SUPPLY CHAIN ANALYSIS OF

THE WAFER INDUSTRY

THESIS

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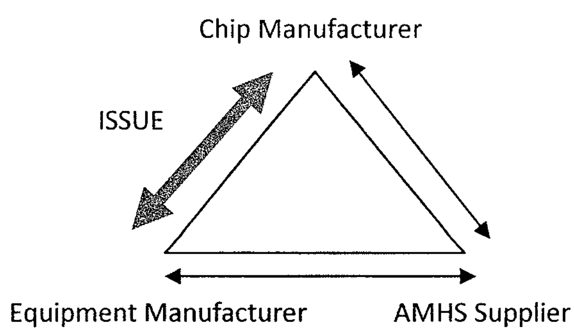
CHAPTER I

INTRODUCTION

The semiconductor industry is currently driven by the ability to design and successfully manufacture smaller, faster, more energy-efficient chips in order to follow Moore's Law.

I have identified a tri-part framework which is illustrated in the diagram below showing the relationship between the chip manufacturer, equipment supplier, and AMHS supplier in a semiconductor supply chain (SC).



In this paper I will analyze specific parts of the SC of the semiconductor industry, namely the relationship between the chip manufacturer and the equipment supplier and the issues that this industry faces to obtain collaboration from its supply chain partners through archive literature. Every time there is a new transition, this relationship is very important in its implementation which is described in chapter 4. The equipment technology is the frontline requirement in a transition. The problem would be if there is a stressed chip manufacturer and equipment supplier relationship, hence resulting in a strain on the semiconductor supply chain.

According to my research and literature review, the equipment manufacturers paid for the development cost of the 300 mm equipment, after which they did not recuperate their investment. Hence, the equipment manufacturers are reluctant to fund anymore transitional costs. This was the motivation for my thesis and to solve this strain in the relationship between the chip manufacturer and the equipment supplier, I propose collaboration through profit sharing in the supply chain as a solution in chapter 4.

In chapter 2, I will also discuss the players in the semiconductor supply chain with emphasis to how the equipment manufacturers and the chips manufacturers collaborate and interact with each other to offer the best product for their customer and the decisions they make to add value to the supply chain management (SCM) process. SCM allows organizations the potential to improve customer service and reduce cost among other things.

As the semiconductor industry are on the verge of a new transition to 450 mm pushed by Intel, I will show my research on lessons learnt from previous transitions to understand the pitfalls of the past transitions and how the semiconductor industries can avoid them to make efficient decisions for the future. Factors such as R&D, transition cost, equipment cost, standardization, material usage, reduced lead times, increased inventory turns, reduced operational costs and improving customer satisfaction with on-time delivery are the most critical factors identified in a 450 mm transition in chapter 3 of this thesis that affect the entire supply chain

Semiconductor manufacturing is the lifeline of the high-tech and IT industries. Although the customer demand driven product in the semiconductor industry has forced a rethinking of the expenditure on manufacturing technologies for the already struggling semiconductor business, by my opinion the economic recession has aided in its cost reduction restructuring. The semiconductor industry is constantly confronted by multiple issues like increasingly shrinking product life cycles, mass modification, rapid inventory reduction, complicated outsourced supply chains, supply and demand misalignment, and the rising expectations of vendors and consumers.

In chapter 5, a few of the other challenges in the supply chain that the industry faces today are mentioned as well·

- Reducing lead time resulting in reduction of time-to-market
- Ramping-up manufacturing capacity and yield quickly
- Globalization and Outsourcing
- Management of inventory and forecasting

This paper will delve into these factors briefly and how they affect the semiconductor supply chain as a whole.

In chapter 6, I conclude this thesis by connecting the problem statement, which is the strained relationship between the chip manufacturer and the equipment supplier, to the solution which is collaboration and profit sharing. This solution will help wafer transitions go more smoothly.

CHAPTER II

PLAYERS OF THE SEMICONDUCTOR INDUSTRY

A simplified version of the Semiconductor supply chain consists of the equipment manufacturer, the chip manufacturer, the electronics industry, and lastly, the electronics consumers. The supply chain in my view is vertically disintegrated with each member concerned in reaching their own goals resulting in a chain-wide performance inefficiency.

The globalization of the semiconductor industry has pushed the chip and equipment manufactures to find ways to attain a competitive advantage through focusing on effective SCM which will help them reduce costs and improve the quality of customer service. In a semiconductor manufacturing environment, lead times vary considerably ranging from weeks to a whole year, thus resulting in unnecessary safety stock which is a balancing challenge between reducing inventory and getting rid of stock outs in this industry [2].

SCM includes planning and managing the flow of information and material from manufacturing to distribution of the final product to the consumer with the objective of maintaining low inventories and high performance in customer service. SCM is even more important in this industry due to large capital investments and high value of end products which have a short market life span because of rapid changes in technology [1].

The semiconductor supply chain continues to experience dramatic change, with competition between original equipment manufacturers (OEM) increasing hardware commoditization. Direct suppliers and other players that are positioned "upstream" in the semiconductor supply chain now create more value than ever before. Intense and continuous pressure on profit margins and costs drives this upstream migration of value [2].

The sheer volume of electronic gadgets, including cell phones, video games, iPods and Blackberries, has had a tremendous impact on our daily lives. So it is not surprising that lower price points and 6–18 month refresh rates would impact the industry responsible for the electronic components. To the fabrication plants (fab), it has meant producing devices that are smaller, lighter, faster, cheaper and better, giving the chipmakers an incentive to put more functions on an increasingly smaller piece of real estate that weighs and costs less. To accomplish this, the fab has added a degree of complexity at the device level and, more importantly, at the integration level [3]. This shrinking of product lifecycles combined with mass modification requires a cost effective approach to survive in this industry.

The next part will include a brief overview of the players of the semiconductor supply chain individually to better understand this industry.

Equipment Manufacturer

The equipment supplier plays an important role in facilitating the chip manufacturer by delivering the equipment required for each transition. The demand for semiconductor production equipment is initiated by the demand for chip supplier's end products. Two major factors have made the translation of product demand into manufacturing- equipment orders a challenging and risky business for both chip manufacturers and equipment suppliers: Capital Investment and an uncertain market.

The semiconductor industry is very capital intense; chip companies spend the most capital on building wafer fabs, in which equipment procurement accounts for 70% of the cost. For instance, the industry leader, Intel, spends more than 5 billion dollars in the procurement of equipment each year. Therefore, companies are very cautious about making equipment procuring decisions due to its capital intensive nature, even a minor under-utilization of equipment can have a huge financial impact [4].

Electronics companies are constantly updating or upgrading old products and introducing new lines of exciting consumer appealing products. Also, due to the rapid change in technology transitioning to smaller, faster, and better chips, the life cycle of each chip generation is short, resulting in shortened life cycles for the wafer fab equipment. Therefore, equipment suppliers have to constantly manufacture equipment built on new wafer blueprints and standards, catering to the new generation of wafer fabs.

Chip Manufacturer

There are tiny components on a chip known as transistors. Basically, they are switches and there can be billions of them on a chip. Together they do the hard work of computing and memorizing of large amounts of data. By making transistors smaller, chips are cheaper to manufacture, which is important and smaller transistors are also faster which render the chips more powerful, thereby increasing the functionality of the chip. . However, reducing the size of the chips needs equipment development and buying new technology.

