PORTLAND STATE UNIVERSITY

OPEN INNOVATION TREND IN SEMICONDUCTOR INDUSTRY – A FOUNDRY'S PERSPECTIVE

ETM 536 – R&D Management

PROFESSOR: DR. TUGRUL U. DAIM

BY:
MAMATHA MURTHY
CHIHSUN LIN (THOMAS)
LOKESHHONNAPPA
YUAN XU

ABSTRACT

Open Innovation is the new paradigm that most of the industries are incorporating in order to enhance mutual firm-customer value. Companies are bringing customers, suppliers, and partners under the common goal of shortening design time, minimizing time-to-volume and speeding time-to-market and ultimately time-to-money. This paper analyzes the trend of open innovation in top pure-play foundries through literature research. Case study company, TSMC, is evaluated against a set of criteria that were derived out of the general trend in top foundries such as Chartered Semiconductor, UMC, Global Foundries and SMIC. The results show an increasing trend in the adoption of a collaborative style of open innovation in these companies.

Contents

ABSTRACT 2
1.0 INTRODUCTION 4
2.0 RESEARCH OBJECTIVE & METHODOLOGY 4
3.0 WHAT OPEN INNOVATION IS 4
3.1 Generic Open Innovation Process 6
4.0 POPULAR OPEN INNOVATION MODELS: 6
4.1 Four models of collaborative innovation: 7
4.2 The four models of network-centric innovation 8
5.0 OPEN INNOVATION TREND IN SEMICONDUCTOR FOUNDRY: 9
6.0 CRITERIA 12
7.0 CASE STUDY: TSMC 12
8.0 CONCLUSIONS 18

1.0 INTRODUCTION

The establishment of Taiwan Semiconductor Manufacturing Company (TSMC) in 1987 marked a new era in the electronics industry by opening a dedicated merchant foundry (Yea-Huey Su & Shih-Ting Huang, 2006). Being the founder and leader of IC Foundry segment, the company consistently offered leading technologies, pioneering design services, manufacturing productivity and product quality. Over the years, many companies have emerged as pure play foundries, operating as semiconductor fabrication plants focused to produce ICs for other companies. According to the Industrial Economics and Knowledge Center (IEK), TSMC ranks first among the top foundries worldwide followed by UMC, Chartered, SMIC and Global Foundries in 2009(Mark LaPedus, 2011). The foundry segment as a whole has grown rapidly compared to the overall semiconductor market driven by leaps in innovation. Companies are considering innovations as a major engine to enhance their performance and to strengthen their competitive position in the market. More and more organizations have intensified collaboration across industry networks and partnerships, opening up their innovation processes in line with the open innovation framework.

The notion of open innovation was first proposed by Henry Chesbrough, an adjunct professor and the executive director of the Center for Open Innovation at the Haas School of Business. Internal R&D no longer is the invaluable strategic asset for companies due to a fundamental shift in how they generate new ideas and brings them to market. The old concept of closed innovation has shifted to being more open; companies have recognized the need to open up their innovation processes and combine internally and externally developed technologies to create business value.

2.0 RESEARCH OBJECTIVE & METHODOLOGY

The purpose of this paper is to analyze the open innovation trend in semiconductor industry from foundry perspective. The research is based on the literature review on the top five pure play foundries. Initially, the report aims at explaining the open innovation concept as described by Henry Chesbrough followed by some of the popular open innovation models available in the market. Next, we analyzed the open innovation trend in the foundry industry and derived certain factors/criteria based on the generic trend and the popular models. Finally, the report analyzes the trend of open innovation with respect to the criteria identified in the case study company TSMC. Fig 1 shows the methodology that was followed during this research.

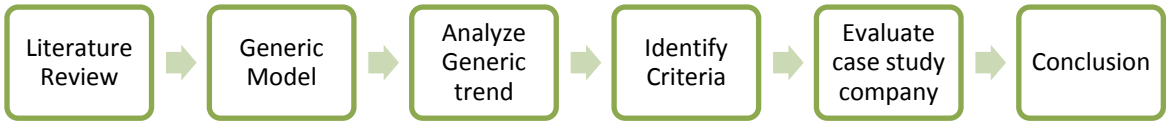

Fig 1 Methodology

3.0 OPEN INNOVATION

Traditionally, internal R&D was the primary and only sought option for firms. R&D labs were a strategic asset that complemented to outperform competitors. This process in which large firms discover, develop and commercialize technologies internally has been labeled as 'closed innovation' (Henry, 2006).

For long, company's objective was increased margins, reduced time-to-market, and market share within existing market. The attitude was to own and protect ideas. However with the change in the innovation landscape, ideas have been shared by companies with no firm having a monopoly. The acceleration of the product lifecycle has turned intellectual property (IP) into an increasingly perishable asset (Yea-Huey Su & Po-Min Chang, 2008). Companies have in fact realized the need for "Out of the box" thinking in today's economy and are changing their mindset from traditional or closed innovation to being more open. Table 1 provides a brief overview of closed versus open innovation.

	Closed Innovation	Open Innovation
Corporation Ethos	Not invented here / "We can do it, we will do it"	Best from anywhere
Role of Customers	Passive recipients	Active co-innovations
Core Competency	Vertically integrated products and service design	Core competitive differentiation and collaborative partner management
Innovation Success Metrics	Increased margins/ revenues, reduced time-to-market, market share within existing market	R&D ROI, breakthrough product or business models
Attitude Towards IP	Own and protect	Buy, sell - the corporation is a knowledge broker using both licensing and commercial development to monetize IRP
Role of R&D and Operations	Design, develop and market in-house inventions	Optimize performance of owned assets through both in-house and external development; do enough R&D internally to recognize significant external R&D

Table 1: Open versus Closed Innovation [(Kari-Pekka, n.d.), modified version]

Open innovation, thus has been proposed as a new paradigm for the management of innovation .Open innovation is the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively. This paradigm assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as they look to advance their technology. It thus comprises both outside-in and inside-out movements of technologies and ideas, also referred to as 'technology acquisition' and 'technology exploitation' (Lichtenthaler, 2008).Technology acquisition or exploration is an outside-in movement, where companies get access to technological developments/assets through external resources such as universities, suppliers, start-ups and even competitors while technology exploitation is a inside-out movement focusing on commercialization of technology assets either through out-licensing agreements or strategic alliances(Yasuda, 2003). Thus companies use both concepts together in order to succeed in the global market and attain sustainable development. Fig 2 shows the main sources of open innovation for a company.

