11

STATUS AND FUTURE OF MICROSYSTEMS / MEMS FOUNDRIES

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Executive Summary

The focus of the foundry chapter is to provide assistance to microsystems foundries and their users. We aim to assist designers in finding appropriate "Fabs" early in their device development phase, help foundries understand the direction of technology, and provide trends in fab construction and conversion. For example, it is comparatively easy for the MEMS designers to find prototypical foundry services. But, there remain prerequisites to finding a reliable path from product concept to commercializable volume.

The contributors to this chapter recognize that the cost involved in changing fabs or processes (see MEMS/MST Cost Modeling chapter), in both time and money, is enormous. The challenge for MEMS manufacturing lies in cost-effective fabrication facilities that can embrace

both large and small volumes. MEMS is still an emerging and disruptive process technology with many application specific technology choices. However, as discussed in both the Non-IC and the IC-like processing chapters the trend is toward concentration on fewer but more robust manufacturing. Further, dominant MEMS manufacturing technologies, in many application spaces, are still to be determined. If not the full process, some process steps are becoming more standard. Yet standardization does not exist to any great breadth or depth (Standards chapter). Therefore, MEMS manufacturers must be prepared to deal with multiple substrate materials of various shapes and sizes, as well as supporting multiple process technologies, some of which have little or nothing to do with traditional semiconductor technologies.

Here we also state that the cost of any new MEMS foundry infrastructure is very high and the trend is for that cost to continue to increase. Fortunately, last-generation IC foundries can be used for fabricating present-generation MEMS for IC like process technologies and this has contributed to a larger trend for existing semiconductor fabrication facilities to move to MEMS facilities or dual facilities providing both semiconductor and MEMS based processes for commercial and internal customers. However, as MEMS devices mature, becoming more complex, many contributors foresee more MEMS specific foundries offering unique process capabilities. The contributors to this chapter have discussed the increasing trend toward MEMS only foundries. The roadmap contributors suggest a model similar to the fabled semiconductor concept. Two scenarios will potentially evolve, (1) independent design/development companies will act as liaisons between the MEMS end users and the foundries, and/or (2) foundries will offer integrated product development services by providing turnkey design/development capability as part of the front-end process support, pushing the industry closer to its standards. In the Design Simulation and Modeling (DSM) chapter, contributors provide a short discussion on methods that current foundries and MEMS DSM suppliers are using and suggest future trends.

The contributors to the Foundry chapter also have recognized a number of trends. First, there has been an explosion of MEMS based foundry service providers in the last 5 to 7 years. Fewer than 10 foundries for MEMS device manufacture existed less than a decade ago. Now, some of our contributors suggest that there are over 80 foundries offering MEMS services currently in operation. Second, semiconductor fabrication facilities are currently fueling this growth. Further, the conversion of semiconductor to MEMS foundries will continue in the short term.

Moreover, there are a small and growing number of MEMS only foundries being developed and they will become the mainstay of MEMS foundry construction five to ten years from now. Finally, there is a large trend to embrace some sort of quality standards. This is a natural outgrowth, in that there is a rush to embrace quality standards for MEMS manufacturing facilities. A large percentage of exiting foundries already having some sort of ISO 900X certification or are in the certification process.

In the early days of MST, the foundry concept came up as a way to lower the barriers of bringing a design to market. This is still a viable concept. The market is dynamic, as can be expected in this fast growing segment, and there are forces pulling foundries into the captive market; i.e., the success of their own products or the "IP Hunger" of larger companies. However, now interesting commercial opportunities are bringing new players into the field. The number of foundries is growing, especially in the Far East.

There are 5 categories of foundries:

1) University originated, mostly research oriented and/or SME
2) Smaller semiconductor companies offering MST service for balancing the capacity
3) Larger semiconductor companies offering MST to protect the customer base
4) Smaller non-semiconductor companies offering MST service for balancing the capacity
5) Pure foundries

In particular it is categories 2 and 3, semiconductor companies, which are growing in number.

There are other signs of maturation of this industry. There is now much more attention to quality and production professionalism compared to the early days of MST. The foundries are also concentrating more on smaller areas of technology and marketing. This focus will deepen and improve the technology base of the foundries. This trend is supported by the rising attention of the larger equipment suppliers to the needs of the MEMS market.

1.0 Introduction

Why does the evolution for microsystem-based devices to become products take so long? This is one of the questions often asked of the microsystems community. Previously, an infrastructure model for discontinuous MEMS innovations was outlined (Walsh, 2001). The four stages identified are:

1) In the initial stage, MEMS based technologists utilize existing techniques optimized for microfabrication to produce expensive products of limited utility, while the market channels are not yet existent. Large corporations and government funding agencies must coerce potential suppliers into manufacturing items they need or obtain required products through internal R&D.
2) In the second stage, the industrial manufacturing begins and initial market acceptance is seen. The pilot or limited production of product results in modifications to existing manufacturing equipment. Market channels widen spin-offs from institutes, universities and large companies appear.
3) In the third stage, the techniques are designed to optimize the characteristics of the technologies resulting from the discontinuous innovation. Market channels increase and widen as variations of the same product are applied to the same market and the same product is introduced into different markets. Industry newsletters and dedicated representative organizations appear. The rising demand for MEMS technologies will result in capital equipment suppliers and vendors entering the market. The entry of these suppliers and vendors will allow firms that do not have the capability to produce capital equipment, raw materials, and other consumables to enter the MEMS market.
4) The fourth stage shows the maturation and stabilization of the technologies and the new markets emerging.