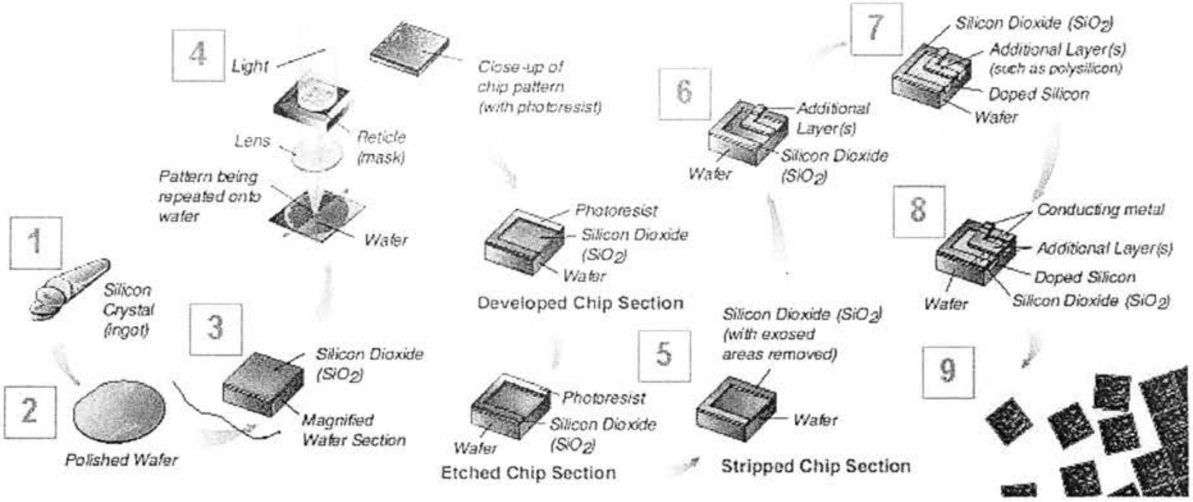


Figure 1. Wafer manufacturing sequence [63]

Semiconductor fabrication is the process used to create wafer chips. It is a sequence of photographic and chemical processing steps during which electronic circuits are created on a wafer made of pure silicon. The above figure shows the wafer manufacturing sequence. Wafers are formed of highly pure, nearly defect-free single crystalline material. Each Material, chemical and process is associated with its own supply chain that together cumulatively is responsible for the production of a chip.

Wafer Manufacturing Process

In this section I will describe the wafer manufacturing process briefly. Semiconductor manufacturing consists of the following steps according to Elmer Epistola [5]:

Front end production of silicon wafers from very pure silicon ingots

Front-end processing refers to the formation of the transistors directly on the silicon The first step in the wafer manufacturing process is the formation of a large, perfect silicon crystal. The crystal is grown from a 'seed crystal' that is a perfect crystal The silicon is supplied in granular powder form, and then melted in a crucible. The pure silicon seed crystal is immersed carefully into the crucible of molten silicon, and then slowly withdrawn. This crystal will be pulled out slowly as it is rotated. The dominant technique is known as the Czochralski (cz) method. The result is a pure silicon cylinder that is called an ingot.

Fabrication of integrated circuits onto these wafers

After the ingot is ground into the correct diameter for the wafers, the silicon ingot is sliced into very thin wafers. This is usually done with a diamond saw. Following slicing, silicon wafers are often sorted on an automated basis into batches of uniform thickness to increase productivity in the next process step, lapping. Lapping removes the surface silicon which has been cracked or otherwise damaged by the slicing process, and assures a flat surface.

Wafers are then etched in a chemically active reagent to remove any crystal damage remaining from the previous process step. The resulting thin wafers can then be doped to achieve the desired electronic properties. The size has gradually increased to improve throughput and reduce cost with the current state-of-the-art fab considered to be 300 mm (12 inch), with the next standard set to be 450 mm (18 inch).

The following is a list of the thickness of wafers [6]:

- 1 inch.
- 2 inch (50.8 mm). Thickness 275 µm.
- 3 inch (76.2 mm). Thickness 375 µm.
- 4 inch (100 mm) Thickness 525 µm
- 5 inch (127 mm) or 125 mm (4.9 inch). Thickness 625 µm.
- 150 mm (5.9 inch, usually referred to as "6 inch"). Thickness 675 µm.
- 200 mm (7.9 inch, usually referred to as "8 inch"). Thickness 725 µm.
- 300 mm (11.8 inch, or "Pizza size" wafer). Thickness 775 µm.
- 450 mm ("18 inch"). Thickness 925 µm (expected).

Assembly of every integrated circuit on the wafer into a finished product

The process of putting the integrated circuit inside a package to make it reliable and convenient to use is known as semiconductor package assembly. An assembly process would consist of the following steps:

1) Die preparation, which cuts the wafer into individual integrated circuits or dice.

2) Die attach, which attaches the die to the support structure (e.g., the leadframe) of the package.

3) Bonding, which connects the circuit to the electrical extremities of the package, thereby allowing the circuit to be connected to the outside world.

4) Encapsulation (usually by plastic molding), which provides 'body' to the package of the circuit for physical and chemical protection.

Testing and back-end processing of the finished products

Prior to shipment to the customer, assembled devices must first be electrically tested. Electrical testing of devices in big volumes must be done fast and inexpensively. Mass-production electrical testing, therefore, requires an automated system for doing the test. Testers and handler systems are also known as automatic test equipment (ATE). Software written for testing a device with an ATE is known as a test program. Test programs consist of a series of subroutines known as test blocks. Generally, each test block has a corresponding device parameter to test under specific conditions. This is accomplished by subjecting the device under test (DUT) to specific excitation and measuring the response of the device. The measurement is then compared to the pass/fail limits set in the test program.

After the device is tested, the handler bins it out either as a reject or as a good unit. Once tested, the wafer is scored and then broken into individual die -- wafer dicing. Only the good, unmarked chips go on to be packaged.

Tape and reel is the process of packing surface mount devices in tapes with pockets while this tape is being wound around a reel. Boxing and labeling is the process of putting the reels or tubes in shipment boxes, and labeling these shipment boxes in accordance with customer requirements.

Electronic Industry

The electronics company acquires chips supplied by the integrated circuit manufacturers and incorporates them into systems and devices used in communication, entertainment, household and office appliances. In fact, the global consumer electronics market is growing at an unprecedented speed: the worldwide sales of consumer electronics exceeded 506 billion $ in 2007 with an annual growth rate of 12.7 % during the past five years [7]

Electronics companies, such as Dell, Apple, Samsung, Toshiba, Hewlett-Packard and Sony, are market leaders of this industry. Samsung Electronics Co. said third-quarter net profit tripled to a record amid higher prices for computer memory chips and increased sales of consumer products from flat screen televisions to mobile phones. South Korea's biggest corporation and a world leader in consumer electronics earned $3.14 billion dollars in the three months and ended Sept. 30, 2009. Samsung is a major force in global electronics, making not only consumer products but also key components such as memory chips and panels. The company is the world's biggest seller of flat screen TVs, computer memory chips and liquid crystal displays [8]. Intel gets most of its revenue from selling chips that are the "brains" of personal computers; they are indicating that PC makers are loading up on new chips faster than expected. Intel is benefiting from the fact that PC makers had burned through a lot of their inventory, instead of buying new chips, as the financial crisis worsened [9].

Apple weathered the economic meltdown better than other computer companies, giving it a running start while PC sales slumped slowly. Apple sold 3.05 million Macs, a 17 percent unit increase from the same period a year ago. For the quarter ended Sept. 26, 2009, Apple said it earned $1.67 billion. Revenue jumped 25 percent, to $9.87 billion [10]. Intel, Samsung and Texas Instruments have become the top three chip manufacturers worldwide. As a result of outsourcing production, many chip companies no longer owned fabs, and concentrated on their core business. These small and middle sized companies, such as Qualcomm and Nvidia, are known as fabless firms. They are showing a high expansion rate of 23% annually. Some chip manufacturers are called "pure" foundries, serving as the contract manufacturers of fabless firms. The Taiwan Semiconductor Manufacturing Company (TSMC) was the first and currently largest foundry firm The beginning of fabless and foundry firms have indicated the structural change of the wafer manufacturing supply chain: from vertically integrated models to multi-level decentralized structures.

