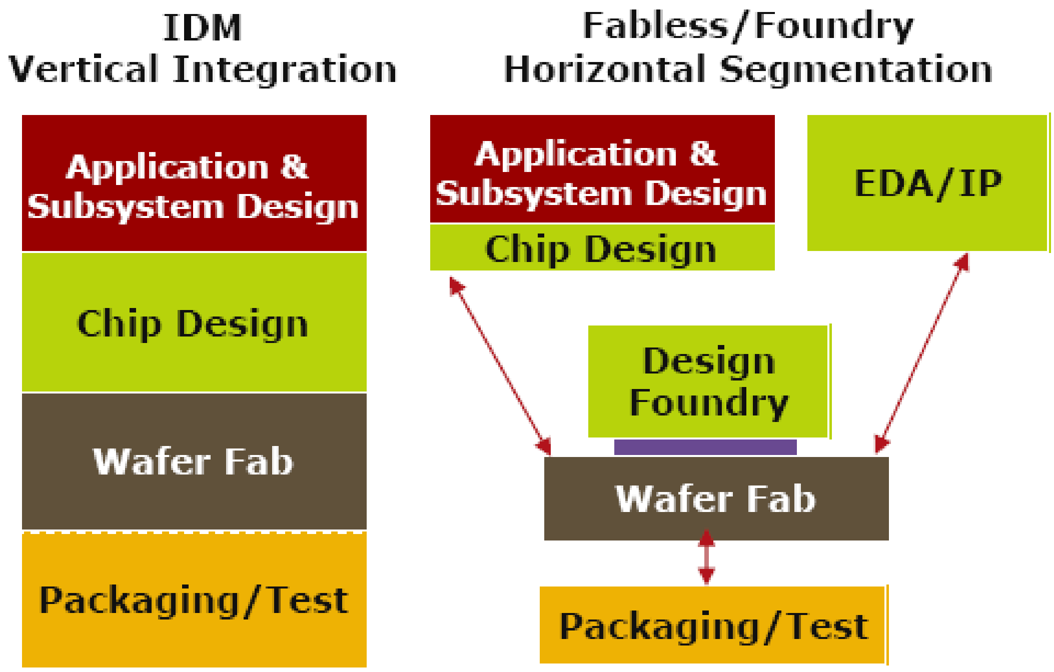

Fig. 5.1 The IC design business model and its relation with downstream industry.

5.1.1 Technical Capacity

IC design companies must have sufficient design capability and organization pattern that adjust to the design capacity for effective changes of output. The IC design industry also must maintain technical capacity because both design capability and technology and technical capacity are necessary to achieve feasible IC design.

5.1.2 Supply Capacity

The IC design industry is facing the ever-rising cost of improving design and technology. The design cost increase due to (1) changes in wafer fabrication and advances towards the 12-inch wafer manufacturing process, (2) the high price of EDA software and (3) the SOC development trend.

5.2 IC foundry and IC Design Relationship

The integrated circuit (IC) production process is becoming more and more challenging as it increase in complexity and wafer size continuous to grow (Pgitzer, et al., 1999). IC foundries are one of the most important systems for the next generation (Kuo, et. al., 2000). An IC foundry manufactures ICs for IC design house or other semiconductor manufactures. The correlated complexity of business processes, which include design, manufacturing, engineering and logistics management seen in the IC foundry area has increased tremendously over the past decade.

Figure 5.2 shows that IC devices are mostly produced by integrated device manufactures (IDMs) and application specific integrated circuit (ASIC) manufactures in the initial phase of the IC business (Tseng, 2002). The IDM and ASIC companies include functions of system/IC design, wafer manufacturing, assembly, and testing. After the emergence of IC design companies (fabless companies), IC foundries began to play a very important role in the business. Foundries manufacture ICs for design companies or other IDM and ASIC companies and have currently their technical support for intellectual property (IP) design companies by integrating design service and wafer manufacturing.

IC designers typically have different objectives than foundries; IC designers want to achieve the greatest performance while doing the least amount of guard-banding, Schedules and predictability are also paramount concerns for designers. IC foundries want designs to adhere to design for manufacturing (DFM) and design for yield (DFY) rules and recommendations in order for their advanced process nodes to achieve the highest yield. A common misconception is that these IC design and manufacturing objectives are always in opposition.

