



Semiconductor manufacturing strategy: Where in the world to locate a fab or cleanroom?

Stephen M. Rothrock, Founder, President & CEO, ATREG, Inc.

Presented at IMAPS' 52nd International Symposium on Microelectronics
October 2019

Abstract

The global market for advanced technology manufacturing assets is becoming ever tighter, compelling semiconductor companies, including OSATs (outsourced semiconductor assembly and test), IDMs (integrated device manufacturers), and foundries, to carefully explore all available options when planning manufacturing operations relating to fabs, tools, and cleanrooms. Despite the semiconductor industry's optimistic growth forecasts, global uncertainty generated by the continuing trade wars between the U.S. and China is causing anxiety among advanced technology companies and forcing them to constantly rethink their manufacturing strategies – buy vs. build, best fab location, risk mitigation, local incentives, etc. In 2018, semiconductor companies showed increased renewed interest in U.S.-based manufacturing in the midst of a continued lack of 200mm and 300mm capacity. As we have seen with the recent sale of Texas Instrument's 150mm / 200mm facility in Greenock, UK to Diodes Incorporated and Vanguard International Semiconductor Corporation's acquisition of GLOBALFOUNDRIES' 200mm Fab E3 in Tampines, Singapore, 200mm fabs are still in very high demand and manufacturers are becoming increasingly proactive as they look to expand capacity.

In 2019, infrastructure-rich cleanroom manufacturing assets are going to continue to play an essential part in shaping these strategies to ensure global competitive advantage as more wafers are needed and more facilities are being built worldwide, particularly in China. Despite a slowdown in semiconductor mergers and acquisitions activity, the global semiconductor market will continue to consolidate as the manufacturing needs of advanced technology companies evolve with market changes. This has put a strain on manufacturing space and resulted in a number of new capital projects and expansions that may become difficult to fulfill in the current market. A shortage of existing manufacturing space means cleanrooms and operational fabs will sell at a premium. Many companies are also looking at greenfield sites with local government incentives playing an active role. Running in tandem, there is still a shortage of used and new production tools with lead times in excess of one year to purchase new fabs from OEMs (original equipment manufacturers) or equip new fabs.

Drawing on some 20 years of infrastructure-rich manufacturing asset dispositions and acquisitions as well as a series of real-world fab transaction case studies, ATREG Founder, President and CEO Stephen M. Rothrock will provide insights into how to best approach manufacturing strategy decisions in the context of today's global semiconductor landscape.

I. Introduction

After strong growth in 2017 and early 2018, global economic activity slowed notably in the second half of last year, reflecting a confluence of factors affecting major economies. As is always the case, when the global economy sneezes, the chip industry catches a cold. What started as a tightening of financial conditions in emerging markets in the spring of 2018 progressed to the advanced economies by the end of the year. China's growth declined following a combination of internal regulatory tightening, an increase in trade tensions with the U.S., as well as the blacklisting of several Chinese firms, led by Huawei, by the U.S. with an associated ban on component suppliers ricocheting throughout the industry. In Europe, the Euro area fell victim to weakening consumer and business confidence and the UK continues to battle with its Brexit unknowns and uncertainties, adding a further negative strain on both its economy and the European Union's. In this rather chaotic global context, the market for infrastructure-rich manufacturing assets has remained very tight, making it very difficult for advanced technology companies to plan their manufacturing strategies. In 2018, companies showed renewed interest in U.S.-based advanced technology manufacturing in the midst of a continued lack of 200mm and 300mm capacity. In 2019, 200mm fabs are still in very high demand and semiconductor companies are becoming increasingly proactive as they look to expand capacity.

II. Global Fab Overview

Fab capacity has been running on empty now for several years. Utilization rates are high and supply remains tight, especially on 200mm where demand seems insatiable. The lack of 200mm capacity and 200mm used tools is driving renewed interest in operational 200mm fabs. Values of 200mm tools and operational 200mm fabs are spiking as a result of market constraints. After years of under-investment caused by low selling prices and poor investment returns, wafer substrate supply remains in tight with most major suppliers sold out under long-term supply agreements, especially at the leading market edge. 2018 saw a sizeable increase in fab equipment spending, but this needs to be put into perspective of several previous years of underspending. With advanced fab supply now concentrated in just a handful of manufacturers, managing supply and demand has become both easier and a way of life. The cavalier wild-west fab over-investment days are gone – advanced fabs are now built against committed demand, not speculation. Plunging memory prices and a sudden shift in companies' strategies in response to trade tensions are driving rapid drops in capital expenditures, especially among leading-edge

memory manufacturers, some fabs in China, and some mature node projects.