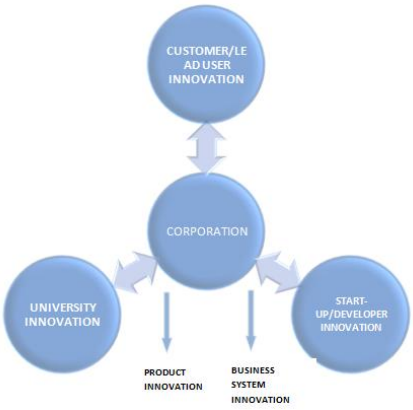

Fig 2 Sources of Open Innovation [("Open Innovation and TSMC | The Strategy Group," 2010), modified version]

Open innovation thus has been widely used in various ways by almost all industries including automotive , service industry, biotechnology, pharmaceuticals, healthcare, computers, software, communication, banking etc. Proctor & Gamble, Toyota Motor Corp. and many more exemplify the aspects of the open innovation. Semiconductor industry is no different. Companies such as TSMC, Intel, IBM, have excelled and are enjoying the success of open innovation.

3.1 Generic Open Innovation Process

The fig. 3 depicts the open paradigm to manage innovation. Ideas generated within a company can sometimes seep out, either in early or later stages of the innovation process through prototypes or external licensing or start-ups etc. Further companies can utilize many great potential ideas generated externally to speed up the innovation engine. Thus adoption of open innovation means the introduction of valuable knowledge, ideas, technology or inventions from outside the organization into innovation process or using internal IP outside the conventional innovation process boundaries (S.J. MARAIS & C.S.L. SCHUTTE, 2009).

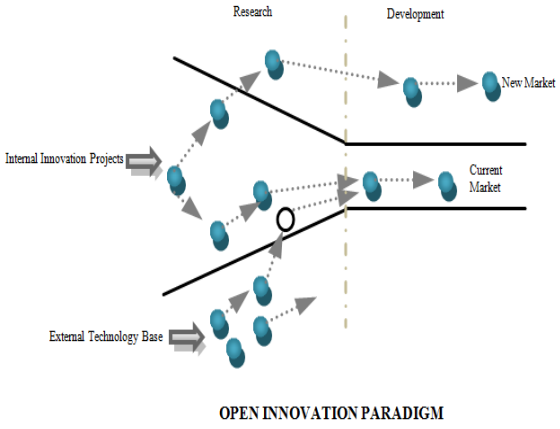

Fig. 3 [(Kari-Pekka, n.d.), modified version]

Though open innovation can be beneficial to most companies its implementation should be based on the company's strategy.

4.0 POPULAR OPEN INNOVATION MODELS:

As the competition of markets gets fiercer and life cycle of new products become shorter, more and more companies realize the importance of managing innovation. Sometimes, the innovation strategy of the company can decide it as an extraordinary success or completely disaster. The traditional closed innovation model is no longer suitable for all the companies in all the areas. Companies begin to reach out of their own yard and collaborate with others. Right now, most popular innovation models are Collaborative Innovation and network-centric innovation.

Collaborative Innovation model identifies companies with two critical dimensions (Pisano & R. Verganti, 2008). The first dimension is how open (or closed) the participation is. In other words, "open" collaborative should be free to let anyone (suppliers, customers, designers, research institutions, inventors, or even competitors) join in. A "closed" collaboration means the participation is only among the ones by invitation, like private clubs. The second dimension is how the collaboration is governed. A "hierarchical" model means there is one or some participant as leader to propose problems and make decisions. A "flat" model gives equal authority to participants.

By these two dimensions, the framework of collaborative innovation model divides companies into four groups (Normandin, Studies, & Research, 1991).

4.1 Four models of collaborative innovation:

1. **Innovation Mall model**: As the figure 4-1 shows, this is an "open, hierarchical" model. In this model there is a leading company who propose problems and make decisions of which will be carried into execution. Other participants take part in with providing potential solutions to the problem. Usually, they don't have any authority to take part in making decisions.

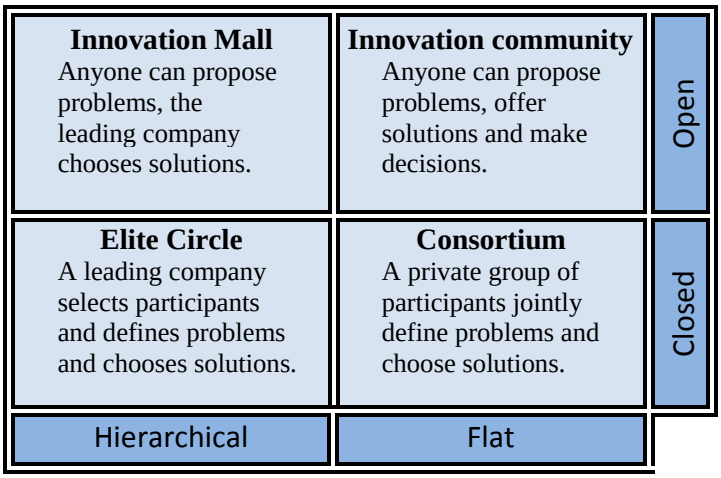

Fig. 4.1 Four models of collaborative innovation framework (Pisano & R. Verganti, 2008)

2. **Community Innovation model:** This is an "open, flat" model. Like a "community", any participant can propose problems, offer possible solutions and make decisions of which solution to use. And because it is open to everyone and everyone is given maximum power and freedom, this model has great potential to attract massive volume of ideas and data from any possible corner of the world. And because of the massive size of the data pool, sometimes, it is very hard to extract useful ideas or materials and hard to manage.

3. **Elite Circle model**: As a "closed, hierarchical" model, this kind of "group" is a relatively small with only participants selected by a leading company. And this leading company masters everything relevant in this innovation circle. In this model, because the members who are selected often possess considerable ability or resource in the area and the presence of a powerful leader, groups under this model often are very clear in research direction and works very efficient in managing resource.

4. **Consortium model:** This model is "closed, flat". Like a private club, only a small group of selected participants work together in this innovation circle and they share authorities of proposing problems, providing solutions and decision making.