Below is a table of the top 10 semiconductor companies by sales as of May 2009 to better understand where the market is at the moment [11]. According to the Semiconductor Industry Association due to the economic recession, global semiconductor sales fell 2.8 percent last year and are expected to fall a further 21.5 percent to $195.6 billion in the year 2009.

Table 1. 2Q09 Top 20 semiconductor sales leaders (US$m) [11]

2Q09 Top 20 Semiconductor Sales Leaders ($M)

2Q09 Rank	1Q09 Rank	2008 Rank	Company	Headquarters	2008 Tot Semi	08/07 % Change	1Q09 Tot Semi	2Q09 Tot Semi	2Q09/1Q09 % Change
1	1	1	Intel	U.S	34,490	-2%	6,573	7,382	12%
2	2	2	Samsung	South Korea	20,272	2%	3,686	4,767	29%
3	3	5	Toshiba	Japan	10,422	-12%	2,008	2,310	15%
4	4	3	TI	U.S	11,618	-13%	1,939	2,285	18%
5	10	4	TSMC*	Taiwan	10,556	8%	1,162	2,238	93%
6	5	6	ST	Europe	10,325	3%	1,657	1,993	20%
7	6	8	Qualcomm**	U.S	6,477	15%	1,316	1,786	36%
8	8	7	Renesas	Japan	7,017	-12%	1,233	1,381	12%
9	7	9	Sony	Japan	6,420	-11%	1,270	1,360	7%
10	13	10	Hynix	South Korea	6,182	-33%	927	1,301	40%
11	11	14	Micron	U S	5,688	3%	1,020	1,225	20%
12	9	12	AMD	U.S.	5,808	-1%	1,177	1,184	1%
13	12	11	Infineon	Europe	5,903	2%	970	1,150	19%
14	14	13	NEC	Japan	5,732	2%	863	1,005	16%
15	16	18	Broadcom**	U.S.	4,509	20%	827	966	17%
16	15	19	Panasonic	Japan	4,321	13%	850	920	8%
17	19	25	MediaTek**	Taiwan	2,845	16%	704	847	20%
18	21	20	Nvidia**	U.S.	4,959	-11%	597	795	33%
19	20	15	NXP	Europe	5,020	-14%	648	788	22%
20	18	16	Freescale	U S.	4,959	-11%	798	784	-2%
—	—	—	Total Top 20	—	173,523	—	30,225	36,467	21%

*Foundry **Fabless

Electronics Consumer

Rising customer demands and their needs are one of the top supply chain inadequacies that the electronics industry need to address. Supply chains will not be able to afford the excess inventory nor the lack of product innovation without customer collaboration. Continuous replenishment, proper forecasting and inventory management can only be achieved through improving visibility in the supply chain from manufacturer to customer. The information required for collaboration to achieve the required visibility for a leaner supply chain to make proper decisions will put the electronics industry back on the road to success and higher profitability for all the partners.

Below is a snapshot of consumer electronics sales of the last two years of the top 10 retailers [12] showing increasing customer demand to better understand the dynamics of the industry.

Table 2. Top 10 Consumer Electronics Retailers (in billions) [12]

Rank 2008	Rank 2007	Retailer	CE Sales 2008	CE Sales 2007	% CE Change 08' Vs '07	Total Sales 2008	Total Sales 2007
1	1	DELL	36.28 B	35.62 B	0.018	36.28 B	35.62 B
2	2	Best Buy	31.85 B	30.63 B	5	33.88 B	32.24 B
3	3	Wal-Mart	25.4 B	23 8 B	6.72	253.66 B	238.32 B
4	4	Circuit City	10.14 B	11.43 B	(11.29)	10.14 B	11.43 B
5	5	CDW Corp.	8.15 B	8.14 B	0.12	8 15 B	8.14 B
6	7	Staples	7.35 B	6.59 B	11.53	18.37 B	16.47 B
7	8	GameStop	7.09 B	5.78 B	22.66	7.09 B	5.78 B
8	6	Target	6.7 B	6.6 B	1.5	67.22 B	66.39 B
9	12	APPLE	6.07 B	4.18 B	45.21	6.07 B	4.18 B
10	9	Best Buy Canada	6 B	5.7 B	5.26	6 B	5.7 B

This chapter was a brief overview of the semiconductor supply chain which consisted of the equipment manufacturer, chip manufacturer, the electronics industry and the electronics customer. In a supply chain there are many relationships between these players for example the relationship between the electronics industry and the electronics customer. In this relationship the electronics customer drives innovation to deliver a continuous supply of new products from the electronics industry.

This chapter also helps in describing the wafer manufacturing process briefly which gives an overview of the nature of equipment complexity required for this process. This complexity and extremely high equipment cost for the wafer manufacturing process shows how important a smooth relationship is required between an equipment supplier and a chip manufacturer.

Chapter III

TRANSITIONAL ISSUES

This chapter includes all the observations from the literature review and research findings categorized into factors that are most critical for a 450 mm transition. I have divided the research under 'Operational cost' and 'Cycle time & productivity'. The category 'operational cost' consists of the factors: wafer transition cost, R&D, standardization & integration, equipment & material, AMHS, and return on investment.

Operational Cost

The nature of the electronics manufacturing industry has no room for operational inefficiency and error considering the shrinking product life cycles with high product-mix, along with a plethora of business challenges that affect the bottom line.

Wafer Transition Cost

Consistent with the historical growth rates specified by Moore's Law, the semiconductor industry has experienced transitions to larger wafer sizes every ten to fifteen years. A 300 mm wafer can contain up to 2.5 times as many *dies per wafer* than those contained by a 200mm wafer, and thus the associated *die per wafer* cost is 30%-

40% less [35].

A 300 mm wafer processing tool provides practically the same amount of throughput as a 200mm wafer processing tool. However, these tools also cost approximately 40% more than 200mm wafer processing tools. The total transition cost was estimated to be $14 Billion.

A process deviation is a costly one, as a single 300 mm wafers lot is roughly worth $1 million [36]. A transition to 450 mm wafers is an extremely expensive and risky proposition, estimates run to well over $25B at the high end. The industry simply cannot afford to make such an expensive investment based on future "expectations" without an objective analysis of cost and benefit. An examination of the cost structure of current devices shows that a 450 mm wafer increase will impact <10% of final product cost in a positive way.

The opportunities for reducing the cost of *die per wafer* are not only realized by maximizing the equipment utilization, but also by reducing the wafer cycle time. [13] This strategy of reducing cycle times to make existing fab applications 30%-40% more productive while eliminating unnecessary time is the main focus of 300 Prime [37], [38], [17]. This is critical particularly in high mix, low volume fabs [21]. It is claimed that waiting time of wafers represents nearly 75% of the total time that wafers spend in the fab [39]. Similar in spirit to the Toyota Production System (TPS), 300 Prime seeks to reduce the number of wafers per carrier from 25 to less than 5, reduce WIP levels in the factory, eliminate unnecessary AMHS moves, and enable single wafer processing [40], [41]. 300 Prime also seeks to serve as a bridge to 450 mm wafers by developing standards that facilitate the transition [37], [42].

Manufacturers worry about wafer costs partly because 300 mm wafers have been relatively expensive. The 300 mm wafers initially cost >$1000 for volume manufacturing and then dropped slowly to ~$250, with the reduction occurring more slowly than the curve for the 200 mm wafers, according to Gartner. For 200 mm fabs, the wafer cost is about half the materials cost. For a 300 mm manufacturer, the wafer accounts for about 64% of the total materials cost, making the issue of 450 mm wafer prices a critical question in their minds. The early 450 mm wafers will be in the $15-20,000 dollar range, Freeman said in a matter-of-fact tone. After his presentation, he said large wafer customers such as Intel Corp. may get a break, paying $10-15,000 in the early going when pilot 450 mm production is underway [43].