This model helps to understand the "How Long" question by demonstrating where it is that the time lag is occurring for each techno-industrial stage of commercialization awaiting on the road to full commercialization. The microsystems industry finds itself challenged across stages two, three, and four of the infrastructure model. (See Commercialization Chapter, Figure 1).

This chapter provides a brief history of today's status of microsystems manufacturers, who act as general suppliers to OEM MEMS foundries. It complements earlier initiatives to describe the development of the MEMS infrastructure (Elders and van Heeren, 1999) by providing an overview of the elements forming the infrastructure; manufacturers and their technologies, products, volume, capacity, performance limits, quality procedures; and markets. Based on this overview, a better understanding of the current status of the new entrants, mergers and acquisitions, and directions within the microsystems industry can be obtained.

The reader should be aware that the terms fab and foundry refer to the facility that actually manufactures the MST/MEMS (or semiconductor) devices. While often used interchangeably, the distinction appears to be one of "Captive" versus "Merchant." A **"**Fab**"** *produces devices for internal use,* whereas a "Foundry" *also produces devices for others* on a contractual basis. Thus a "Fabless Vendor" or "Fabless Business Model" of MST/MEMS devices has no fabrication (production) facility of its own, but procures its product from a separate foundry. This summary uses "Fab" as a generic term meaning "Fabrication Facility." "Foundry" is employed when referring to a fabrication facility doing merchant production (Gulliksen, Gaboriault, and Aylward, 2000).

In this chapter, the results of private research are presented. The research has been executed in part by the Academy of Brabant in the Netherlands and is based on three methodologies, namely, expert interviews, e-mail enquiries and public sources. The manufacturers are compared on different aspects of their business, specifically their background and financial structure; their technologies and technical core competencies; their quality systems; and the market/technology areas they cover. The results are based on the first and second surveying rounds and partial results from an ongoing third round.

2.0 The 1999-2001 Investigations

In the following sections, general industry trends are examined. Public sources information was obtained from which a list of companies was based. In 1999, the list consisted of eight companies that had very small activities, and were characteristic of R&D companies, institutes, or universities. One company was producing only for internal customers. The seventeen companies initially investigated in 1999 are still being tracked today and are being complemented by new additions to the original list. In addition to these companies, new initiatives have been observed, especially in the Far East. The study has been extended to these new companies as well.

2.1 Background of the Companies Studied

From the seventeen foundries and manufacturers in 1999, eleven were based in Europe and six were located in the USA. The most interesting area from a MEMS production point of view seems to be the "Upper Rhine" area (Benelux and Nordhein-Westfalen): four foundries are based in this area. Second, was the East Coast of the USA and the Swiss/French border area. This situation is explained by the presence of leading MEMS institutes in those areas. (Among them are the University of Twente, New Jersey Institute of Technology, and University of Neuchâtel). Noteworthy, was the absence of the Far East in these early days.

The total group could be divided into three parts: A) four university spin-offs, B) seven small-to-medium enterprises (SMEs), and C) six captive or dedicated MEMS foundries, which were part of larger companies (ex-semiconductor or magnetic-head manufacturers). Nearly all SMEs and university spin-offs offered development services. Larger companies focused more on "Pure" production, but would do small batch orders to balance their production line. A typical MEMS foundry in 1999 employed about 50 people and produced about $10 million in revenue (see Figures 6 and 7). University spin-offs and SMEs, in general, lagged behind the rest of the industry in clients, income, staffing, and clean-room space. Also, government funding and government-supported projects were a popular source of funding for the MEMS foundry community in 1999 and continue to be so.

2.2 Technical Capabilities

2.2.1 Manufacturing technologies used

Out of the seventeen foundries, eight offered monolithic integration. Larger companies more often favor the integration of MEMS and ICs on one wafer compared to smaller companies and university spin-offs. Today, as in 1999, bulk micromachining is still the most popular technology (Figure 1), followed by surface micromachining. LIGA can be regarded as a niche technology. Only two of the respondents reported using it. In addition, there are two other companies that offer non-conventional rapid prototyping services for MEMS devices, MEMGen and MicroTec. MEMGen offers product development and contract manufacturing services for micro- and milli-scale devices and components. MEMGen calls their process EFAB, which is a micro-manufacturing technology that uses a layered micro printing technique that can produce small-scale 3D structures in metals on metallic or dielectric substrates. EFAB offers micro-stereolithography that's different from that offered by MicroTEC **("EFAB's** micro-stereolithography is generally limited to photopolymer materials**)**. Both MEMGen and MicroTec claim to have ways to work around some of the limitations these prototyping services offer. These techniques may be an excellent way to prototype a first-generation device.

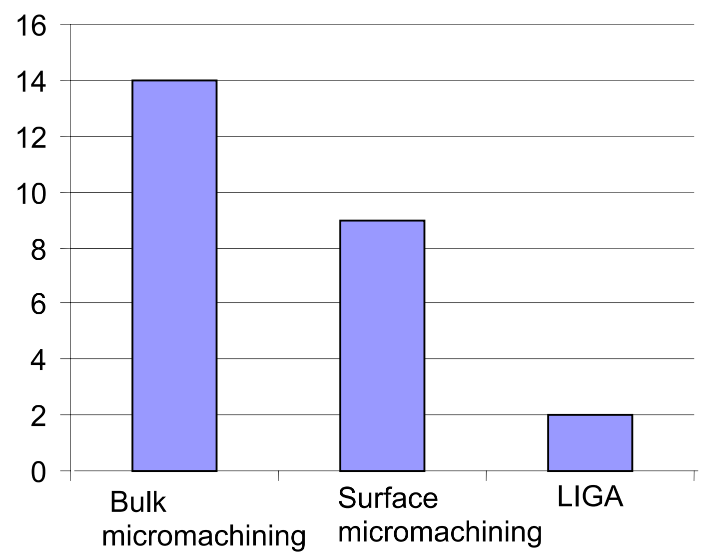

Figure 1. Manufacturing Methods.