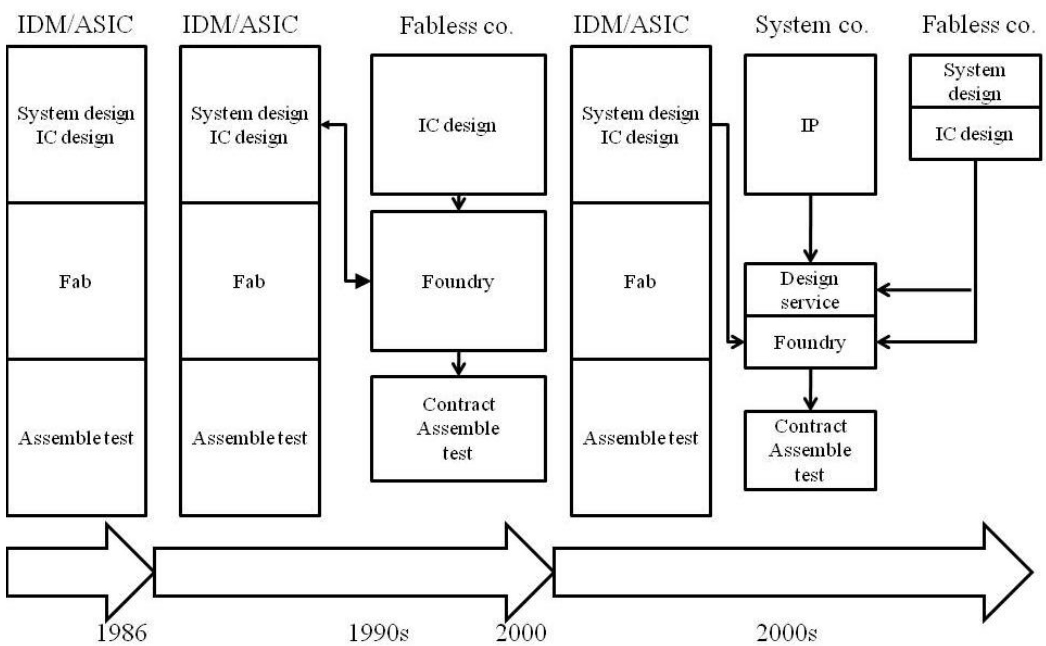

Fig. 5.2 IC industry evolution since 1986

5.3 The Bottle-neck of IC Foundries

5.3.1 Moore's Law Extension

Moore's law describes a long-term trend in the history of computing hardware, in which the number of transistors that can be placed inexpensively on an integrated circuit doubles approximately every two years. It is often incorrectly quoted as a doubling of transistors every 18 months, as David House, an Intel Executive, gave that period to chip performance increase. The actual period was about 20 months.

The capabilities of many digital electronic devices are strongly linked to Moore's law: processing speed, memory capacity, sensors and even the number and size of pixels in digital cameras. All of these are improving at (roughly) exponential rates as well. This has dramatically increased the usefulness of digital electronics in nearly every segment of the world economy. Moore's law precisely describes a driving force of technological and social change in the late 20th and early 21st centuries. This trend has continued for more than half a century and is not expected to stop until 2015 or later. The law is named after Intel co-founder Gordon E. Moore, who described the trend in his 1965 paper. The paper noted that number of components in integrated circuits had doubled every year from the invention of the integrated circuit in 1958 until 1965 and predicted that the trend would continue "for at least ten years". His prediction has proved to be uncannily accurate, in part because the law is now used in the semiconductor industry to guide long-term planning and to set targets for research and development. Will Moore's Law soon become no more? A new report from iSuppli Corp suggests that the law, named after Intel co-founder Gordon Moore and making up much of the foundation of the semiconductor industry, could brcome academic by 2014.

ISuppli argues that the high cost of semiconductor manufacturing equipment is making continued chip-making advancements too expensive for volume production. That, in turn, relegates Moore's Law to the laboratory and "alters the fundamental economics of the industry," according to the market research company.