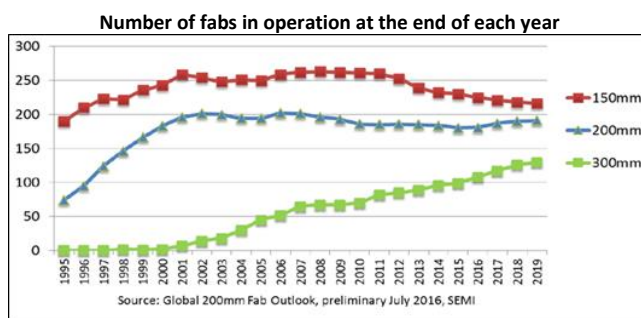
In 2018, mergers and acquisitions (M&A) and semiconductor industry consolidation activity did continue although an increasing number of deals were blocked due to regulatory reviews by governments in Europe, China, and the U.S. (e.g. Qualcomm / NXP deal):

- 76 transactions (\$35,879 million) in 2017*
- 32 transactions (\$48,244 million) in 2018*
- 35 transactions (\$44,192 million) in 2019 YTD*

**Source: Stifel,
includes announced and closed transactions*

There was a major slowdown in operational fab sales in 2018, in fact no operational fab closed. This is the first time this has happened since ATREG began tracking operational fab sales in 2001. Despite this, we saw resurgence in interest in used operational fabs in the second half of 2018 which has led to multiple sales being announced or closing in 2019.

Figure 1



The market has seen a high level of fab transaction activity so far this year, with five high-caliber assets sold in 2019 already, representing a value of nine billion highlighted by ON Semiconductor's \$430 million purchase of GLOBALFOUNDRIES' 300mm fab located in East Fishkill, NY. No operational fab transactions were closed in 2018 which has never been seen before. Typically, there are between four and eight fab transactions in a year. The lack of and high interest in 200mm equipment, facilities, and capacity continues. New operational 200mm fab will go for a premium. According to a presentation conducted by Infineon at SEMI's 2018 ITPC conference in Hawaii, another nine 200mm fabs are needed to meet the needs of power applications such as automotive, next-generation handhelds, etc.

In its *Global 200mm Fab Outlook* report from February 2019, SEMI forecasts that 200mm fabs will add 700,000 wafers through 2022 due to the robust demand for more content for mobile, Internet of Things (IoT), automotive and industrial applications, a 14 percent increase. The increase brings total 200mm wafer fab capacity to 6.5 million wafers per month as many devices have found their sweet spot with 200mm wafer fabrication. A total of 16 new facilities or lines, 14 of them volume fabs, are expected to begin operation between 2019 and 2022.

Figure 2

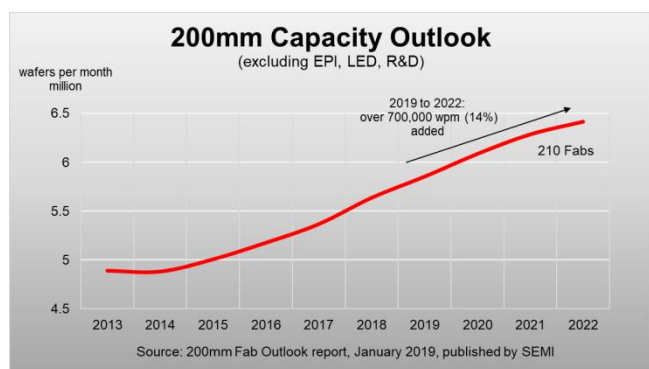
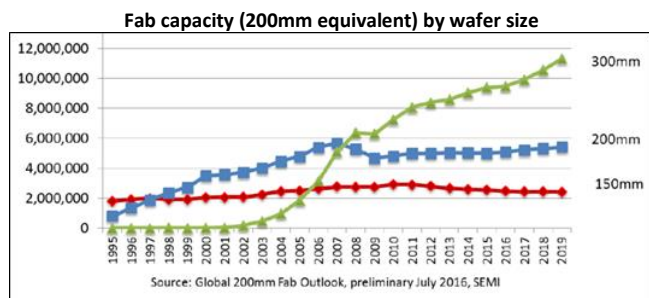


Figure 3



Strong 200mm wafer growth mirrors sound capacity demand seen across various industry segments. From 2019 to 2022, for example, wafer shipments for MEMS and sensors devices are expected to increase 25 percent while shipments for power devices and foundries are forecast to jump 23 percent and 18 percent, respectively. The increases in 200mm fab count and installed capacity reflect continuing 200mm industry strength as it continues to add capacity and even open new fabs.