Anodic bonding is more often offered than fusion or eutectic bonding. As for feature sizes, larger companies are more conservative in the estimation of minimum feature sizes (Figure 2). There was no relation between the type of equipment used (stepper or contact aligner) and the minimum feature size. Steppers are more often used by larger companies, and not as often by companies also offering development.

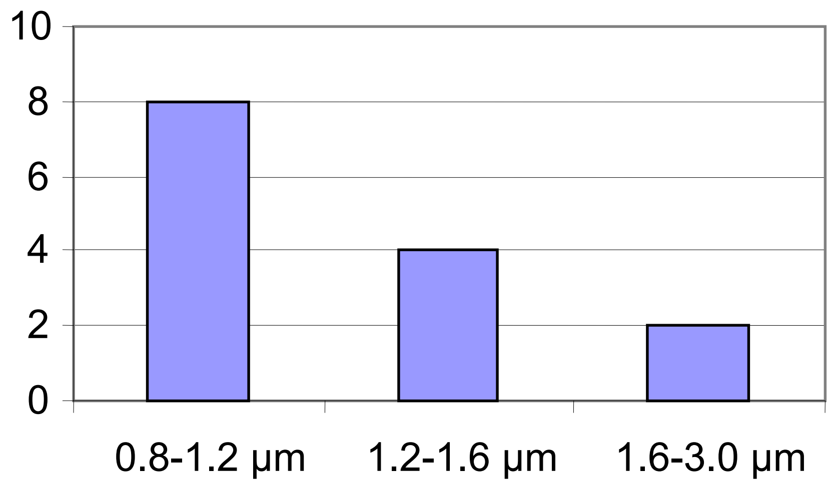

Figure 2. Feature Sizes.

2.2.2 Substrate size

Although the majority of foundries are producing on 4-in. wafers, there are indications of a shift to 6-in. wafers. There are two reasons for some of this shift. First, most MEMS fabs are older semiconductor fabs that are extending their useful life by converting or expanding into MEMS. Second, new MEMS fabs are being built with 6-in. equipment because of the low cost and availability used 6-in. processing equipment. Large-volume production MEMS devices are, in general, being produced on 6-in. wafers, and smaller-volume production MEMS continue to be made on 4-in. wafers.

2.2.3 Back-end processes

Nearly all respondents reported activity in back-end processing, although most of it is either small-scale assembly or high-volume, IC-compatible packaging.

2.3 Quality Systems

No factory can act as a reliable producer without proper quality systems. ISO 9000 is regarded as the bare minimum. However, five foundries reported not being ISO 9000 (or equivalent) qualified or nearly qualified. Elementary control systems like statistical process control and lot tracking are used by eight of the respondents. In this research, only five foundries and manufacturers could be regarded as fully quality oriented by addressing issues such as cycle time, recipe management, etc. (Figure 3). Generally speaking, large companies have better quality management and systems in place.

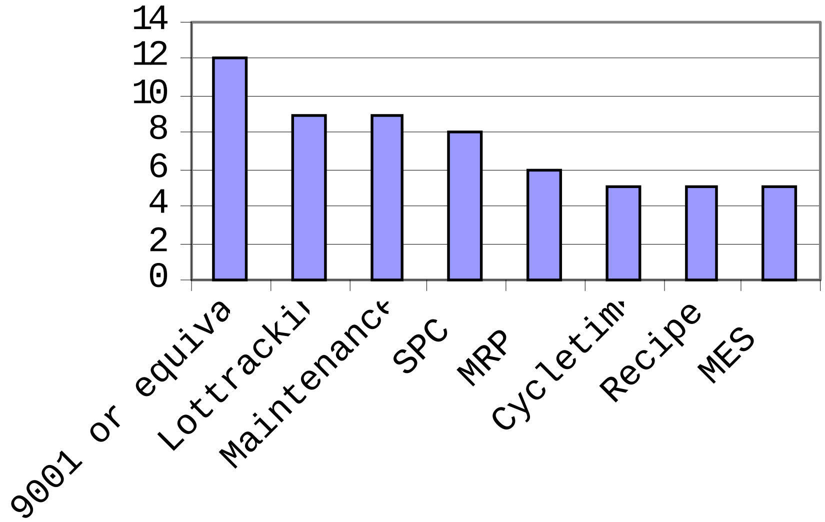

Figure 3. Quality Systems.

2.4 Application Areas and Products

Most of the companies were offering a diverse range of products (Figure 4). It was not clear from the responses how many of those products are in a mature state.