Each of the models has advantages and disadvantages. Some are good at attracting potential solutions and novel approaches from outside sources. Others can work more efficiently and have a lower cost. It is very hard to say which is better than others. How to pick the right model for a company not only depends on which area its products are but also the needs and situation of the company.

4.2 The four models of network-centric innovation

Another popular framework is network-centric innovation (Nambisan & M. S. Sawhney, 2008)(Nambisan & M. Sawhney, 2009)(Van de Vrande, De Jong, Vanhaverbeke, & De Rochemont, 2009). Described by Satish Nambisan and Mohanbir Sawhney in their book "The Global Brain", the authors describe network-centric innovation as an external approach to innovation that relies on harnessing the resources and capabilities of external networks and communities to amplify or enhance innovation reach, innovation speed, and the quality of innovation outcomes. They introduce this framework to help companies to acquire the benefits of a rapidly expanding horizon of innovation opportunities.

Like Collaborative innovation framework, this framework also provides four types of models divided by two dimensions: innovation space and network leadership. Innovation space refers whether there are well-defined modifications or enhancements to products or services. If the objective and direction of the innovative activity are well-defined, participants will understand and collaborate better. Network leadership is introduced as a continuum of centralization, with the two ends being centralized and diffused, which means the degree of hierarchy in the group of establishing innovation architecture, making critical decisions and even defining the characteristics and membership of the network itself.

1. **The Orchestra model:** This model is often found in markets where a proprietary dominant design has emerged. As a symphony orchestra, there is a "conductor" in this model directing other "musicians". And each of the "musicians" is a specialist in a specific musical instrument. So when they work together, they act as complement to one another. The structure of the innovation space is fairly well defined, too. In this model, both the dominant "conductor" and "musicians" are highly organized and coordinated; they cooperate together and resonate with each other to make a great "show".

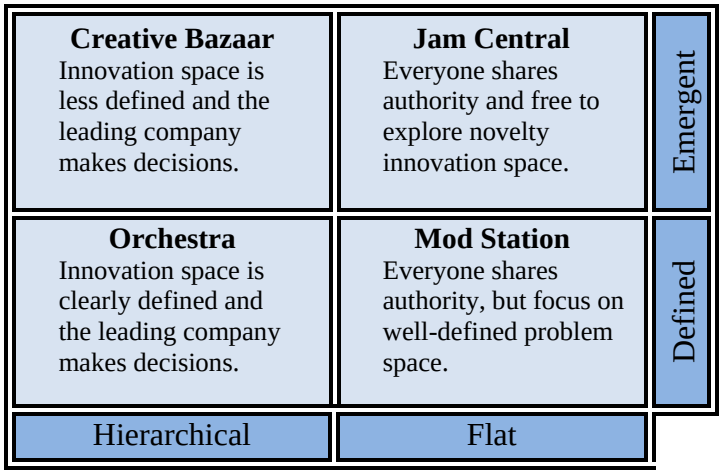

Fig. 4.2 Four models of network-centric innovation framework (Satish & Mohanbir, 2011)

2. **The Creative Bazaar model:** Function as an Innovation Seeker, this model focuses on interrogating innovation opportunities which fit the need and innovation agenda of the dominant firm. So it is often found in markets that are diverse in terms of customer choices or technology application contexts. In this model, a dominant company goes around this "creative bazaar" shopping for new ideas, products, and technologies. And other companies help to source new ideas and technologies from various inventors.

3. **The Jam Central model:** Working as the Innovation Champion, the model focuses on exploring novel market or technological problems. The innovation space is usually not well structured so

that participants collaborate together to develop the main parameters of the problem space and decide the objectives and direction of the innovation tends. And there is no dominant company in this model, so members share authority and responsibility together. Because these characters, this model is often found in market areas in which novel idea creativity and problem solutions demand a massive variety of technology and knowledge.

4. **The Mod Station model:** Function as an Innovation Catalyst, this model focuses on exploiting in a predefined or existing area of technology or market. Community of innovators get together to develop new meanings by modifying and leveraging the already existing products or technologies. In this model, innovation space is well-defined and value appropriation and governance mechanisms are managed by the whole community.

In this network-centric innovation framework, the models could serve companies well, if had been chose and managed appropriately, with developing a atmosphere of "openness", create the suitable organizational structure and adopt a portfolio of success metrics.

5.0 OPEN INNOVATION TREND IN SEMICONDUCTOR FOUNDRY:

The nature of semiconductor industry being technology driven and capital intensive, forces companies to enter into close technological dependence or alliance relationships between different semiconductor companies. Strategic technological alliance is defined as the establishment of common interests between independent (industrial) partners which are not connected through (majority) ownership (Wang C. etal, 2000). Multiple alliances across companies for strategic or joint innovative purposes lead to groups or constellations.

This process is becoming popular amongst foundries, design houses and IDMs. Top foundries such as TSMC, Global Foundries, Chartered, SMIC etc. are partnering with IBM, Intel, Cadence and many more, hence reducing the costs of the product and drawing customers into the heart of product development process. Though each of the companies would have varying business models, it adds a layer of versatility. Figure 5.1 shows all the technology alliance relationships between foundries, its vendors and customers. The following paragraphs discuss the generic trend in open innovation in top pure play foundries.

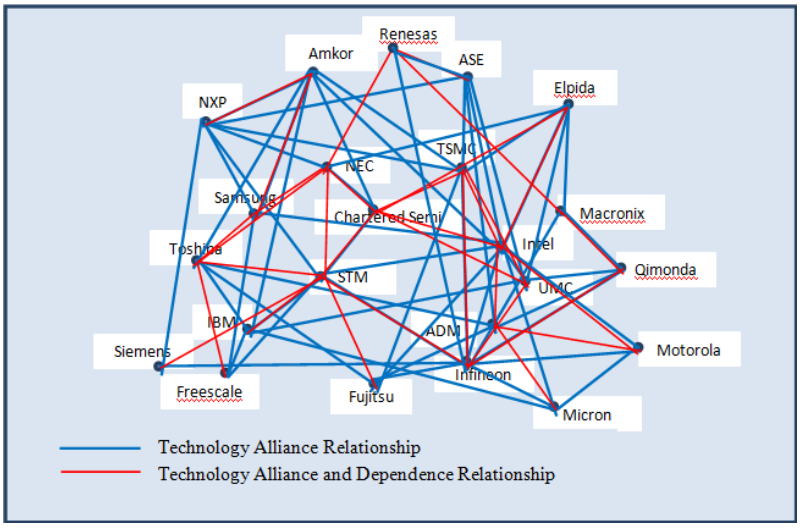

Fig. 5.1 Relationships of Semiconductor Manufactures [(Wang C. etal, 2000), Simplified version]