"The usable limit for semiconductor process technology will be reached when chip process geometries shrink to be smaller than 20 nm, to 18-nm nodes," said Len Jelinek, director and chief analyst, semiconductor manufacturing, for iSuppli, in a statement. "At those nodes, the industry will start getting to the point where semiconductor manufacturing tools are too expensive to depreciate with volume production, ie, their costs will be so high, that the value of their lifetime productivity can never justify it."

Noting that while further advances in shrinking process geometries can be achieved after the 20-nm to 18-nm nodes, iSuppli estimated that Moore's Law will no longer drive volume semiconductor production after 2014.

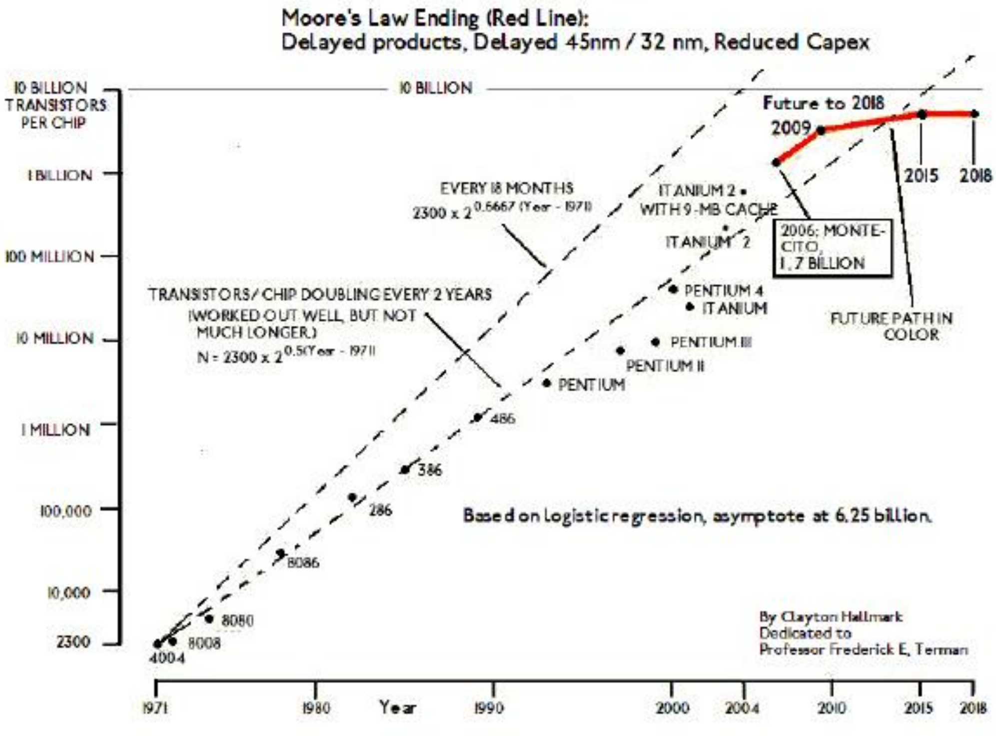

Fig. 5.3 Moore's law diagram

5.3.2 Process of Increasing Complexity and Difficulty

With the IC line width narrowing and the complexity of the process of gradually increasing, process variability is posing considerable challenge to the capability of lithography and manufacturing techniques, and thus impacts both performance and yield of advanced node chips. To ensure the manufacturability and performance of chips at small dimensions, one approach the industry is considering is restrictive design, limiting the type and placement of features used in designs. Gridding of critical layers significantly reduces the total physical design space available and makes restrictive design possible.

The IC process needs to tightly follow design rules when the IC line dimension drives to 22 nm and beyond. Therefore, the IC foundry should be closely related to the IC designer because of process difficulty. This implies that pure-play foundries may need to change their business model in the future.