Chip manufacturers can mitigate 450 mm wafer transition cost by focusing on high volume and high margin products in the previous node (300 mm products).

Research & Development

Research & Development, in my opinion is the lifeblood and a costly investment for survival in the semiconductor manufacturing industry. The players in the industry are facing hard choices about how to fund their R&D departments and which wafer size to pursue as the budget (2009 - 2012) for semiconductor equipment vendors are slashed to a third due to the downturn of the economy.

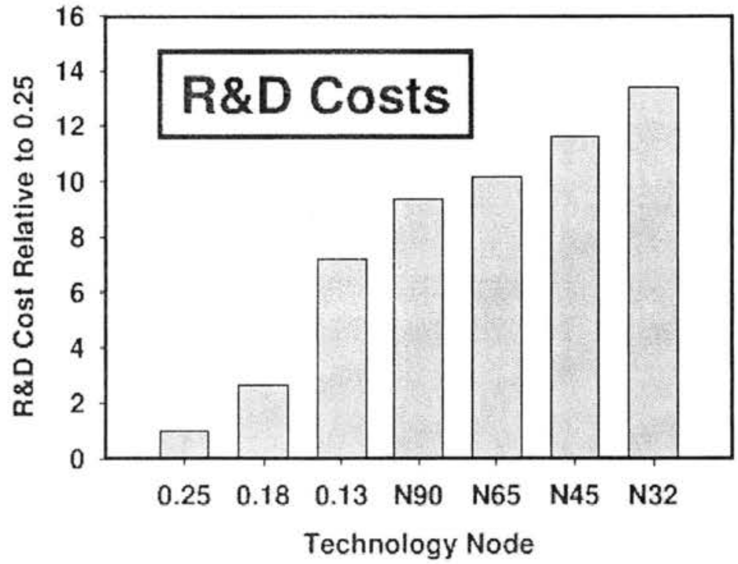


Figure 2. Increasing R&D required to meet growth challenges [68]

Above is an illustration of the increasing R&D cost from the previous to current transitions. The transition to 450 mm wafer size requires a careful R&D stage that includes a cost benefit analysis and a feasibility study so that, the pricey and massive transition is better understood before it is undertaken. Actual data related to cost and production yields from the last transition are instrumental to predict costs and yields for the next transition. The actual data sharing involves real visibility between fabs and suppliers.

Standardization & Integration

Through the Semiconductor Equipment and Material International (SEMI) and the International 300 mm Initiative (I300I), the wafer manufacturers developed guidelines and standards for 300 mm wafer processing, which enabled and facilitated the transition to this wafer size. These standards and guidelines helped cutting unnecessary costs and time, such as those incurred in equipment development and installation [44], [13]. One of the biggest challenges affecting fab productivity during the transition to 300 mm wafers was the lack of guidelines for process/automation integration, e.g. facilities planning and material handling systems design [45], [46].

As a result, the industry formulated solutions to reduce manufacturing inefficiencies and integrate the factory components (i.e. equipment, operations, AMHS, information systems, facilities, etc.) under the International Technology Roadmap for Semiconductors (ITRS) [47]. These guidelines specifying factory integration issues were critical for the transition to 300 mm wafers. However, some authors believe that factory logistics will provide competitive advantage to chip manufacturers in the next transitions [40].

Equipment & Material

The cost of a 300 mm wafer fab is approaching $3.5-$4.0 Billion [48]. Approximately 80% of this investment is due to the processing equipment, and approximately 10% is due to the AMHS [49], [50]. Below is an illustration of the increasing fab cost from the previous to current wafer transitions.

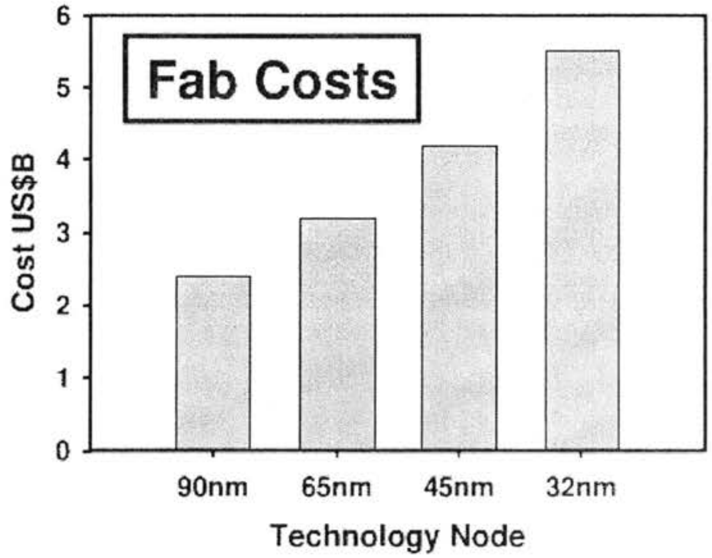


Figure 3. Increasing Fab costs required to meet growth challenges [68]

The costs of 300 mm wafer processing tools typically range from $0.7-$4.0 Million, while steppers may approximately cost $40 Million [49]. Tool utilization is a critical factor that determines overall operational efficiency and fab profitability [48], [51]. Studies showed that a 200mm tool is idle about 20% of the time due to scheduling conflicts, lack of a human operator, or lack of work-in-process (WIP) ready to process [52]. Such wasted capacity rates are hardly affordable in a 300 mm wafer fab.

The lesson learned is that automation, including the AMHS, must not limit the equipment capacity. Standards specifying the equipment-material handling interfaces were developed to improve overall equipment effectiveness (OEE). These standards enabled the use of internal buffers inside the processing equipment. This feature helped the equipment maintain a constant supply of material, thus reducing unnecessary idle time.

Demand for new process technologies and materials are the lifeblood of semiconductor equipment and materials providers. As leading-edge semiconductor technology continues to move to smaller geometries, we provide periodic analyses of new manufacturing techniques and device structures and how these will affect equipment and materials suppliers [27].

AMHS

The effectiveness of the automated material handling system as well as the investment's rate of return are primary concerns related to the decision on the acquisition of production equipment of wafer fabrication. The primary role of an AMHS is to deliver and store wafers to the right processing step, in between different processing steps, at the right tool, and at the right time [53] [54].

Wafers are generally grouped and moved in carriers of 25 units. As most wafer processing tools are significantly expensive in relation to the AMHS, timely wafer deliveries are critical to achieve high equipment utilization, and thus increase fab productivity. The AMHS has also become a significant factor reducing ergonomic problems and protecting wafers from damage and contamination.

Return on Investment

Several equipment industry representatives, including executives from ASML (Veldhoven, Netherlands), Lam Research Corp. (Fremont, Calif.) and Tokyo Electron Ltd., (Tokyo) appeared at a SEMI-organized event on the final day of the SEMICON

West show (July 17, 2008) to argue that the likely return on investment (ROI) for 450 mm R&D does not justify the expense [55]. While technical discussions process and ISMI's test bed plans go forward, the industry remains deeply divided over the cost benefits of going to 450 mm.

An ISMI economic analysis, which contends that 450 mm wafers would produce a 30% improvement in wafer processing costs at some point, is being strongly challenged. Iddo Hadar, an economist working for Applied Materials Inc. (Santa Clara, Calif.), said, "There are critical flaws in the ISMI analysis, and yet most people think that it is based on solid analytical work." He said many companies are accepting the 30% cost benefit blindly [56]. Recent industry sentiment shows that continuing to improve on the existing and future 300 mm base has tremendous payoff for the industry. Winners will place their bets on the continued 300 mm technology evolution with improved factory agility and "smart" tools with reduced variability, while avoiding a premature, high-risk adventure into a larger wafer size anytime soon [57].