Chartered Semiconductor:

Chartered Semiconductor Manufacturing (second largest foundry), IBM and Samsung have now developed a new model that addresses both the cost of fab capacity and process development, while providing a cohesive design ecosystem through their Common Platform Technology ("A New Model For

Semiconductor Manufacturing," 2007). They have extended their joint bulk CMOS development alliance to include joint manufacturing capability. The Common Platform Technology partners have generated number of new benefits such as full product development, manufacturing and product lifecycle support from three leaders in semiconductor design, process technology and manufacturing, multi-sourcing a single design through GDSII compatibility to globally diverse synchronized fabs for risk mitigation and/or upside support, choice of design enablement resources (libraries, IP, reference flows, EDA tools and packaging), and engineering services and support from three companies with expertise in every aspect of semiconductor design and manufacturing.

Chartered acquires innovation ideas mainly through its technical alliance of IBM, Samsung and Infineon (Common Platform Alliance). With expertise of each company in their area, Chartered can develop technology innovation jointly along with cooperating with existing and new customers closely. And a various tax benefit provided by Singapore government can also help to attract high quality engineers for technology innovation (Sang Jin, 2010).

Further Chartered is solidifying its relationship with Amkor, a leading packaging company. Also, due to the availability of common resources including intellectual property (IP), Chartered has a considerable amount of licensable IP available. Thus this new model is gaining tremendous momentum with at least 14 design tool / EDA / IP partners joining to provide a comprehensive design ecosystem plus the industry-leading packaging vendor, Amkor. So Chartered cooperates closely with several expertise companies - IBM, Samsung and Amkor, in a model like a private party. And they share resources and lead jointly in this community, thus following the Consortium model in collaborative innovation framework.

UMC:

UMC, ranked third among the top foundries, partnered with GCT semiconductor, one of the leading fabless semiconductor companies that designs, develops and markets innovative LTE and WiMAX integrated circuit solutions for wireless applications(Vivek Naik, 2009).Thus UMC collaborates closely with customers as well as partners throughout the entire supply chain, including equipment, EDA tool, IP vendors, and memory partners to work synergistically towards each customer's SoC silicon success. This has resulted in a broad range of resources available to SoC designers, including silicon validated reference flows, broad IP portfolio, libraries, embedded memory macros, and cost effective prototyping (Shih-Wei Sun, 2007).

Further, the ASICplus program established in 2000 by UMC enables UMC and its fabless ASIC partners to offer comprehensive, front-to-back ASIC development capabilities from design initiation, manufacturing and testing, to packaging. In particular, the ASICplus program provides its members with guaranteed access to UMC's leading edge process technologies, including the 0.13micron generation. Companies such as Flextronics Semiconductor have become members of UMC's ASICplus program (*FLEXTRONICS SEMICONDUCTOR JOINS UMC's ASICplus PROGRAM*, 2001).

About the sources of innovation, UMC tends to employ external sources, like technology transfer or technology cooperation from technical alliances or outside innovation networks. UMC also developed an agility sense to utilize various innovation networks, such as strategy alliances, joint ventures, licensing arrangement and joint R&D development (Liu, Chu, Hung, & Wu, 2005).

Further, according to Wu, S.Y., Hung, S.C. and Lin, B.W, the IC industry is divided into three stages based on the lifecycle of the foundry: embryonic (1985-1990), growth (1991-2000) and shaker-out stage (2001-beyond) (Wu, Hung, & Lin, 2006). From this division, it seems that UMC focuses on the

traditional partnership strategy and design to do technology area, comparatively. The company concentrated on IDM during embryonic stage and joint venture strategy, technology alliance and M&A and five-in-one strategy in growth stage (Wu et al., 2006). However, UMC focused to go solo on technology partnership strategy beyond 2001which is the shaker-out stage.

Also, UMC partnered with SEMATECH, the international consortium of semiconductor manufacturers in 2008, focusing on research and development for exploratory technologies a beyond process generations, thus providing a win-win situation for both companies (*UMC Joins SEMATECH Research Consortium*, 2008).UMC believes in external partnerships for enhancing its process technology and manufacturing service capabilities. Further, UMC provides more authenticated IP to its customers as value network. Thus UMC developed the partnership of manufacturing service attempting to enhance service by collaboration with partners in phase 1 (2001-2002) and intensified design service support and the partnership in the second phase to facilitate process technology development (Yea-Huey Su & Po-Min Chang, 2008).

Global Foundries:

Global Foundries, the world's first full-service semiconductor foundry, was launched through a partnership between AMD and the Advanced Technology Investment Company. The company follows a collaborative approach of open innovation that combines a shared objective with a shared investment by partners around the world. Their partnerships range from early stage R&D to the evaluation of production ready process technologies centered in East Fishkill, New York that include Freescale, IBM, Infineon, NEC, ST, Samsung, Toshiba etc. Further with the integration of Chartered in January 2010, Global Foundries significantly expanded its capacity and ability to provide best-in-class foundry services from mainstream to the leading edge. Thus the company's strategy is to not compete with partners; rather purchase products and services from said partners (Juan Ignacio Igartua, Jose Albors Garrigós, & Jose Luis Hervas-Oliver, n.d.).

Global Foundries recently joined IMEC's core CMOS program to bolster its internal R&D capabilities. According to Global foundries, this work will bring Global foundries into collaboration with other foundries, integrated device manufacturers (IDM's), fabless and fablite companies, and equipment and material suppliers who also participate in IMEC program (David Lammers, n.d.).