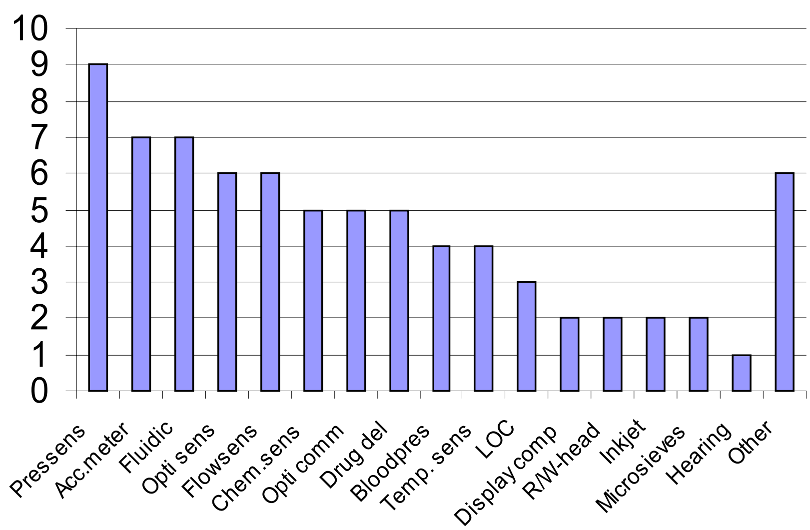

Figure 2. Products Offered.

Pressure sensors, accelerometers and fluidic products are the most popular products, followed by flow sensors and optical communication products, drug-delivery systems, optical communication and sensors. Hearing aids, read/write heads, ink-jet printheads, microsieves and display components are more specialized subjects. In general, the number of products offered is higher then the number of clients.

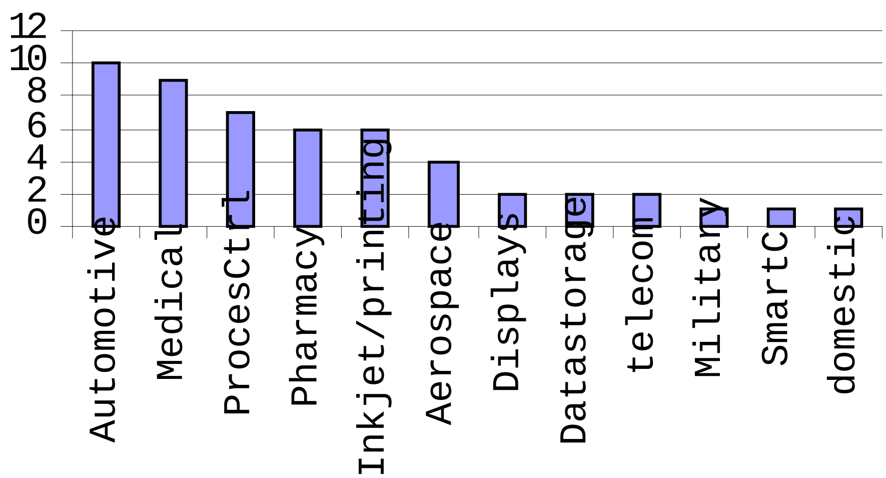

Figure 5. Market Segments.

Automotive and medical seems to be the most attractive market areas, followed by process control, pharmacy, and ink-jet printheads. Domestic applications, smart cards, and the military are segments dominated by specialists (Figure 5).

3.0   General Status: 2000 Versus 1999

The most remarkable change in 2000 was the increase in both small and large foundries. Two indicators supported this conclusion: the number of people per foundry involved in MST (Figure 6) and the turnover (Figure 7).

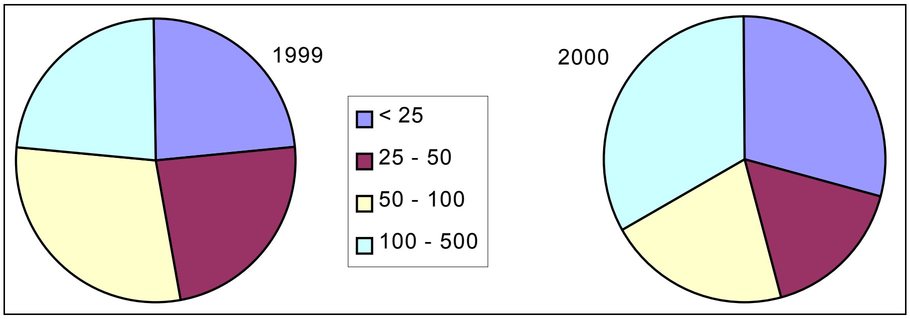

Figure 6. MST Personnel per Foundry.

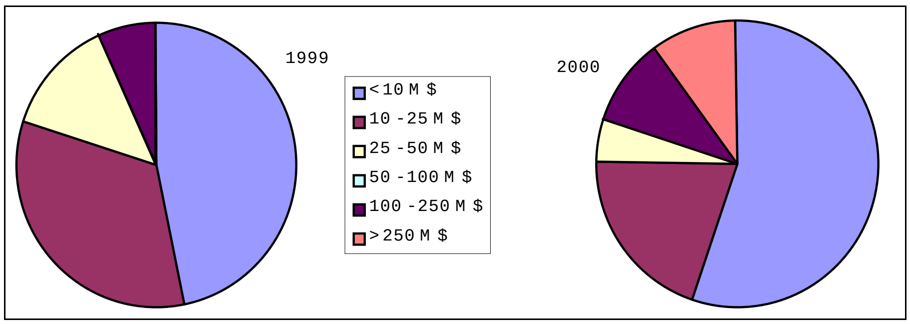

Figure 7. Monetary Turnover per Foundry

Also the increasing capability to use 6-in. substrates (Figure 8) indicated growth, although according to information received from silicon vendors, 6 in. was not yet the dominant wafer size in MST in 1999. There was also a trend to smaller feature sizes noted (Figure 9). Interestingly, this trend was not supported by an increasing use of steppers, as expected.