Cycle Time & Productivity

As the semiconductor industry is in the planning stages for its next wafer diameter increase (i.e. from 300 mm wafers to 450 mm wafers), the design of highly efficient wafer fabrication factories (fabs) and automated material handling systems (AMHS) is critical to enable high productivity and reduce costs.

As electronics become commodity items, manufacturers are forced to make regular new product introductions to command a premium price, sustain profits and preserve market share. This leads to very short product life cycles which complicate the prediction of consumer demand since these new products may have functionality or capacity enhancements that are as yet untested. Furthermore, most forecasting algorithms work best when they have a reasonable (at least one year) amount of sales history for similar products. Accordingly, manufacturers must work very closely with retailers and resellers. Market demand can only be managed effectively by getting closer to the customer and using collaborative planning techniques [28].

Effective standards and guidelines regarding AMHS were expected to be significant contributors to lower wafer cycle times. However, cycle time decreased and WIP increased due to delivery control conflicts. Guidelines will help streamline processes and provide much needed cycle time reduction opportunities. Older generation fabs (150 mm and 200 mm wafer) were not designed to use space effectively. Efficient layout space is required to be cost effective and make maximum use of the expensive equipment in place. The proper flow of material is also essential in attaining maximum capacity.

Cycle time reduction benefits are well known in the industry. Fabs with shorter cycle times require smaller inventory for the same number of wafers out and can produce at a lower cost per wafer [59]. Shorter cycle times promote process stability, improve the ability to schedule processing, and increases the ability of a fab to respond to customer demand.

An analysis of potential 300 mm improvements shows 300 mm Prime has cycle time opportunity but falls short of the traditional cost reduction required to stay on

Moore's which should give a 30% cost reduction and 50% cycle time improvement. The financial benefit of cycle time reduction is difficult to quantify for different business models. Faster new product introduction means efficient time to money resulting in faster product delivery to customers [60].

"The data shows that 300 mm Prime has theoretical potential to achieve the targeted reduction in cycle time, but it does not sufficiently address our members' cost reduction needs," Abell said. "It appears that the key to significant wafer cost reduction can be found only in larger wafers." [61].

I believe that the biggest factor in increasing 300 mm fab productivity will be improved tool availability resulting from enhanced software capabilities. Specifically, these include increased effectiveness of identification and diagnosis of problems, increased allowances for remote tool access for problem resolution, improved tool maintenance support systems, and better tool control system reliability and error recovery capabilities [62].

One opportunity for productivity improvement at 300 mm and beyond is to significantly reduce or eliminate waits throughout the manufacturing process. Waits are delays in the temporal continuity of manufacturing and movement of wafers from one process step to the next. Reduction of such waits can significantly improve manufacturing productivity by increasing equipment utilization and reducing cycle time and work-in-process (WIP).

In this chapter, I have discussed the most critical factors that are impacted during a 450 mm transition. According to the literature, 300 mm wafer transition cost 14 billion and a 450 mm wafer transition cost is estimated to be around 25 billion. As budgeting is tight due to the economic downturn and a proper feasibility analysis is required to calculate actual yields of the 450 mm transition, R&D is very critical in the next transition. Standardization and guidelines provided by the ITRS is an important factor for cost reduction. Eighty percent of a wafer fab cost comes from wafer processing equipment and ten percent from AMHS shows the criticality of optimum tool utilization to reduce wafer cycle time and increase productivity. According to my research, companies are blindly accepting a 30% improvement in wafer processing costs at some point for the 450 mm wafer. This improvement needs to be verified and further research and R&D are required to prove this statement.

CHAPTER IV

SUPPLY CHAIN OF THE WAFER INDUSTRY: IMPACT

In this chapter I will focus on the semiconductor supply chain namely the equipment supplier and the chip manufacturer relationship, how important capital intensive transition equipment is and their importance to the value chain. As mentioned before, my research and literature review indicates that the equipment manufacturers paid for the development cost of the 300 mm equipment, after which they did not recuperate their investment. Hence, the equipment manufacturers are reluctant to fund anymore transitional costs.

The issue of the thesis is described in this chapter. The motivation of this research as mentioned previously in the thesis was the strained relationship between these two semiconductor players created by the misalignment of the supply chain in previous transitions. My suggested solution summarized from my readings and research would be collaboration of the chip manufacturer and the equipment supplier by increasing visibility in the value chain, thereby increasing profitability for both players. Profit sharing is an additional solution I have suggested to incentivize the equipment suppliers by the chip manufacturers.

There is a section on what the equipment acquisition process looks like in the supply chain. Finally the last section of this chapter will focus on the transitional factors described in chapter 3 that have impacted the 450 mm transition after collaboration of equipment suppliers and chip manufacturers.

The past decade has witnessed a major change in the characteristics of the semiconductor supply chain. The industry experienced supply and demand equilibrium, which oscillated every three to four years. The high investment costs required to begin and operate a manufacturing fab, combined with the reduction in average selling prices, made it a challenging environment to stay in business.

The Relationship between Equipment Manufacturers and Chip Manufacturers

In my readings I have found scenarios where fabs absorbed the costs of development and equipment, but I have also found scenarios where the tool suppliers paid for development and equipment. Additionally, the literature suggests that the equipment suppliers have not recuperated their investment from the last conversion and the cost of transitioning was very high. From the last transition, it is noted that expected cost reductions were not achieved, and results were not consistent and directly proportional to the inputs. All involved should try to recover the previous high transition costs to make the next transition to 450 mm wafer size feasible. Collaboration between fabs and tools suppliers might be the only option to proceed. In the first two transitions, the lead companies (i.e. IBM and Intel) assumed most of the development costs and manufacturing inefficiencies without obtaining significant cost benefits [13]. In the most recent transition (i.e. 200mm to 300 mm wafers) little 200mm wafer processing technology was used for 300 mm wafer processing. The equipment suppliers and the fabs have incurred significantly high costs in the last conversion - 200mm to 300 m0m wafer size. The equipment manufacturers agreed to fund the development costs of 300 mm equipment, with additional financial support provided by the major semiconductor wafer manufacturing companies. In this collaboration, equipment manufacturers paid for equipment development, while wafer manufacturers paid for equipment testing [13]. After the transition, equipment manufacturers have faced the challenge of recovering their investments. Therefore, fearing financial loss, most equipment suppliers are currently reluctant to develop and manufacture the equipment required for the next transition to 450 mm wafers [14], [15], [16], [17]. This is a very important statement in this paper It is the inability of the equipment suppliers to recuperate their investment that has motivated this research to analyze the strained relationship between the chip manufacturer and the equipment suppliers. The lesson learned is that win-win collaborations among equipment suppliers, automation suppliers, and wafer manufacturers are crucial for a smooth, successful transition [18], [19], [20]. Otherwise, the benefits of a potential transition to 450 mm wafers will be obtained by a highly exclusive group (i.e. Intel, Samsung, and TSMC) [26]. An alternative solution to bring the industry together is to use as much as possible the technology developed for 300 mm wafers to minimize tool development cycles and reduce capital investment associated with the 450 mm wafer size transition [16], [22].

There are some companies that are resisting the move, however, because the switch will require the industry to invest billions of dollars, and some companies say they are content with manufacturing on the current 300 mm wafers [23]. The reluctance of the equipment industry, however, is not slowing down interest by the largest chipmakers. ISMI Director Scott Kramer said the ISMI members have more than doubled the budget for the 450 mm program, largely to bring up the 450 mm Interoperability Test Bed at Sematech's Albany, NY facility, where automation and metrology equipment is being installed. "Intel, TSMC and Samsung in particular have increased the amounts they are spending on the 450 mm program. They have authorized supplemental spending," he said [24].