SMIC:

Semiconductor Manufacturing International Corporation (SMIC), the fourth largest dedicated semiconductor foundry in the world, grew exponentially occupying about 7.6 percent of the whole global foundry market. The reason behind this success was the amount of openness in its supply chain management (SCM) and the supply chain network (SCN) which is evolved by the strategic partners or alliances with all related companies, rather than only conventional SCM theory of suppliers and customers SMIC, in order to build SCN with strategic partners or alliances, shared information, gained investments, and developed cooperation on R&D. The company opened up to develop relations with IDMs, fabless and equipment suppliers, finance companies, other foundries, IP providers and service agencies. The company's R&D cooperation channel (RDCC), the most important fountain of innovation extended its relations with research institutes, universities and colleges, semiconductor designers and so on (Youqing & Bai, 2010).

SMIC had over 55 cooperative partners in total by 2006. Thus SMIC followed a three step strategy towards open innovation i.e., take off step to import technology, competency building step to master process technology and leadership step to attach more importance to innovation (Youqing & Bai,

2010). The company signed agreements with upstream partners such as Toshiba, Chartered along with developing new collaborations with downstream and supporting partners, other advanced semiconductor organizations or IT companies, IMEC, Dolphin, Cadence, Synopsys and so on.

TSMC:

Finally, TSMC, the most successful semiconductor company in Taiwan, developed an open innovation model known as "Open Innovation Platform" (OIP). The OIP includes a set of sub-systems with a variety of partners and promotes timeliness-driven innovation among the semiconductor design community (Buganza & Roberto Verganti, 2009). The model and advantages gained by TSMC has been dealt in detail in the following section as a case study.

6.0 CRITERIA

Table 6.1 shows all the criteria that were identifies during our research. They will be used to measure the extent of open innovation at our case study company TSMC.

	Criteria	Definition
1	**Open innovation Style**	Identify the type of open innovation model used by pure play foundries to answer an unmet consumer need or a specific business problem.
2	**Type of value network adopted**	Value network refers to the external partners such as suppliers, partners, alliance partners, customers and stake holders. This criterion identifies the extent of value created by outsourcing business activities.
3	**Extent of collaboration**	Identifies if collaboration is happening at particular stages or at all stages in pure play foundries.
4	**Degree of openness**	Extent of openness and flexibility provided to customers
5	**Sources for idea generation**	Identify if the companies are generating ideas externally i.e., through business partners, customers, consultants, competitors, academia or through internal sources such as employees, internal R&D etc.

Table 6.1 Criteria

7.0 CASE STUDY: TSMC

TSMC (Taiwan Semiconductor Manufacturing Company), established in 1987, is the world's first dedicated semiconductor foundry with the revenue of $13.982 billion in 2010. Its corporate headquarters are in Hsinchu, Taiwan. The company has one 150 mm (6 inches) wafer fab, four 200 mm (8 inches) wafer fabs in full operation, and two 300 mm (12 inches) wafer fabs in production. The company's total managed capacity is expected to reach 13.6 million eight-inch equivalent wafers in 2011. TSMC is well known for its logic chip product line. Various fabless high-tech companies such as Applied Micro Circuits Corporation, Qualcomm, Altera, Broadcom, Conexant, Marvell, NVIDIA, and VIA are customers of TSMC. Also, some fab-owning companies like Intel outsource some production to TSMC ("Intel outsourcing some Atom manufacturing to TSMC," 2009).

Open Innovation Style:

TSMC follows a collaborative strategy aimed at breaking the bottlenecks of semiconductor design enablement in order to promote for the industry as a whole. The Open Innovation model brings together the innovative thinking of customers and partners under the common goal of shortening design time, minimizing time-to-volume, and speeding time-to-market, and ultimately time-to-money (*Open Innovation Platform*, 2011).

In 2005, TSMC started to operate its new business model called Open Innovation Platform (OIP) in order to reduce design barriers and maintain its long term success. According to TSMC office announcement data, this model would speed up the implementation of innovation among the semiconductor design community, its ecosystem partners and TSMC's IP, design implementation and design for manufacturing capabilities, process technology and backend services. In one Taiwanese master paper written by Kai-Chi, Yuan, "The analysis of evolutionary process of open business model - a case study of TSMC", provides a clear illustration which shows how TSMC business model fits in the traditional open innovation paradigm (Yang, Kai-Chi, 2008). The detail of this illustration is shown below as Fig. 6.1.

In this illustration, we can see the internal technology base is consisted by TSMC innovation and Global Unichi5p (GUC). TSMC focuses on process, design IP, and packaging and GUS is responsible for design service and IP. On the other hand, TSMC also deals with compatibility issues from external technology base such as new manufacturing process from Intel.

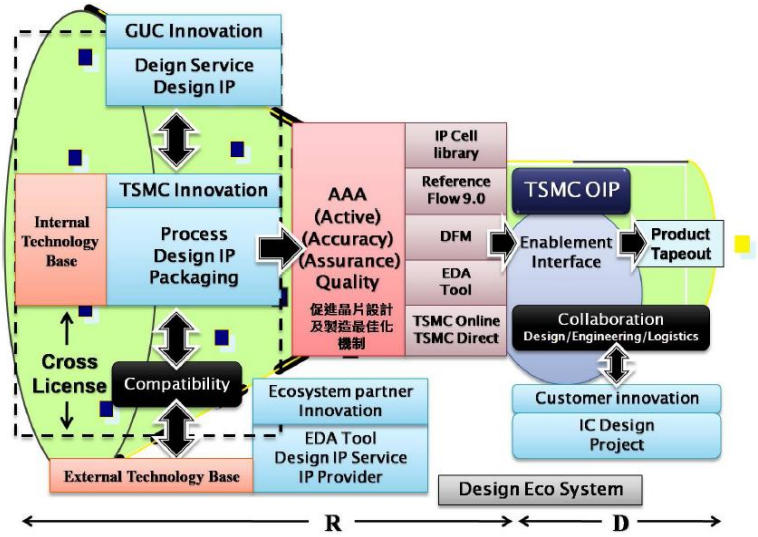

Fig. 6.1 TSMC open innovation business model (Yang, Kai-Chi, 2008)

TSMC OIP is a significant bridge between OIP leaders, design partners, and 3rd party partners. Based on this platform, each of OIP leaders, design partners, and 3rd party partners can distribute their R&D Knowledge through the two-way channels to other alliances directly. So, the goal of open innovation business model can be seen as to provide a win-win situation in all alliances in this ecosystem. The relationship of this model is shown in Fig. 6.2.