Figure 4

OSATs

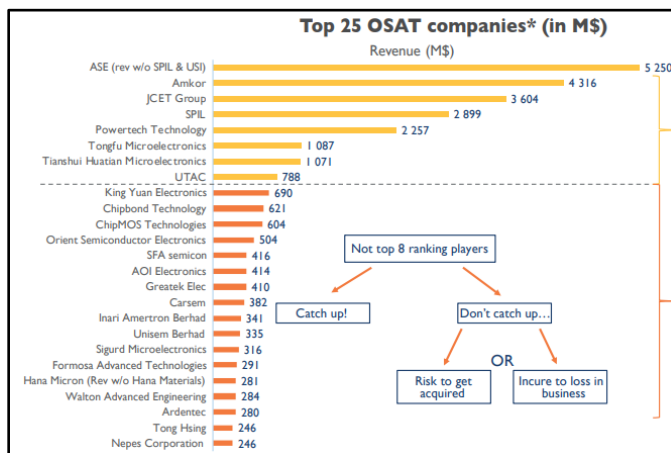
Currency in millions	ASE GROUP	Amkor Technology	JCET	中芯国际	台积电	ChipMOS	TF
2018 Revenue	371,092 TWD	4,316 USD	-	-	-	18,480 TWD	-
2018 Gross Profit	61,163 TWD	711 USD	-	-	-	3,430 TWD	-
2018 EBIT	26,648 TWD	258 USD	-	-	-	2,100 TWD	-
2018 Capex	40,259 TWD	547 USD	-	-	-	4,154 TWD	-
Regional Presence	Asia, North America	Asia, USA	Asia	Asia, USA	Taiwan	Asia	USA, Asia, Europe
Fabs / Facilities	17	24	6	7	2	7	20
Core Applications / Products	Wafer bumping / probing	Wafer bumping / probing / IC assembly / semi packaging	Packaging & testing	Packaging	IC testing & packaging	High-density memory / FPD packaging and memory	IC assembly & testing (MEMS, automotive)

Source: Yahoo Finance as of March 14, 2019

So who controls the OSAT market? Figure 5 below tells us more:

- Annual revenue among top 25 OSATs amounted to \$27.9 billion in 2018
- 65% of the A&T market is controlled by three Asia-based companies: Amkor, ASE, and JCET
- Top eight OSATs (33%) account for \$21.2 billion or 76% of revenue
- Companies outside of the top 8 risk being an acquisition target if they cannot grow revenues beyond current levels

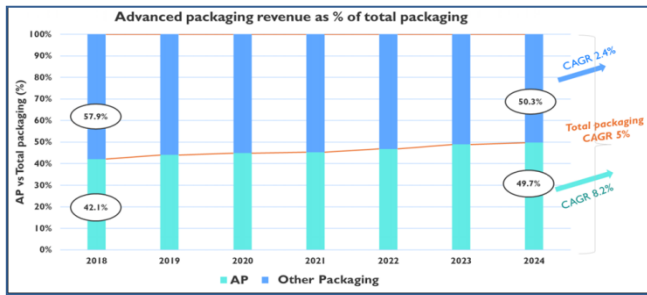
Figure 5



Source: Yole Développement, 2019

According to Figure 6 below, advanced packaging will account for effectively half of total packaging by 2024. CAGR for advanced packaging is three times higher than other packaging. Advanced packaging revenue is expected to increase by 43% by 2024.

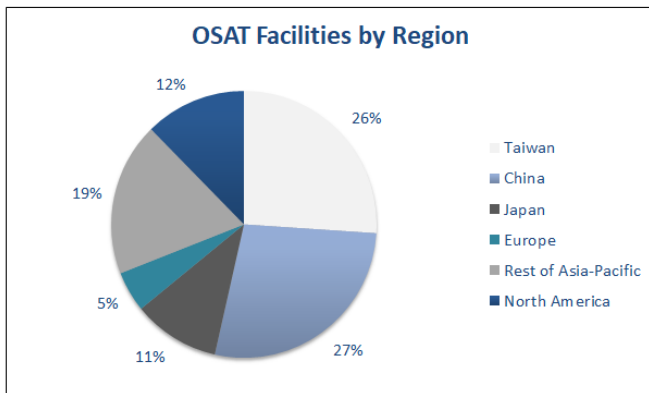
Figure 6



Source: Yole Développement, 2019

So where are all the OSAT fabs? More than 80% of OSAT facilities are located in Asia. More than 50% of OSAT facilities are located in either China or Taiwan. The remainder of the Asia-Pacific region makes up a significant portion of OSAT facilities (source: *The Conference Board*, 2016).