5.3.3 Complex Logistics

An IC foundry fab can be classified into those with complex production routes, high product mixes, and short life cycles (Kuo et. al., 2000). By collaborating with their business partners, foundries must focus on developing specialized technologies and providing seamless integrated service. Due to the increasingly complicated issues of production and logistics processes in the IC foundry business, designing and implementing efficient business processes for collaboration is an important key to success. In the logistics process of the IC foundry business, process designers and participants must deal with the complex procedure of inbond and outbond logistic workflow to coordinate the production function and fulfill customer requirement. Contracting with new joint ventures always occurs during IC foundry business expansion, causing major changes in business processes. The inbound and outbound process must be redesigned owing to the change in the overall logistic structure. Those events exhaust significant time and resource in handling the negotiation problem and thus delay expansion progress.

5.4 Predicted Business Model of IC Foundry & IC Design in the Future

The necessary functional collaboration, it can be achieved through four different models-design, engineering, manufacturing and logistics, which are significantly related to the overall operating function in IC industries.

Design collaboration: typically distributes multiple function perspectives addressing interrelated aspects of a single product design (Li, Zhou and Ruan, 2002). For example, in the IC process, two jointed enterprises need to collaborate to aid customers in selecting an IP design pattern to fit the design requirement and then configure the mask layout when it is ready for production.

Engineering collaboration is widely discussed by many researched and includes the information infrastructure (Ye, 2002) engineering team adaptation modeling (Reiter, Jr. 2003), objective, science-industry agreements and matching (Carayol, 2003), engineering data sharing (Noel and Brissaud, 2003), as well as other engineering related problems. Engineering collaboration may always occur during the IC operation process before the finished goods are shipped to the customers for the two joined enterprises.

Manufacturing collaboration is an important factor in enhancing the production performance (Cloutier et. al., 2001). In recent years, the model of manufacturing has changed. Manufacturing management may now extend outside an enterprise in geographically distributed from or according to business logic (Wang Yung, 2004). The enterprise expansion may collaborate on the manufacturing processes and share or back up production capacity.

Logistic collaboration may occur in two joined logistic systems to increase the inbond and outbond efficiency after structure reorganization. This factor has become increasingly important to achieve the success of enterprise expansions. A weak integration in the logistic system for the two joined enterprises may result in serious profit losses.

5.4.1IC Foundry and Joint Ventures

To increase their competition in the international market, more and more IC foundry enterprises have been engaging in joint ventures in the areas if technological support, increased capacity, knowledge sharing, and development, even to the extent of marketing. This triggers competition wars that change the dynamic of the semiconductor market. In general, IC foundry industry joint venture projects can be categorized into four different types: foundry with IDM/ASIC, existing foundry with new foundry, foundry with fabless and foundry with versus assembly test.

Foundry with IDM/ASIC joint venture mostly occurs in IDM/ASIC companies with insufficient capacity. In this situation, the IDM/ASIC companies seek capacity support from foundry companies to meet their market demand.

Existing foundry with new foundry joint venture usually occurs during new technology development and capacity expansion. A new foundry company may have more advanced technology to support the joint companies. The advanced foundry companies may gain the necessary capacity from the new foundry company.

Foundry with fabless joint venture occurs in the technological support and strategic joint venture for fabless companies. The original relationship of customer and supplier will promote collaboration in this type of joint venture.

Foundry with assembly test joint venture occurs in an extension of customer service from wafer to chip. Most IC foundry customers are from fabless companies and systems. A joint venture of assembly test with foundry companies will provide more service for their customers.

In the IC foundry business, most system companies do not engage in the joint venture game. They maintain the pure relationship of customer and supplier using IC foundry companies to support their capacity since they have less profit conflict issues in the IC foundry business.