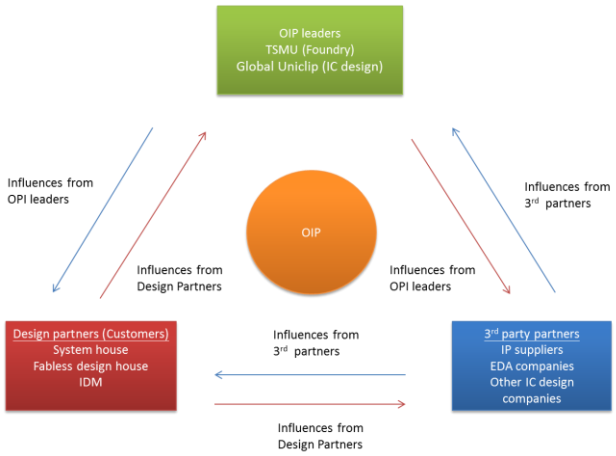

Fig. 6.2 TSMC OIP ecosystem (Yang, Kai-Chi, 2008)

It has been researched that neither technology innovators nor technology pioneers absolutely lead to be the winners in industries rather it is the business model innovations (BMI) that drive competitive success. TSMC is one of the well-known companies known for its business model innovation, executed in phases; "pure foundry phase," "manufacturing service and value added phase," and "inter-firm collaboration phase". From the study made by Yea-Huey Su and Shih-Ting Huang, National Central University, Taiwan, it was concluded that the TSMC's collaborative strategy was one of the important reasons for company's success. Further, the development of deep submicron technology and the trend of SOC forced foundries like TSMC to collaborate with others such as 3rd parties or design houses in the inter-firm collaboration stage. The fig 6.3 shows the three phases of TSMC's BMI.

Fig. 6.3 TSMC's BMI Phases [(Yea-Huey Su & Shih-Ting Huang, 2006), Modified]

Type of Value Network Adopted:

TSMC apart from maintaining the leadership of wafer foundry industry around the world is involved in R&D activities and innovated new products/procedures for keeping the competitive advantage superior to other competitors. Several R&D collaborative programs were made to achieve it (Hsu & Tai, n.d.). Table 6.1 shows some of the alliances TSMC has done since 2002. Also, by acquiring more IP licenses, TSMC enhances its process technology to enrich its manufacturing service.

Alliance	Year	Description
Synopsis	2011	The relation aims at having mutual customers access to a proven and productive custom IC design solution that has been verified by both companies to address 28-nanometer design challenges and deliver innovative solutions rapidly to the marketplace.
Cadence Design Systems, Inc.	2011	To extend its interface IP offering (*Cadence Extends IP Offering, Collaborates with TSMC via Open Innovation Platform*, 2011). Building on that relationship, TSMC is jointly working with Cadence engineers to develop IP by contributing "seed IP" to the effort.
CSR plc.	2011	To adopt TSMC's leading edge 90-nm embedded flash process technology, IP and RF CMOS processes for CSR's next-generation wireless products (*Leading edge technology implemented in newly launched CSR8600 wireless audio platform*, 2011).
NetLogic Microsystems, Inc.	2007	Regarding 55nm semiconductor process technology for NetLogic Microsystems' advanced knowledge-based processors (*NetLogic Microsystems and TSMC Collaborate on Industry-Leading 55nm Technology for Advanced Low-Power Knowledge-based Processors*, 2007).
NXP, Freescale Semiconductor, Inc. and STMicroelectronics	2006	To develop new products.
ITRI	2005, 2004	To develop 1K magnetic random access memory (MRAM)
Philips	2004	Both companies shared know-how and authorized their own patents to each party, and TSMC acquired 'incoming spillovers' in the meantime .
National Chiao Tung University (NCTU)	2004	University cooperative research; TSMC disbursed approximately 5 billion NT dollars expenditure, and nine research plans were developed jointly
Stanford University	2003	To develop semiconductor technique that was two generation ahead of industrial technique at that time
OmniVision Technology, Inc.	2003	To provide integrated backend manufacturing services for image sensors, including color filters (Ku, Gurumurthy, & Kao, 2007)
Freescale Semiconductor, Inc.	2003	To develop 65nm silicon on insulator technology cooperatively
Motorola Inc., Philips and STMicroelectronics	2002	To innovate 90nm to 65nm advanced complementary metal-oxide semiconductor (CMOS) logic technology collectively

Table 6.1 TSMC Alliances

Extent of Collaboration:

Fig. 6.4, 6.5 shows all the IP and EDA alliances/collaborations that TSMC has made till date. Fig 6.6 shows TSMC's design related alliance partners worldwide. Thus it can be inferred that TSMC keeps increasing its alliances in strategic, technology and design service areas and looks to partner during the shake-out stage (Wu et al., 2006).

Fig. 6.4 TSMC IP Alliance Partners ("Taiwan Semiconductor Manufacturing Company Limited," n.d.)

Fig. 6.5 TSMC EDA Alliance Partners ("Taiwan Semiconductor Manufacturing Company Limited," n.d.)

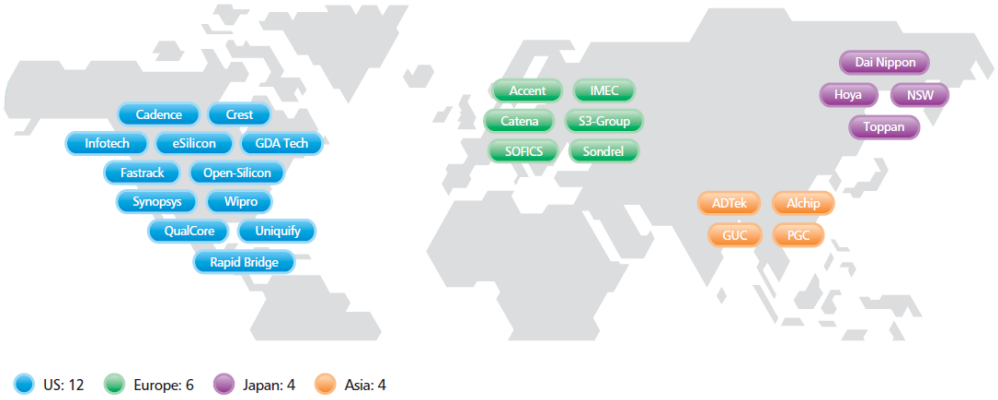

Fig. 6.6 TSMC Design Centre Alliance Partners ("Taiwan Semiconductor Manufacturing Company Limited," n.d.)