A 25 Billion dollar 450 mm transition based on blindly expecting 30% returns is too big of a gamble that the industry can't afford [64]. In the first two transitions, IBM and Intel did not acquire noteworthy cost benefits after spending on development costs and manufacturing inefficiencies. Last transition (200mm - 300 mm wafers), 200mm wafer processing technology was not scalable to 300 mm wafer processing which the equipment manufacturers funded with the support of major semiconductor wafer manufacturing companies. The equipment industry is skeptical of the 450 mm ROI. About 80% of the investment will be towards processing equipment, and 10% towards AMHS. Tool utilization is an important factor that will determine total operating efficiency and fab profitability [25], [26].

Global demand for semiconductor equipment and materials is determined by the industry's global supply-and-demand situation and specific production needs. Changes in capital investment strategies of semiconductor markets add further complexity to the semiconductor manufacturing demand picture. In 2009, the investment stance of the industry is ultraconservative because of a high degree of uncertainty about the depth and extent of the current economic recession.

As the costs of developing new technology continue to escalate, outsourcing manufacturing continues to provide a viable alternative to maintaining a dedicated manufacturing capability. In recent years, renowned integrated device manufacturers, such as TI and Sony, have moved to a "fab-lite" or fabless model, bolstering the foundry business opportunity. Similarly, on the packaging side, increased outsourcing associated with new packaging technologies has led to a market that outperformed its customers' market growth in recent years [27].

Looking at this problem from a forecasting point of view, the semiconductor equipment supply chain faces an order fulfillment dilemma as in many customized capital goods industries. On the one hand, buyers of equipment expect their suppliers to be responsive and to be able to fulfill orders within a relatively short order lead-time. On the other hand, the high value and the customized nature of the product makes it risky for the supplier to keep sub-systems or even finished products in inventory, leading to long and variable manufacturing lead-times [65].

To resolve this dilemma, the buyers (producers of chips) provide their equipment suppliers with forecasted orders for the next 24 months and longer. Unlike firm purchase orders, such forecasted orders, sometimes also referred to as ‘soft orders’ are a reflection of the buyers purchase intent and are not legally binding [65].

Equipment Acquisition process

This section of the paper is inspired by Z. Ren and extracted from his dissertation, *Sharing Forecast Information in a Supply Chain.*

Demand for semiconductor production equipment is triggered by the projected demand for chips which in turn is generated by the demand for electronic devices, eg., personal computers, semiconductor equipment makers find themselves at the end of the bull whip effect [66]. They face business cycles that flood them with orders in one year and are starved for work in the coming year. Once the capacity planning process has generated requests for additional pieces of equipment, an elaborate tool acquisition process commences. This process includes three stages: forecast sharing, manufacturing and installation [65].

During the forecast sharing stage, the chip manufacturer (buyer) creates a forecasted order (soft order), which is shared with the equipment manufacturer (supplier) via an online collaboration system. This soft order includes the tool's specifications, and the requested delivery date (RDD) which is merely preliminary information. Since in the presence of market and capacity uncertainties, the buyer does not want to commit to an order at such an early stage. The buyer can, after getting more information about his market demand and production yields, decide to (a) cancel the order, (b) to move it to another date, (c) or leave the soft order unchanged.

The supplier becomes aware of the buyer's purchase intent, both through the online information system as well as through customer interaction from its sales and marketing department. At some point the supplier needs to initiate the production of the tool, which include procurement of sub-systems from second tier suppliers and the entry of the order into the production schedule.

The supplier faces a difficult situation, as starting the order too early can lead to holding and cancellation costs, while starting the order too late can lead to late shipment costs. The typical manufacturing lead-time of the supplier ranges between 3 – 5 months. The lead-time however exhibits a significant variability as a result of differences in product-mix going through the supplier's facility, changes in equipment demand, process generation and/or uncertainty in lead-times from the second tier suppliers.

Finally, the tool is shipped to the corresponding fab, where it is installed and must then move through an elaborate qualification process before it can produce commercial output. The overall equipment acquisition cycle is illustrated by Figure 'X' In total, the equipment acquisition cycle is approximately one year. Some tools, especially in the lithography domain, can take even longer [65].

Note that the equipment acquisition process applies only for tools that have already been developed and proven their technical feasibility. The buyer uses a different contract for the supplier during the development of a new piece of production technology. One important difference between such development contracts and the procurement contracts as outlined above is that the buyer might fund more than one supplier for the development of a single tool type. In contrast, once the equipment specification is established, the buyer typically switches to a single sourcing approach [65].

Collaborative Supply chain Planning

Today, semiconductor companies already share their most important asset with contract manufacturers, the design of their chips, so why not share additional information and place trust in them executing the supply chain in the same way. Through successful collaboration efforts to utilize real-time demand signals and processes to address product return costs, a consumer electronics company can gain real insights into the end consumer. Meaningful demand signals include information that includes: price point, promotional attribute and causal information, on hand inventory, and point of sales consumption and if possible respective attributes. Sensing the in-store activity and true point of sale (PoS) demand signals, enables some electronics manufacuturers to rapidly respond as an organization to optimize their supply chain, inventory quantities and therefore maximize profitable revenue [67]

Collaboration among all involved in the next transition, 300 mm to 450 mm wafer size, will require adequate actual data, collaborative planning at the strategic, operational and tactical levels to estimate potential savings, if any [28]. A cost reducing strategy will help in the broad picture to make it a cost effective transition. Conversely, such collaboration among equipment suppliers and fabs may bring a conflict of financial interest in the development and deployment of the new wafer since the costs involved are high. Fabs as well as suppliers tend to compartmentalize their knowledge. This increases the workload at both ends and decreases efficiency. Information has not been documented in a systematic manner because decision makers have not had easy access to disperse information and therefore unavailable to use knowledge of past experiences and learnt lessons.

There are many equipment suppliers who also understand the requirement and benefits of the incremental demand data coming from an integrated demand signal solution resulting from collaboration with the chip manufacturers.

Collaborative supply chain planning involves improving the coordination and information sharing for all activities, from design to delivery, across functions within an enterprise and across enterprise boundaries [28]. As companies engage in collaborative planning activities, the results are decreased lead times, lower inventory levels and improved responsiveness resulting in improved profitability and customer service levels. Collaboration is increasingly more critical due to ongoing product innovation and increased competition, especially during new product introduction and promotion programs [67].

In addition to coordinating activities across the entire product life cycle, collaborative planning involves a comprehensive solution including changes made in alliance strategy, business process, performance measures and technology. Exploiting the Internet for collaborative supply chain planning provides a critical link for sharing information, planning and scheduling supply chain activities, and improving coordination within the design process [28].

As customers share demand plans with upstream suppliers, these suppliers have more accurate visibility of future demand requirements from customers. This increased visibility enables the suppliers to better plan their business while providing commitments back to customers for product availability. In addition, customers and suppliers can better plan and coordinate design activities, leading to improved time-to-market.

Additionally, as product life cycles continue to shrink, managing product transitions and end-of-life events requires collaboration within and across enterprises. When products reach full maturity, make or scrap decisions must be made based on inventory availability, market demand, available capacity and profit margins, as well as new product launches for superseding products. These decisions can have a major impact on profitability, and affect several participants up and down the supply chain. Planning systems with business rules and optimization techniques are available to evaluate various alternatives for managing product retirement and end-of-life decisions. Significant opportunities for improving financial performance is realized through this form of optimization. Supply chain excellence can decrease inventory and cycle times while significantly increasing on-time deliveries and inventory turns. Taken together, these results can provide companies with greater profits, improved customer service and that ever elusive competitive advantage. But it takes the right vision, the right strategy and above all, the right software tools for theory to become reality [28].