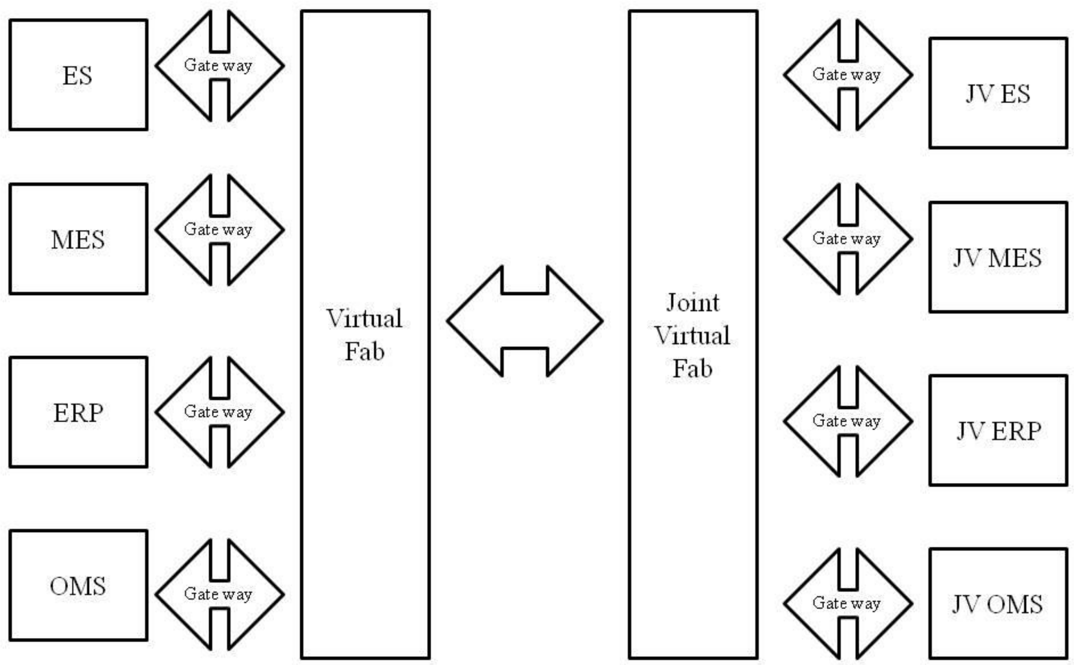

Fig. 5.4 Virtual network structure

5.4.2 Vertical Integration of IDM Integrates Plant and Pure play Foundry

In microeconomics and management, the term “vertical integration” describes a style of management control. Vertical integrated companies in a supply chain are united through a common owner. Usually each member of the supply chain produces a different product or market-specific service, and the products combine to satisfy a common need. It is contrasted with horizontal integration. With the increasing complexly of IC design and manufacturing, we propose that the foundry and IC design need to be integrated. This harkens back to the beginning of the IDM model. Figure 5.5 indicates the schematic diagram of a vertical IDM (integrated device manufacture) and a pure-play foundry. An IDM is a semiconductor company that designs, manufactures and sells IC products. With the increasing technology difficulties, IDMs may need to handle semiconductor manufacturing in house. A fabless semiconductor company, which outsources production to a third-party, is not suitable for next-generation technology.