By collaborating with industry leaders, TSMC is providing the most comprehensive portfolio of libraries, silicon-proven IP, and memory compilers in the foundry segment. These specific libraries and IP are used to provide shorter design cycle time, increased first-time silicon success, and faster time-to-production. TSMC's portfolio includes over 3,500 IP macros and libraries from over 40 IP suppliers across TSMC process technologies, including the 0.35-micron, 0.25-micron, 0.18-micron, 0.13-micron, 90nm, 65nm, 40nm, and 28nm nodes. Libraries are also available for TSMC's 0.22-micron, 0.15-micron, 0.11-micron, 80nm, and 55nm half-nodes. Further, it has helped designers choose from a large selection of TSMC and third-party standard cell libraries to meet their needs for area, power, speed, or the best tradeoff among the three. Thus the company provides a one-stop shop of services to help customers.

As TSMC develops more of a value chain in-house (EDA tools, IP blocks, IC-packaging and test), the company is stepping on the toes of its partners. By developing its own IP, TSMC is trying to lock foundry customers into its own, internal fabs (Mark LaPedus, 2008). For example, TSMC's third-party IP is portable and works across several competitive foundries. In contrast, TSMC's physical IP is proprietary and does not work in competitive fabs.

Degree of Openness:

Ever since the start of OIP, TSMC is setting standards for ecosystem collaboration. The global Ecosystem Alliance programs have grown to include 30 EDA partners, 38 IP partners, 23 Design Center Alliance (DCA) partners and 9 Value Chain Aggregator (VCA) partners ("Open Innovation and TSMC | The Strategy Group," 2010). Also TSMC has started to work collaboratively with industry organizations such as IPL Alliance and Si2, to promote the interoperability standards based on TSMC interoperable EDA formats ("Open Innovation and TSMC | The Strategy Group," 2010). The company apart from opening up the manufacturing is opening up design as well. They sell references, process technologies and methods, share their intellectual property in how to do all this well. Thus TSMC not only creates its own IP to support manufacturing but also invites third parties to have their own specialty design tools to IP to TSMC. OIP takes all this IP and makes it available to all its customers. OIP helps remove technology adoption barriers by showing more openness nature and offering more choices to its customers. Thus being first with their open innovation model, TSMC has a hard-to-beat competitive advantage.

Sources of Idea Generation:

TSMC manages its sources of technology innovation mainly through several methods. First, it keeps close collaboration with customers. Second, it initiates strategic alliance with design partners of semiconductor area. And third, it encourages internal innovation by distributing stock bonus among employees, investing massive budget on R&D development and IT infrastructure (Grace T. R, n.d.) (Sang Jin, 2010) (Satish & Mohanbir, 2011).

The TSMC Open Innovation Platform thus promotes the speedy implementation of innovation amongst the semiconductor design community, its ecosystem partners and TSMC's IP, design implementation and design for manufacturing (DFM) capabilities, process technology and backend services. With all these efforts, TSMC has become the world's largest contract chip manufacturer by revenue with rising net profit year after year. The company's first quarter revenue rose 14 percent to 105.38 billion Taiwan dollars from 92.19 billion Taiwan dollars (LORRAINE LUK, 2011).

8.0 CONCLUSIONS

Since the introduction of the term Open Innovation, it has been applied widely in much high tech industries such as automotive, biotechnology, pharmaceuticals, healthcare, computers, software and so on. This new businesses model also pervaded to semiconductor industry, especially in foundry companies. In our research, we investigated the Open Innovation trend in top foundry pure play companies and selected the top most foundry company, TSMC, to be our case-study target.

With the world moving to co-creation era, it becomes highly important for companies stay up-to-date with the trend. Our research shows an increasing trend in the implementation of open innovation in semiconductor industry especially in pure play foundries. Initially, though only few companies accepted the new business model, more foundry leaders have started to recognize the huge potential advantages. Foundry companies are incorporating a collaborative style of open innovation model into their business model. The style serves as a good communication channel to share R&D knowledge, exchange information, and share the risk and harvest. This was clearly observed in the case study company, TSMC.

The model brings the thinking of customers, suppliers, and partners under the common goal of shortening design time, minimizing time-to-volume and speeding time-to-market and ultimately time-to-money. Open Innovation model is really working well in semiconductor foundry industry, and it could definitely be a good choice for other areas of semiconductor to apply in their business innovation systems.

Reference

A New Model For Semiconductor Manufacturing. (2007, February). *GSF*.

Buganza, T., & Verganti, Roberto. (2009). Open innovation process to inbound knowledge: Collaboration with universities in four leading firms. *European Journal of Innovation Management*, *12*(3), 306-325. doi:10.1108/14601060910974200

Cadence Extends IP Offering, Collaborates with TSMC via Open Innovation Platform. (2011). . Cadence. Retrieved from http://www.cadence.com/cadence/newsroom/press_releases/pages/pr.aspx?xml=060611_tsmc

David Lammers. (n.d.). GlobalFoundries Joins Imec's Core CMOS Program.

FLEXTRONICS SEMICONDUCTOR JOINS UMC's ASICplus PROGRAM. (2001). . UMC. Retrieved from http://www.umc.com/english/news/2001/20011010.asp

Grace T. R, L. (n.d.). Technology management and strategy composition: innovation of IC foundry. *Journal of intelligent manufacturing (0956-5515), 21 (6)*, 885.

Henry, C. (2006). Open Innovation: The New Imperative for Creating and Profiting from Technology. *Academy of Management Perspectives*, *20*(2), 86-88.

Hsu, C. C., & Tai, W. S. (n.d.). R&D Collaboration and Financial Performance in Taiwan.

Intel outsourcing some Atom manufacturing to TSMC. (2009, March). *OregonLive.com*.

Juan Ignacio Igartua, Jose Albors Garrigós, & Jose Luis Hervas-Oliver. (n.d.). How innovation management techniques support an open innovation strategy. *Research Technology Management*, *53*(3), 41.