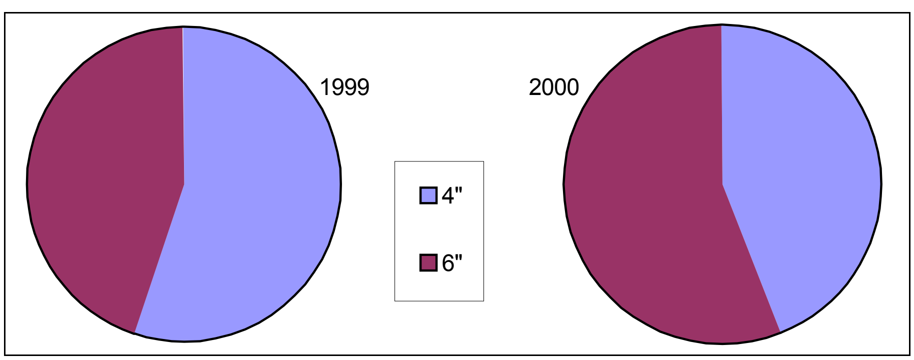

Figure 8. Increasing Foundry Wafer Size.

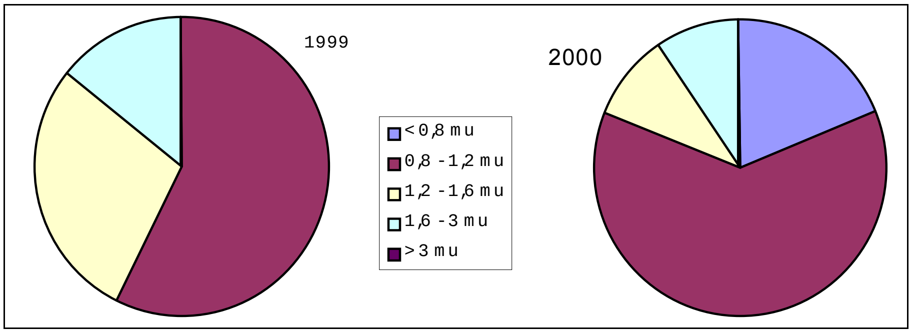

Figure 9. Minimal Feature Sizes.

Financial markets responded to the increasing opportunity for MST products by investing in foundries, as seen in several press releases last year. This is consistent with the decreasing role of the government as a source of funds for the MST community (Figure 10).

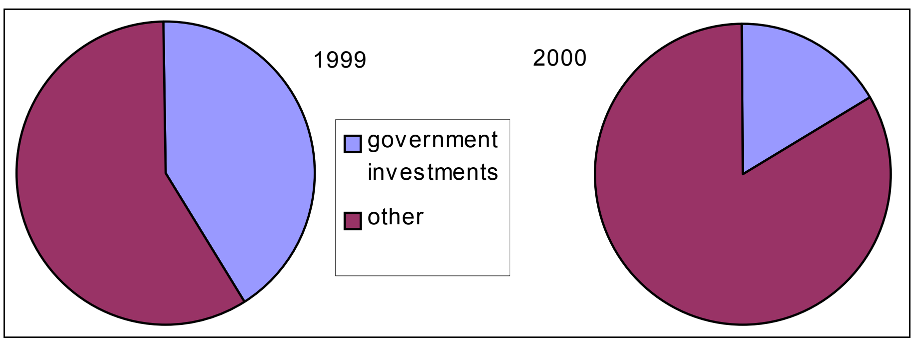

Figure 10. Funding Sources.

There is still not much indication that the foundries are focusing on certain technologies or market areas. They are offering a wide range of technologies and products. This dedication to market demand is also seen in the increasing number of foundries offering products for the telecom industry. In 1999, telecom was a much smaller market area, while in 2000 it was one of the largest. (It should be noted that the biochemical arena was not in the first survey.)

4.0 Trends in 2001

Several trends have been observed after reviewing the responses from participants and monitoring the industry. One of the most important trends affecting the industry is a rapid increase in the number of foundries (Table 1). This is not a comprehensive list but does provide many of the current and historical commercial foundries. As seen in Figure 11, the largest increase in foundries has occurred in the Far-East, especially in Taiwan and Korea. In Korea, for example, Microwise (www.microwise.co.kr) started operations in June, 2000 as a Daewoo spin-off, applying their expertise in the field of micro-actuators for DDDs, accelerometers, micromirrors, and sensors. Microwise will open its high-volume fab in 2003. In another example, Taiwan's Walsin Lihwa (www.walsin.com.tw) entered the MEMS market after first entering the IC, passive components, and display production markets. Walsin Lihwa hopes to transfer its expertise from the IC foundry market to the MEMS area. Their main focus will be on actuators, optical components and RF components. They plan to start building a MEMS facility before the end of 2002.