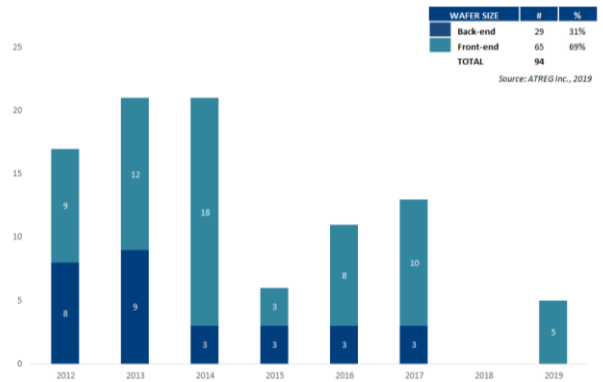
Figure 7



Source: SEMI Worldwide OSAT Manufacturing Database, Oct. 2017

Figure 8

Fab Transactions Over The Last 8 Years (By Facility Type)

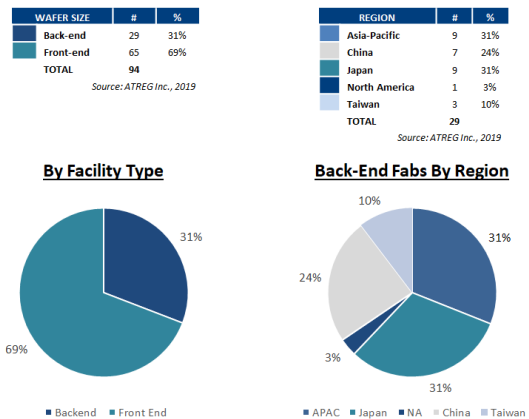


Source: ATREG, Inc., 2019

("Facility types" refer to back-end and front-end manufacturing fabs.)

Figure 9

Fab Transactions Over The Last 8 Years



Source: ATREG, Inc., 2019

III. Manufacturing Strategy: Internal Factors

A sound manufacturing strategy starts with looking at a company's own internal considerations, including available investment, needed capacity / supply agreements, and risk mitigation.

A. Financial investment

The investment needed to purchase a fab will vary depending on the type and size of fab you are looking for. Securing used tools over new ones will reduce the capex needed to start a fab. However, finding a complete and integrated used tool line that can be moved from an existing fab

into a new fab is difficult and these types of opportunities have dried up as the market has tightened, especially on 200mm. The lack of and high demand in 200mm equipment, facilities, and capacity means that operational 200mm fab will go for a premium. Companies looking for a used and complete tool line (either 200mm or 300mm) must consider purchasing a fab operationally and operating it in place for a period of time before the relocation of the tool set could be considered.

B. *Existing loading and supply agreements*

Ensuring continuity in manufacturing capacity is of utmost importance, and this is where supply agreements and gradual transitions come in. The ability for a buyer to neutralize operating costs as they introduce and qualify their own processes is a key component to most operational fab transactions. Here are some recent, real-life examples:

- Acquisition by ON Semiconductor of GLOBALFOUNDRIES' 300mm fab in East Fishkill, NY – transfer of ownership over three years to allow ON to transition from 200mm to 300mm manufacturing (April 2019)
- Acquisition by Diodes Inc. of Texas Instruments' 200mm / 150 mm fab in Greenock, Scotland, UK – additional fab capacity to support product growth, especially in automotive (February 2019)
- Acquisition by VIS of GF's 200mm Fab 3E in Tampines, Singapore – way to increase capacity in a global market with limited supply of 200mm manufacturing assets (January 2019)
- Disposition of Micron's operational back-end facility in Akita, Japan to Powertech Technology, Inc. (PTI) (August 2017)

C. *Risk mitigation*

Some regions are safer than others when it comes to natural disasters and this is an important consideration to take into account when looking at fab location to mitigate risk along your global supply chain. Most back-end facilities are located in a handful of countries, the bulk of which are mostly located in Asia-Pacific (China, Japan, Taiwan, Thailand, Vietnam, Indonesia, and Malaysia) and more prone to natural disasters such as earthquakes, tsunamis, and flooding.