Kari-Pekka, E. (n.d.). Open Innovation. *Scribd.com*. Retrieved August 12, 2011, from http://www.scribd.com/doc/430077/Open-Innovation

Ku, K. C., Gurumurthy, C. K., & Kao, H. P. (2007). Inter-firms collaboration of joint venture in IC foundry business. *Technovation*, *27*(5), 296–305.

Leading edge technology implemented in newly launched CSR8600 wireless audio platform. (2011). . CSR. Retrieved from http://www.csr.com/news/pr/release/444/en

Lichtenthaler, U. (2008). Open Innovation in Practice: An Analysis of Strategic Approaches to Technology Transactions. *IEEE Transactions on Engineering Management*, *55*(1), 148-157. doi:10.1109/TEM.2007.912932

Liu, T. H., Chu, Y. Y., Hung, S. C., & Wu, S. Y. (2005). Technology entrepreneurial styles: a comparison of UMC and TSMC. *International Journal of Technology Management*, *29*(1), 92–115.

LORRAINE LUK. (2011, April). TSMC Profit Up on Shipments. *The Wall Street Journal*. Retrieved from http://online.wsj.com/article/SB10001424052748704463804576290611475523034.html

Mark LaPedus. (2008). TSMC wants more of IC pie. *EE Times*. Retrieved from http://www.eetimes.com/electronics-news/4076881/TSMC-wants-more-of-IC-pie?pageNumber=1

Mark LaPedus. (2011, January). Samsung lags in foundry rankings. *EE Times*. Retrieved from http://www.eetimes.com/electronics-news/4212366/Samsung-lags-in-foundry-rankings-

Nambisan, S., & Sawhney, M. (2009). *Network-Centric Innovation: Four Strategies for Tapping the Global Brain*. Pearson Education.

Nambisan, S., & Sawhney, M. S. (2008). *The global brain: your roadmap for innovating faster and smarter in a networked world*. Pearson Prentice Hall.

NetLogic Microsystems and TSMC Collaborate on Industry-Leading 55nm Technology for Advanced Low-Power Knowledge-based Processors. (2007). . NetLogic. Retrieved from http://www.netlogicmicro.com/news/pr/2007/07-11-27.asp

Normandin, Y., Studies, M. U. F. of G., & Research. (1991). *Hidden Markov models, maximum mutual information estimation, and the speech recognition problem*. McGill University Department of Electrical Engineering.

Open Innovation and TSMC | The Strategy Group. (2010, June 13). . Retrieved August 12, 2011, from http://tobiaslist.wordpress.com/2010/06/13/open-innovation-and-tsmc/

Open Innovation Platform. (2011). . Retrieved from http://www.tsmc.com/download/brochures/2011_Open%20Innovation%20PlatformTM.pdf

Pisano, G. P., & Verganti, R. (2008). Which kind of collaboration is right for you. *Harvard Business Review*, *86*(12), 78–86.

S.J. MARAIS, & C.S.L. SCHUTTE. (2009). THE DEVELOPMENT OF OPEN INNOVATION MODELS TO ASSIST THE INNOVATION PROCESS (p. 101). Presented at the Southern African Institite for Industrial Engineering Conference Proceedings.

Sang Jin, O. (2010). A Study of the Foundry Industry Dynamics. *Massachusetts Institute of Technology, Sloan School of Management*.

Satish, N., & Mohanbir, S. (2011). Orchestration Processes in Network-Centric Innovation: Evidence From the Field. *Academy of Management Perspectives*, *25*.

Shih-Wei Sun. (2007). Semiconductor Foundry Partnership. *IEEE Conference on Electron Devices and Solid-State Circuits, 2007. EDSSC 2007* (pp. 13-13). Presented at the IEEE Conference on Electron Devices and Solid-State Circuits, 2007. EDSSC 2007, IEEE. doi:10.1109/EDSSC.2007.4450049

Taiwan Semiconductor Manufacturing Company Limited. (n.d.). . Retrieved August 12, 2011, from http://www.tsmc.com/english/default.htm

UMC Joins SEMATECH Research Consortium. (2008). . Retrieved from http://www.sematech.org/corporate/news/releases/20080728.htm

Vivek Naik. (2009, February). GCT's WiMAX Chips Used in USB, Express Card Modems. *TMCnet*. Retrieved from http://communication-solutions.tmcnet.com/topics/wimax/articles/50330-gcts-wimax-chips-used-usb-express-card-modems.htm

Van de Vrande, V., De Jong, J. P. J., Vanhaverbeke, W., & De Rochemont, M. (2009). Open innovation in SMEs: Trends, motives and management challenges. *Technovation*, *29*(6-7), 423–437.

Wang C. etal. (2000). Characteristics of Technology Dependence in SemiconductorTechnological Alliance Companies. Presented at the PICMET.

Wu, S. Y., Hung, S. C., & Lin, B. W. (2006). Agile strategy adaptation in semiconductor wafer foundries: An example from Taiwan. *Technological Forecasting and Social Change*, *73*(4), 436–451.

Yang, Kai-Chi. (2008). *The analysis of evolutionary process of open business model - a case study of TSMC*. NCCU. Retrieved from http://nccuir.lib.nccu.edu.tw/handle/140.119/36917

Yasuda, H. (2003). *New Analytical Approach for Strategic Alliances from the Perspective of Exchange of Management Resources*. Tokyo Institute of Technology.

Yea-Huey Su, & Po-Min Chang. (2008). System perspective on the business model structures of TSMC and UMC: Foundations of business model design for a company. *2008 International Symposium on Semiconductor Manufacturing (ISSM)* (pp. 40-43). Presented at the 2008 International Symposium on Semiconductor Manufacturing (ISSM), IEEE.

Yea-Huey Su, & Shih-Ting Huang. (2006). Business Model Innovation with Effective Innovation: An Exploratory Study on TSMC. *IEEE International Symposium on Semiconductor Manufacturing, 2006. ISSM 2006* (pp. 483-486). Presented at the IEEE International Symposium on Semiconductor Manufacturing, 2006. ISSM 2006, IEEE. doi:10.1109/ISSM.2006.4493142

Youqing, W., & Bai, Y. (2010). Research about openness cycle of supply chain network. *Artificial Intelligence and Education (ICAIE), 2010 International Conference*, 376-378.