Kumar and Partner [29] explain collaborative supply chain planning effectively in their paper *Contract Manufacturing: Trusted partnerships and collaboration key to success*. The sharing of information both ways goes a long way in building trust and ensuring a company has the right information to make an appropriate decision. Irrespective of the level of control and monitoring companies follow, collaborating helps to ensure both parties are looking at the same information and that there are no barriers to information flow. Companies can collaborate on demand forecasts, supply commits and execution throughout manufacturing operations. Various levels of collaboration exist within the semiconductor industry.

The most common form of collaboration is one-way communication between the contract manufacturer and the semiconductor company [29]. It is like receiving a snapshot once a day rather than receiving one in real time. Moreover, most of the time, collaboration is limited to supply chain execution operations only. Most sophisticated companies do collaborate on all business processes: demand collaboration, supply commit collaboration, work-in-process (WIP) information, shipment information, invoices and payments. Business-2-business (B2B) collaboration results in effective information flow. For companies that feel B2B collaboration is too sophisticated and requires much effort, there are alternate real-time collaboration solutions through service providers. These service providers have worked with most of the big contract manufacturers and have established a mechanism to extract relevant data needed for collaboration. Therefore, companies that work with these collaborative data providers will not have to worry about establishing B2B connection with each of their contract manufacturers. With real-time collaboration, both parties have a complete picture of the supply chain which helps them make correct decisions, minimize information flow latency, avoid miscommunication and build trust between partners.

It is just a matter of time before one can see the true JIT environment of semiconductor chips being delivered to original equipment manufacturing (OEM) or electronic manufacturing service (EMS) assembly lines, and a semiconductor company having multiple manufacturing partners whose relationships are built on trust. New business process management (BPM) initiatives, which drive processes across organizations, will also help semiconductor companies avoid duplicating the transaction monitoring and control process, removing non-value added process steps and simplifying the information flow to manage the supply chain in the most efficient and effective way.

The next big step in chip manufacturing will be the industry's move from 300 mm wafers to 450 mm wafers, which should help chip makers improve the performance of their products while keeping costs down. Chip makers Intel, Samsung Electronics and Taiwan Semiconductor Manufacturing Co. announced that they will collaborate to move chip manufacturing onto 450 mm silicon wafers, with pilot tests to start in 2012 [23].

The Impact of Collaboration on 450 mm transition

Every time there is a new transition, the relationship between the equipment supplier and the chip manufacturers is very important in its implementation. The problem of the thesis as stated previously is the stressed relationship between the chip manufacturer and equipment supplier, hence resulting in a strain on the semiconductor supply chain.

According to my research and literature review, the equipment manufacturers paid for the development cost of the 300 mm equipment, after which they did not recuperate their investment. Hence, the equipment manufacturers are reluctant to fund anymore transitional costs. This was the motivation for my thesis and to solve this strain in the relationship between the chip manufacturer and the equipment supplier, I proposed collaboration through profit sharing in the supply chain as a solution.

In chapter 2, I have discussed the most critical factors that are impacted during a 450 mm transition. In this section, I will discuss the impact of the collaboration I described in the previous section to these critical factors.

Collaborative supply chain planning involves improving the coordination and information sharing for all activities, from design to delivery, across functions within an enterprise and across enterprise boundaries [28]. As companies engage in collaborative planning activities, the results are decreased lead times, lower inventory levels and improved responsiveness resulting in improved profitability and customer service levels. Collaboration is increasingly more critical due to ongoing product innovation and increased competition, especially during new product introduction and promotion programs [67].

According to the literature 300 mm wafer transition cost 14 billion and a 450 mm wafer transition cost is estimated to be around 25 billion. Due to the high capital intensive nature of this transition collaboration is the most important way to reduce costs and increase profitability in the value chain.

As budgeting is tight due to the economic downturn and a proper feasibility analysis required to calculate actual yields of the 450 mm transition, R&D is very critical in the next transition. Collaboration in the R&D sector among the equipment suppliers and the chip manufacturers resulting in sharing the equipment development and testing costs would decrease the burden on both members of the semiconductor supply chain. The feasibility study to calculate actual cost savings transitioning to 450 mm to determine if this implementation is at all possible would be the first step towards deciding whether equipment production is necessary or not. It will also determine if upgrading the current 300 mm equipment is a possibility or not as well.

Standardization and guidelines provided by the ITRS is an important factor for cost reduction. The standards and guidelines developed by ITRS helped cut unnecessary costs and time, such as those incurred in equipment development and installation [44], [13]. Collaboration in this aspect does not impact standardization.

Eighty percent of a wafer fab cost comes from wafer processing equipment and ten percent from AMHS shows the criticality of optimum tool utilization to reduce wafer cycle time and increase productivity. Collaboration through profit sharing will definitely affect the bottom line in this aspect, since most of the cost of the chip manufactures are incurred through the procurement of processing equipment.

Sharing information to achieve collaboration has been an important topic in Management Information System (MIS) area, especially with the adoption of the Electronic Data Interchange (EDI) in industry. The benefits from sharing information with interorganizational information system depend on the loyalty of business partners, and trust and truthfulness are essential in successful collaboration among firms [65].

According to my research, companies are blindly accepting a 30% improvement in wafer processing costs at some point for the 450 mm wafer. This improvement needs to be verified and further research and R&D required to prove this statement. It is not certain if collaboration will impact this criterion since the factor itself requires verification.

Chapter V

OTHER ISSUES

In chapter 3, factors such as R&D, transition cost, equipment cost, standardization, material usage, reduced lead times, increased inventory turns, reduced operational costs and improving customer satisfaction with on-time delivery are discussed and stated as the most critical factors identified in a 450 mm transition that affect the entire supply chain. In this chapter I shall describe other issues that have an impact on the supply chain like lead-time, management of inventory & forecasting, capacity issues and lastly globalization & outsourcing issues that also have an impact on the semiconductor supply chain which need to be taken into account.

Supply chain management involves planning and managing the flow of material and information through multiple stages of manufacturing, transportation and distribution until it reaches the customer. SCM includes planning of replenishments of incoming inventory at each manufacturing stage, includes planning of operations at each manufacturing stage and planning of shipments for products from one stage to the next. Some of these components of supply chain, in particular the operations planning, have been the focus of productivity improvement efforts [1].

Although the biggest supply chain issue is cost containment which I will address later in the paper, there are other issues which are focused on below. The companies seem to be reacting to cost, based on the day's agenda. For example, increasing fuel prices may force them to re-evaluate logistics and transportation. When the fuel prices go down, their priority yoyos back to the importance of service over cost.

Customers increasingly demand electronics companies to produce highly customized-to-order products rapidly and at a low cost. As a result, there is a tremendous amount of pressure on electronics companies today to create responsive and cost-effective supply chains. Many companies have turned to postponement strategies: creating finished products by configuring subassemblies after receipt of an order [28]. The need to have a competitive supply chain is particularly critical in the semiconductor industry, due to the large capital investment and the high value of end products [1] which have a short market life-span because of rapid changes in technology [31].

The electronics industry is a material constrained industry. New products are constantly being introduced and older products are re-designed to use components with enhanced functionality. All of this occurs in an environment in which consumer demand is extremely difficult to predict. To succeed in this marketplace, manufacturers must work in collaboration with suppliers to fulfill demand, similar to how they need to work with retailers to predict demand. With 'time-to-market' being the cornerstone of success, manufacturers that use collaborative planning techniques are the ones best equipped to succeed [28].

Lead Time

To improve customer service, semiconductor enterprises aim at reducing their lead times by keeping strategic products in inventory. These products are either determined by forecasts or by business agreements with strategic customers, specified as intents before placement of the firm order [30].

The emergence of fabless manufacturing made the supply chain model complex because a product underwent manufacturing in multiple companies across the globe. This model came with longer lead times and lead time variability. The industry also saw product proliferation occur, resulting in a large product mix. In addition, the product life cycle was getting increasingly shorter, and the pressure to introduce new products to the market every four to six months was getting higher [29]. Lead time was being improved by allocating their capacities towards their key customers and focusing their production on high margin, high volume products from a previous node rather than on a newer underdeveloped node.