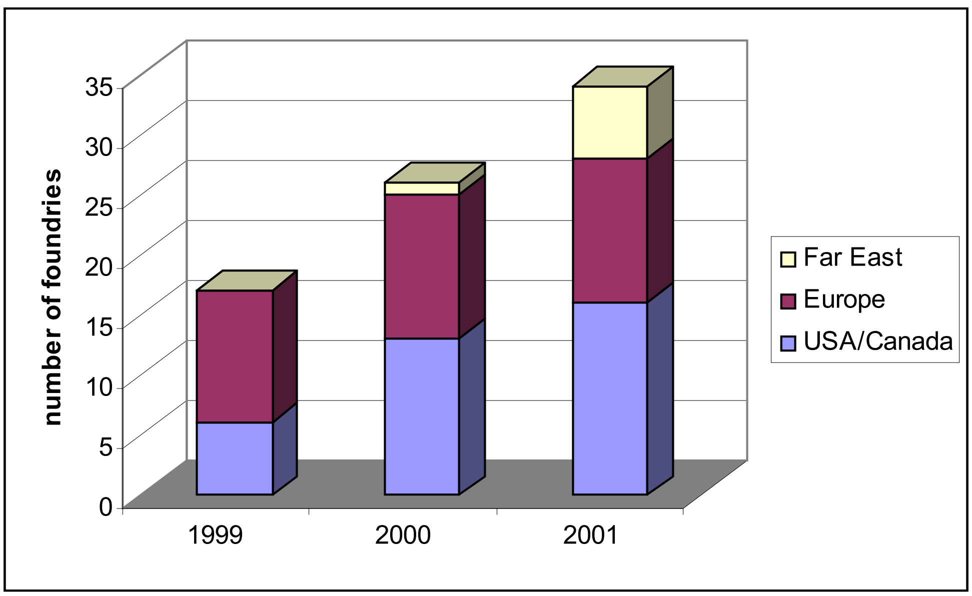

Figure 11. Geographical Distribution of Selected Foundries.

Another remarkable and important trend has been the number of semiconductor fabs turning to MEMS production to offset the current slowing of semiconductor orders. There may be as many as 30 fabs having recently dabbled in MEMS production to offset idle capacity in their operations. Some of our contributors suggest as many as 80 current microsystems foundries. We provide data on a subset of these here. The cost modeling and IC-like and non-IC-like manufacturing chapters also provide some foundry insights.

Table 1. List of Selected Foundries

MST/MEMS selected foundry list		
1999—17 Foundries	**2000—26 Foundries**	**2001 – 35 Foundries**
Analog Devices	ACSI	ACSI
CIS	ACT Micro Devices	Advanced Microsensors
Cronos	Advanced Microsensors	Analog Devices IMEMS
CSEM	Analog Devices IMEMS	APM
HL-Planar	BCO Technologies	Applied MEMS
Intellisense	BF Goodrich Advanced Micro Machines	BCO (part of Analog Devices)
ISSYS	Blu-Si	BFGoodrich Advanced Micro Machines
Melexis X-fab	CIS	Blu-Si
Microfab Bremen	Cronos (now part of JDS-Uniphase)	Colibrys (ex-CSEM)
Microparts	CSEM	Corning Intellisense (ex-Intellisense)
OnStream	HL-Planar	Haleos (ex-ACT Microdevices)
PHS	IMT	HL-Planar
Robert Bosch	Intellisense	IMT
Sensonor	Issys Inc	ISSYS
		JDS Uniphase Cronos
Sentir	Melexis, X-fab	Mems Inc.
		MEMScap
Standard Mems	Memsoptical	MEMS optical
Tronic's	Metrodyne Microsystem Corp	Merit Sensor Systems (Sentir)
	Microfab	Micralyne
	OnStream	Microfab
	PHS	Microsense
	Robert Bosch	Microwise
	Sensonor	OnStream MST
	Sentir	PHS MEMS
	Standard MEMS	Robert Bosch
	Steag microparts (ex microparts)	Sensfab
	Tronics	Sensonor
		Sony - San Antonio
		Standard MEMS
		Steag microparts
		ST Microelctronics
		Tronics
		TSM Tech
		Walsin Lihwa
		Fairchild

Since Table 1 was created**,** many more companies have announced the expansion or conversion of their fabs into MEMS foundries or foundry services. Since these companies were not included in the surveys, we will list them separately: Honeywell MEMSplus in Redmond, WA.; Clare, in the Boston area; Olympus Optical Co. in Tatsuno, Japan; Chinese Academy of Science, Microsystems Center, Peoples Republic of China, Kionix, Inc., of Ithaca, NY; Dalsa Semiconductor Company in Quebec, Canada and Fairchild in Portland, Maine. There also have been some subtractions when Standard MEMS unexpectedly shut down operations at their California fab purchased less than a year before from Xicor. It just might be advisable to ask a few financial questions before giving too much development money to a new enterprise because as in any dynamic industry**,** there will be winners and losers.

Merger and acquisition activities have changed the landscape dramatically (Table 2), supporting a long-term trend to buy rather than make or develop the knowledge/capital necessary to generate products. Most of the large companies entering the MEMS market tend to enter by purchasing companies and their resident knowledge/capital, instead of trying to invent the MST wheel themselves. Recent examples include: Alcatel buying Kymata/TMP, JDS Uniphase buying Cronos, Corning buying Intellisense and Intel Capital investing in Coventor, Colibrys, etc. This trend exists largely because of the long time it takes to mature MST/MEMS technology. In turn, the time to get a return on investment is also long. Waiting a decade or more for profits is not unheard of in the industry. It is not surprising that the bulk of MST investments went to development companies generating IP, which can be sold much faster than the products.