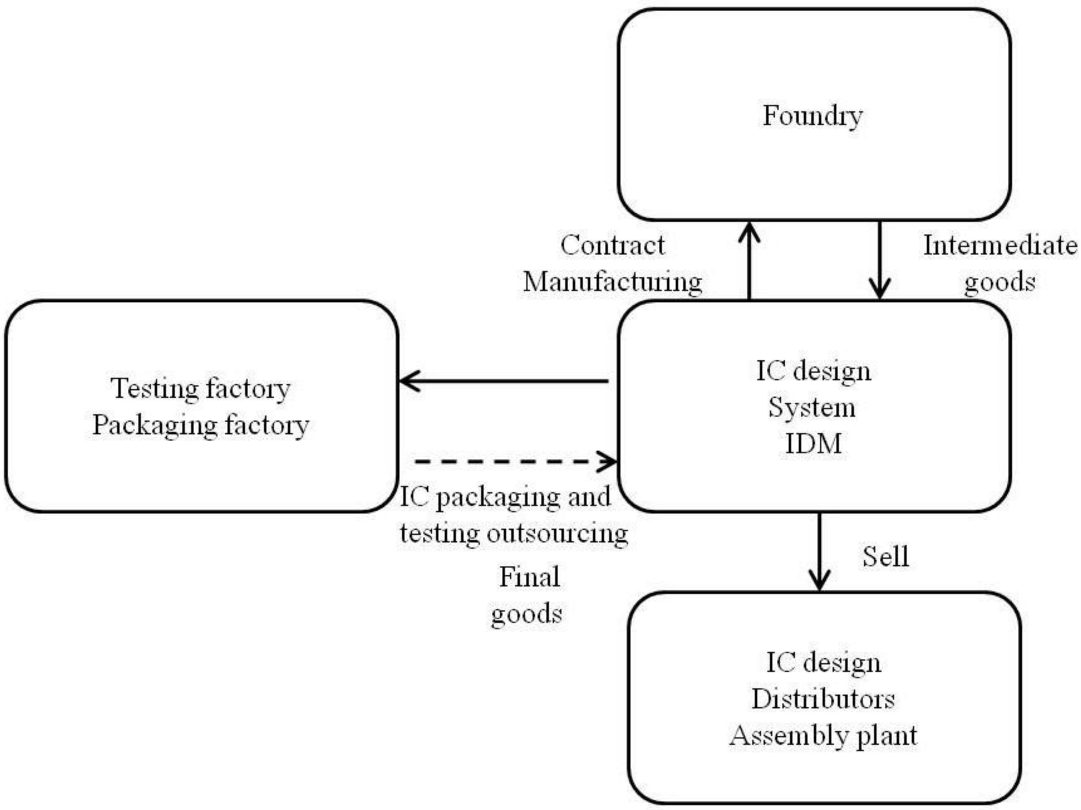

Fig. 5.5 Schematic diagram of vertical integration of IDM integrates plant and Pure play foundry

5.4.3 Virtual Vertical Integration Model

The virtual vertical integration strategy involves the assembly of most the parts that go into the product, optimization of the integrated flow is crucial for product delivery and profits. In microeconomics and strategic management, vertical integration describes a style of ownership and control. Vertically integrated companies are united through a hierarchy and share a common owner. Each member of the hierarchy products a different product and combines the final goods to satisfy a common need. The virtual vertical integration becomes less profitable if the business scale is too large to manage.

TSMC created a vertical division of labor beyond the framework of the semiconductor industry, changing the business model in the late 1980s. Taiwan's semiconductor industry is considered be entering an era of paradigm shift. The semiconductor industry has gradually developed into a common cluster, forming a vertical integration model. The vertical division of labor in Taiwan in the 1980's created a "miracle in the semiconductor industry". The transition from vertical division of labor to vertical integration leads to successful complete resource utilization.

5.4.4 IC Foundry and IC Design Alliance

With the increasing difficulties of IC processes for next-generation technology, a close relationship between IC technology and IC design is necessary to fulfill the common requirements. Therefore, pure-play foundry companies might need to change their business model to form alliances with IC designers. The means that the offerings of the pure-play foundry company cannot fulfill the needs of all customers, and the foundry needs to target specific customers and make their specific products. This is consistent with the original IC foundry concepts of providing process to meet the customers' requirements. If the technology for next generation products causes bottlenecks in fulfilling varied processes, the IC foundry needs to develop its process based on collaboration with IC design houses. The IC foundry and design alliance could be a more effective and profitable business model. Because alliances between company's results in rapid capacity building with limited risk, a well planned alliance could be the fastest way to maximize operational efficiency to benefit all stakeholders.