Management of Inventory & Forecasting

The semiconductor supply chain has a vertical disintegration feature, and each member of supply chain chases for different goals which leads to the inefficiency of supply chain performance and the difficulty in monitoring it. Facing fierce competition along with the need to upgrade the service levels and improve the performance of the whole supply chain, it is necessary for all members to share their inventory information and synchronize their operations [32].

Forecasting highly uncertain demand signals is an important component for successfully managing inventory in semiconductor supply chains. There are many reasons for the existence of erroneous forecasts in semiconductor SCM, among these are inaccurate market research, customer order changes, use of outdated information and misreading product and business cycles. While eliminating all sources of demand forecast error is impossible, it is possible to mitigate some of its detrimental effects.

Semiconductor and component manufacturers are constantly introducing enhanced functionality at lower price points. Not surprisingly, product manufacturers feel obliged to integrate these new components into products to maintain or gain a competitive advantage. At the same time, product manufacturers have to use the existing inventory as soon as possible to maintain margins. While the cyclical nature of the semiconductor industry presents significant challenges in aligning capacity with demand and maximizing return on investment, it can provide considerable benefits. It has been estimated that a ten-day reduction in inventory is equivalent to a 1% increase in profit [28]. Another way the semiconductor industry would legally protect themselves was to make the customer buy 90% of their forecasted product during economic downturns according to the contract.

Capacity

For each customer order in the ranked list, the factory capacity and the wafer lots are first checked for availability to satisfy the order requirement. If both the capacity and the wafer lots are sufficient for the requirement, the order will then be allocated and assigned with the capacity and the wafer lots respectively before it is released into the factory. The actual size of a released order will always be greater than or equal to that of the actual customer order size due to the lot-to order matching policies [33].

Globalization & Outsourcing

The globalization of markets is forcing the producers to look for ways to improve their competitive positions through focusing on supply chain management. The semiconductor companies portray a restructure of their business strategy by saying they are focusing on their core competencies and product development along with research and development while outsourcing their manufacturing, production and logistics.

A fabless semiconductor company owns the intellectual property (IP) of a chip design, but outsources the manufacturing of its chips to another company. The number of manufacturing processes contracted out to other companies varies from company to company. This is a dynamic environment, and more and more integrated device manufacturers (IDMs), such as Intel, Texas Instruments (TI), Siemens, Samsung and others, are outsourcing some of their manufacturing to contract manufacturers. A fabless company can also outsource all its back-end processes, including assembly/packaging, testing, scan and pack, and drop shipping of product to customers [29].

Nowadays with globalization, global supply chain management is becoming a very important issue for most businesses. The main reasons of this trend are procurement cost reduction, purchasing risks control, revenues increasing, etc. For instance, companies may set up overseas factories to benefit from tariff and trade concessions, deregulation of international trade, lower labor cost, capital subsidies, and reduced logistics costs in foreign markets. Moreover, easy access to abroad markets and close proximity to customers result in better organizational learning. On the other hand, improved reliability can be obtained as a consequence of closer relationship with suppliers. There are some issues that should be considered in managing a global supply chain. First of all, the company should decide about its general outsourcing plan. For whatever reason, businesses may prefer to keep some aspects of the supply chain nearer to home.

The second issue that must be incorporated into a global supply chain management strategy is supplier selection. It can be very difficult to comparing bids from a range of global suppliers. Companies usually jump on the lowest price instead of taking time to consider all of the other elements such as value and quality of the product. On the other hand, selecting the right suppliers is influenced by a variety of factors, thus there will be additional complexity in supplier selection due to the multi-criteria nature of this decision. Additionally, companies must make decisions about the number of suppliers to use. Fewer supplies may result in reduced inventory costs, volume consolidation and quantity discounts, reduced logistical costs, coordinated replenishment, improved buyer–supplier product design relationship, thus better customer service and market penetration. However, small number of suppliers could lead to potential problems if one vendor is unable to deliver as expected, especially in a global sourcing strategy. Finally, companies who prefer to ship their manufacturing overseas may face some additional concerns. Questions about the number of plants as well as their locations can pose complex logistical problems [34].

One of the most significant strategies embraced by the electronics industry is the outsourcing of manufacturing and logistics. The motivation for outsourcing is driven by several factors such as increased speed, flexibility, agility and focus. When achieved, reduced time-to-market is the result, which is always a key competitive weapon. Outsourcing also enables OEMs to increasingly focus on the design and marketing of new products, leaving delivery to the contract manufacturer. In addition, outsourcing provides greater operating and financial flexibility, leading to higher ROIC. This type of "virtual supply chain" has helped companies like Cicso, Hewlett Packard and 3Com gain a significant competitive advantage.

Another reason manufacturing would be outsourced is during an economic downturn when the 50/50 rule is followed where 50 % of the production is rerouted to external fabs and 50% to its internal fabs whereas during an economic boom the production is re routed back to an internal fab to meet customer demands in a timely manner.

The availability of sophisticated information systems that allow OEMs to be electronically linked with their providers has been a key enabler of the outsourcing model. In some cases, these electronic links can provide an OEM with detailed operational information from the contractor's factory, just as if the OEM owned it [28].

Chapter V

CONCLUSION & RECOMMENDATIONS

In this paper I have analyzed the relationship between the chip manufacturer and the equipment supplier and the issues that this industry faces to obtain collaboration from its supply chain partners through archive literature.

SCM is even more important to the semiconductor industry due to the large capital investments and high value of end products, which have short market life span because of rapid changes in technology.

Equipment suppliers have to constantly manufacture equipment built on new wafer blueprints and standards, catering to the new generation of wafer fabs which is 70-80% of the cost of the wafer manufacturing process. The equipment suppliers had not recuperated their investment from the previous transitions and were hesitant to move forward with the 450 mm transition. It is the inability of the equipment suppliers to recuperate their investment that has motivated this research to analyze the strained relationship between the chip manufacturer and the equipment suppliers resulting in a strain on the semiconductor supply chain disrupting the smooth implementation of future transitions. I proposed collaboration through profit sharing in the supply chain as a solution in this thesis.

As companies engage in collaborative supply chain planning activities, the results are decreased lead times, lower inventory levels, and improved responsiveness due to the increased visibility this phenomenon creates. Continuous replenishment, proper forecasting, and inventory management can only be achieved through improving visibility in the supply chain from manufacturer to customer.

Supply chain excellence can decrease inventory and cycle times while significantly increasing on-time deliveries and inventory turns. Taken together, these results can provide companies with greater profits, improved customer service and that ever elusive competitive advantage. But it takes the right vision, the right strategy and above all, the right software tools for theory to become reality.

I have also discussed how the equipment manufacturers and the chips manufacturers collaborate and interact with each other to offer the best product for their customer (improving customer service) and the decisions they make to add value to the SCM process.

As the semiconductor industry are on the verge of a new transition to 450 mm pushed by Intel, I have shown my research on lessons learnt from previous transitions which helped understand the pitfalls of the past transitions and how the semiconductor industries can avoid them to make efficient decisions for the future. Factors such as R&D, transition cost, equipment cost, standardization, material usage, reduced lead times, increased inventory turns, reduced operational costs and improving customer satisfaction with on-time delivery which are the most critical factors identified in a 450 mm transition were described in this thesis.

The lesson learned in this paper is that win-win collaborations among equipment suppliers, automation suppliers, and wafer manufacturers are crucial for a smooth and successful transition. A thorough analysis in profit sharing which is suggested as an additional solution between the equipment manufacturers and chip manufacturer would be of interest for future research after reading this thesis.

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VITA

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