Table 2. Foundry Mergers and Investments

Foundry	Investment	Amount	Date
Cronos	**Expansion fab**	?	Nov 1999
JDS Uniphase	Acquires Cronos	750 M US$ in stock	April 2000
Tronic	Finance growth	5 M FF	May 2000
Analog	Acquires BCO	150 M US$	July 2000
Corning	Acquires Intellisense	500 M US$ in stock	Aug 2000
AMS	Financing growth	8 M US$	Oct 2000
Haleos	Opening new facility	?	March 2001
OnStream MST	Expansion of foundry activities	?	April 2001

PHS MEMS	Funding growth	31 M Euro	May 2001
HL-Planar	6-in. fab	14 M US$	mid 2001
MEMS optical	Infrastructure	18 M$	July 2001
Colibrys	Start up	12 M US$	July 2001
Tronic	6-in. fab	10.5 M Euro	2001
Microwise	New fab	?	2002
Walsin Lihwa	New fab	50 M US$	2002
AMP	Start up	50 M US$	2002
TSM tech	6-in. fab	12 M US$	2002

From Table 3, one can also discern another trend. In 2000, the major focus was on mergers and acquisitions among industry players. However, in 2001, investments expanded infrastructure and capacity. As captured in the table, the shift to larger wafer sizes supports this conclusion. The increase in capacity can also be seen from the estimation of wafer usage in 2000/2001, whose total usage in 2001 is estimated at 500,000 4-in. equivalents. Also very important to note is that the investments per foundry are increasing, though this is not indicated in Table 3. Behind this capacity expansion, large equipment companies, such as Applied Materials and ASML, are entering the MEMS equipment market, offering adapted versions of their older type of equipments via specialized business units.

Table 3. Size of Wafers

Wafer size (in.)	% of total	Increase in %
8	10	5
6	48	22
4	30	8
Other	12	Unknown

5.0 Foundry Model, Still Viable?

Since the earliest days of the MST industry, design houses cooperated with foundries to supply OEMs with MST-based solutions (Figure 12). However, recent research begs the question of whether this business model is still an option now that the number of production facilities has increased.

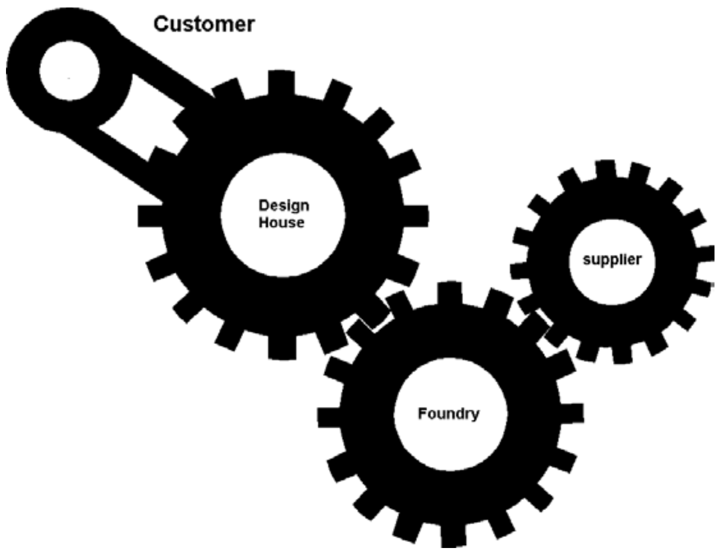

Figure 12. Design House Foundry Supply Chain.

To date, the industry has seen six categories of MST manufacturers (both fab and foundry) emerge, namely:

1) University originated, mostly research oriented and/or SME
2) Smaller semiconductor company, offering MST service for balancing the capacity
3) Larger semiconductor company, offering MST to protect their customer base
4) Smaller non-semiconductor company, offering MST service for balancing the capacity
5) Pure foundries
6) Captive suppliers only

Because the entry barriers for microsystems foundries are very high and the payoff period longer than in other business areas, practically all of the foundries have been started with help from larger organizations or from organizations that have altered their original (IC) activity to MST. Two important forces motivate these organizations to enter the MST foundry market:

1) Available overcapacity (Figure 13, lower left hand corner) and
2) Technology or product ideas (Figure 13, upper left hand corner)

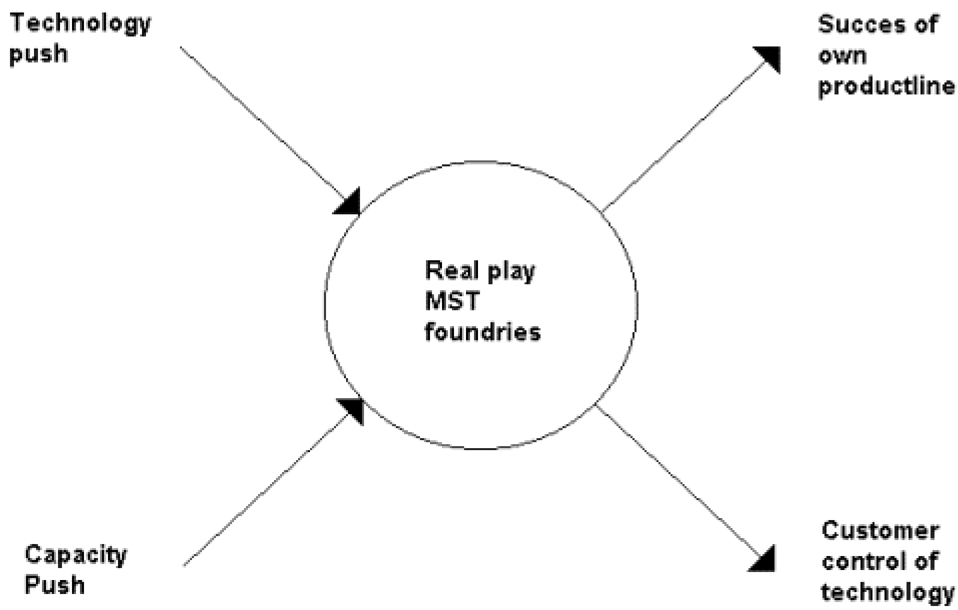

Figure 13. Dynamics Impacting Foundry Market Planning.