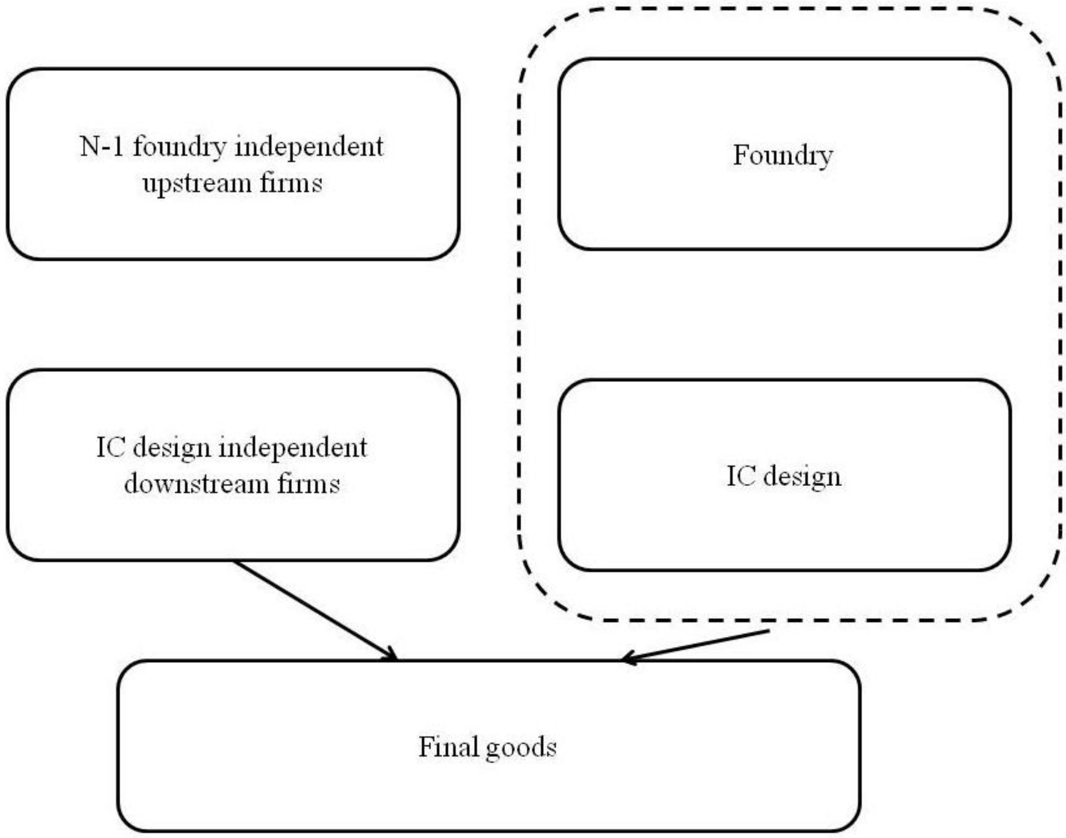

Fig. 5.6 vertically integrated market structure diagram

Chapter 6 Conclusion and Future Research

6.1 Conclusions

The complexities of IC technology and the increasing gap between IC design and manufacturing are the current challenges for the IC industry. The IC foundry model has derived from the pure OEM model of operation. The Taiwan IC industry has the top foundry and packaging company in the world. Despite the business proverb, "Only the biggest survives" managers still need to forecast future trends for the IC industry and consider a suitable business model to adjust to market changes.

The business model of the pure-play foundry has been sustained for about 20 years. IC foundries works with IC designers to share the common goal of products released. IC foundries are not involved in IC design work in order to protect the designer's intellectual property; therefore, the IC designer can fully trust the foundry with new IC applications. However, difficulty with process technology has driven a change in the business model. IC designers may need to bind with IC manufactures for new product applications to ensure match between designing and manufacturing. We propose that the main focus of future business should be an alliance between IC foundry and design. A virtual pure-play foundry business would integrate with the IC design house and retain the customer-oriented business model.

Most managers review the enterprise expansion projects as strategic level issues and may ignore the importance of different perspectives on this subject. Our research adopts multiple collaborative views to analyze the processing of enterprise expansion in the high-tech industry, using the IC foundry industry as a basis for exploring the possibilities in multiply the challenges in this research, but also enhance our confidence in pursuing this topic for research. The IC foundry represents the OEM in the manufacturing industry. It follows the current developing trend of enterprise expansion for high-tech industries. The collaborative relationship is not only upstream to downstream but extends to the network with complicated business environments and one that can be generally applied to other related high-tech industries.

6.2 Future Research

The high-technology business model is always a very interesting topic to research. Technology is now moving toward nanotechnology. Technology is down to the atomic and molecular levels. This advanced technology changes human daily life and fuels the electronic device resolution. The operating philosophy of every company is profit. An effective business model is worth studying to discover how to gain the most profit. The managers need to adjust the business model at any time based on the market forecast. Since high technology is tied to the technology revolution, the high technology business model needs to consider the speed of technology development.

Knowledge sharing and the development of intellectual property, and technical information should be defined in pre-project knowledge management. Knowledge management issues are considered to be one of the major interests for future researchers. The study of the core competence for high technology is also an open area. To advocate green technology, IC technology must change to fulfill green technology objectives. Therefore, the study of business models for new “green” IC technology is worthy of future research.

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