The first force is important for companies operating in the periphery of the semi conductor or data-storage industry. With respect to reliability of supply and quality, the background of companies such as these affords them a stronger position, vis-à-vis smaller firms. The other force of ideas applies to departments of universities specializing in MST, whose strength lies in the ability to grasp the possibilities of microsystems solutions. Because many ideas required proof-of-concept or prototyping, the making of samples and trial runs had to be done at the universities or institutes, who had the time, capacity, skills, and lower cost to handle the job. From here it was only a small step to the offering of foundry services. Those services were often more based on product concept than on fixed and proven technologies.

Last year saw a milestone in microsystems technology development. For the first time, we saw a market enabling foundries to industrialize. How is this a milestone? Some companies experienced being pulled from the foundry market. On one hand, companies needing a specific, strategically-important technology will be tempted to buy a foundry mastering the technology, thereby gaining control of the supply chain, as well as the Intellectual Property behind the technology (Figure 13, lower right hand corner). On the other hand, another force pulling foundries out of the market can be the success of their own products in the marketplace (Figure 13, upper right hand corner). As most of the foundries are bringing products of their own onto the market, success of those products could influence the strategy of the company with regard to its foundry business. Therefore, the question "Is the foundry design house model still valid?" needs to be answered. Everyone is balancing strategic commitment to the core market with the economics of scale in production. However, economics will always dictate the ultimate strategy. No single MST product on its own can sustain a real fab. Combining products in one fab is a must.

As the processes can be divided into generic groups, there is no technological barrier to combining several products into one fab. Therefore, the combinations of the design house (concentrating on a certain market area) and the foundry (concentrating on a core technology platform) are able to fill a distinct and large part of the MST market.

6.0 Foundry Market Needs

MEMS production requires a variety of manufacturing technologies capable of manufacturing a variety of products in a variety of volumes at the lowest cost with the highest quality. Customers are looking for suppliers able to provide best-of-breed processes. At this stage of the technology life cycle, a foundry's challenge lies in the cost-effective manufacturing of small volumes (less than 100,000 pieces per year), as well as high volumes (1,000,000 plus pieces a year), while retaining high quality and yield, which in turn lowers cost. This is a truly difficult challenge to accomplish consistently.

There is also a need for a reliable back-end process, production facilities, production technologies, and employee skills able to handle the (mostly) fragile and sensitive MEMS subassemblies. When the product is built in a complete system, it will react differently from a system based on conventional subassemblies. Therefore, expertise in front-end processing is not enough. Understanding and experience of back-end processing are essential to be a full service foundry.

7.0 Conclusions

Most elements from the four stages of commercialization mentioned in the introduction and detailed in the Commercialization chapter can be recognized when examining the history of the foundry community described above. This market segment seems ready to enter its fourth stage. A complete manufacturing infrastructure is becoming available.

The basic requirements for new industries like MEMS are good product ideas with market potential, venture capital and infrastructure. According to numerous publications, good product ideas with interesting market potential are present. Although the economy of the Western world was booming, much of the venture capital went into the "ICT What Business?" So not unsurprisingly, "Pure" technology like MEMS needed government funding. Regarding infrastructure, in the first stage, the most important elements were well-educated people and availability of basic technologies. Therefore, in the beginning, the most successful MEMS areas were in the vicinity of the leading MEMS universities/institutes.

The niche position of LIGA and the popularity of bulk micromachining can be explained by the infrastructure cost. Similarly, the initial unpopularity of integrated technology is explained realizing the cost of maintaining the CMOS technology. Now more funding is becoming available for the MEMS industry. The availability of integrated technology is growing. The weakest point for the MEMS foundry community as a whole was quality. The influx of large companies forced the older ones to give more attention to this.

MEMS assembly is still in its infancy. There are limited signals of maturation there yet. Although the MST foundry industry molded itself on the successful IC foundry industry, there are remarkable differences. The MST foundry has to cope with a much more diverse technology demand from the customers. This will lead to a higher number of technologies to sustain and a smaller series. Therefore, it will be difficult to reach the quality and economy of scale achieved by the IC industry. Due to the disruptive nature of the MST products, market acceptance and system development time will take more time.

However, the MST foundry industry is growing in capacity and also the first signs of maturation are visible: fewer clients per foundry, increasing use of quality systems and relatively less government support. Also, the appearance on the market of established high-volume electronics suppliers like Sony and ST Microelectronics are signals of a changing marketplace.

It has to be seen if the forces supporting the foundry market, economy of scale and cross-fertilization, will be stronger then the forces minimizing the role of the foundries in the MST market, control of technologies by the MST system supplier and success of their own products.

8.0 References

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