Nature's wrath is getting riskier – climate change is causing more erratic weather patterns. Water shortage can also cause a huge risk as the semiconductor industry is very water dependent. When selecting a fab location, make sure that you have a plan, so your supply chain will not be disrupted:

- Ensure that you have alternate, already vetted, and qualified suppliers on your approved vendors lists (AVLs).
- Establish a sourcing relationship with these alternate suppliers to ensure that procurement requirements, processes, and procedures are in place prior to a disruption situation.
- Ensure that your secondary supply chain sources are not located in the same geographic areas or countries (if the country is small) as your tiered supply chain.

IV. Manufacturing Strategy: External Factors

In this section, we will take a look at a variety of external deciding factors companies need to take into consideration when selecting a fab location, including trade wars and tariffs, global competitors / industry consolidation, intellectual property (IP) protection, local supply chain, local incentives, and talent availability / recruitment.

A. *Trade wars and tariffs*

Not a day goes by without news of an outbidding development in the never-ending U.S.- China trade war saga. After restricting technology transfers to China's Huawei and its alliances to protect national security (companies such as Qualcomm, Intel, Xilinx, and Broadcom stopped supplying to Huawei after its blacklisting), the U.S. imposed on May 20 25% tariffs on \$200 billion worth of Chinese imports. In retaliation against these tariffs, China brought into effect its 10% to 25% tariff on \$60 billion worth of U.S. imports on June 1. On August 1st, the U.S. declared it would impose 10% tariffs on \$300 billion additional Chinese goods. On August 13th, the U.S. President delayed tariff implementation, stock prices improved dramatically.

While trade wars are disruptive for those involved, they can profit others. The U.S.-China trade war has spurred a 1,360 percent jump in

investment in Malaysia, especially the state of Penang who is winning from global investors' search for safe havens. Foreign direct investments into its manufacturing sector surged to USD 2 billion in the first quarter from a year ago, more than for the entire 2018. The state stands to gain from changes in the global supply chain as it's well-connected with a strong talent pool and supportive public policies.

The state of Penang who is already home to Intel and Dell makes up 42% of Malaysia's manufacturing FDI. The latest to join the investment table there includes Micron who invested RM1.5 billion over the past five years to open a new solid-state drive assembly and testing center on a 52-acre plot of land at the Batu Kawan Industrial estate that is expected to create about 1,000 local jobs. The other example is Jabil who purchased 20 acres of land to expand its facility.

B. Global competition & industry consolidation

To cope with rising chip development costs, many semiconductor companies are turning to consolidation. In 2018, the 10 largest companies combined for \$193.6 billion of sales, or more than 40 percent of the total market, according to preliminary results from Gartner. The top 25 companies are projected to grow around 16 percent and hold 80 percent market share in 2018. The rest of the market is estimated to grow 3.6 percent in 2018. Samsung and Intel together made three out of every 10 dollars in the industry.

Figure 10

2018 Rank	2017 Rank	Vendor	2018 Revenue (Billions of \$)	2018 Market Share (%)	2017 Revenue (Billions of \$)	2017-2018 Growth (%)
1	1	Samsung Electronics	75,854	15.9	59,875	26.7
2	2	Intel	65,862	13.8	58,725	12.2
3	3	SK hynix	36,433	7.6	26,370	38.2
4	4	Micron Technology	30,641	6.4	22,895	33.8
5	6	Broadcom	16,544	3.5	15,405	7.4
6	5	Qualcomm	15,380	3.2	16,099	-4.5
7	7	Texas Instruments	14,767	3.1	13,506	9.3
9	9	Western Digital	9,321	2.0	9,159	1.8
9	11	ST Microelectronics	9,276	1.9	8,031	15.5
10	10	NXP Semiconductors	9,010	1.9	8,750	3.0
		Others	193,605	40.7	181,578	6.6
		Total Market	476,693	100.0	420,393	13.4

Source: Gartner, 2018

Here are also the most notable M&A transactions that took place in 2018 and so far in 2019:

Figure 11

Notable M&A Activity

ACQUIRER	TARGET	ANNOUNCEMENT DATE	TRANS. VALUE (\$M)	EV / REVENUE	EV / EBITDA
 STMicroelectronics	 NORSTEL*	2/6/2019	75.6	1.42	6.25
 Infineon	 SILTECTRA	11/12/2018	139.2	2.74	9.97
 IVI	 FINISAR	*11/9/2018	3,200	2.16	11.01
 WINGTECH PROFESSIONAL ELECTRONICS MICROELECTRONICS CO., LTD.	 nexperia	*10/30/2018	3,630	N/A	N/A
 RENESAS	 IDT Integrated Device Technology	*9/10/2018	6,700	N/A	N/A
 BROADCOM	 ca technologies	*7/11/2018	18,900	5.93	12.93
 CREE	 Infineon (RF Power Business)	3/7/2018	425.6	3.24	41.58
 MICROCHIP	 Microsemi	3/1/2018	10,147.2	6.13	19.72

Sources: Press releases / Yahoo Finance as of March 7, 2019; *Denotes announced deals

C. IP protection

It is no news that U.S. companies have been at war with China over IP infringement for some time, but never has it become so heated as of recently, with multiple lawsuits coming to bare – whether Micron, Samsung, or SK Hynix, they all reported that the Chinese government had launched antitrust probes into their firms, and accused them of setting artificially high prices for memory chips. Without the support of the current U.S. Administration which seems more concerned with trade wars and tariffs, the battle over IP is far from being over.

D. Local supply chain

When selecting a fab site, make sure that the location offers an established semiconductor supply chain. Over the past few years, India has entered the race to try and become a top manufacturing destination. Despite attractive incentives, the country does not offer an established semiconductor supply chain and the Indian government is not able to get appropriate funding it needs.

E. Local incentives

In the U.S., many states offer tax exemptions to boost advanced manufacturing. In addition, some states have created grants and programs to incentivize companies to build fabs in their state to advance their manufacturing industry and

create jobs. In addition to Oregon and Arizona that have recently joined the race, here are some of the most competitive U.S. incentive packages currently available to semiconductor manufacturers:

- **New York** - \$1 billion investment over six years to construct and equip Cree's new greenfield 200mm silicon carbide wafer fabrication facility at the Marcy Nanocenter on the SUNY Polytechnic Institute campus near Utica in September 2019
- **Texas Enterprise Fund** - Previously awarded to semiconductor companies (Sematech, Texas Instruments, Maxim Integrated Products, Samsung)
- **Enterprise Florida** - Multiple incentive grants for advanced manufacturing, including sales and use tax exemption in semiconductor transactions involving manufacturing equipment (electricity, labor and machinery components of R&D, equipment repair)
- **Wisconsin** - \$3 billion funding to Foxconn (refundable tax credits and sales tax exemption for construction materials)
- **Oregon** – Multi-billion-dollar Intel CapEx, large tax exemptions
- **Arizona** – Sales tax exemptions for manufacturing machinery / tools

Outside the U.S., governments around the world have funded or created new programs to recruit manufacturing companies to build in their country and to stay competitive internationally, including:

- **Singapore** - Offers tax exemption for companies looking to grow in Singapore various investment categories, including R&D, capability development, and expansion
- **Korea** - 1.5 trillion won to fund the development of new semiconductor materials or devices
- **China** - China Integrated Circuit Industry Investment Co. Fund and Tsinghua Unigroup Fund, both funded at \$47 billion each
- **Israel** - \$700 million funding to Intel for the Kiryat Gat fab and an additional \$200 million for upgrades in 2010

- **European Union** - Important Projects of Common European Interest (IPCEI) status allows up to 20% of total investment to be covered with state money, which promotes large, strategic transnational projects
- **Germany** - Saxony has provided subsidies for semiconductor companies such as Infineon and Siltronic AG for expansion in Dresden

F. *Talent availability / recruitment*

A fab site selection is only as successful as the pool of local talent it sources from. Make sure that the region you choose can provide the desired highly educated workforce your manufacturing operations need now and the college, apprenticeship, and university graduates you will need in the future. Engineering talent, for example, is not available everywhere, which is the case in China where it is not up to par. For China's semiconductor industry to get off the ground, it needs more engineering talent, but more restrictions have been put on that transfer of knowledge due to continuous technology IP infringement.

V. Spotlight on China

Over the past few years, China has developed as a top advanced packaging and test destination in Asia-Pacific for semiconductor players, attracting investors with a huge workforce of cheaper, skilled workers as well as an infrastructure that is more resilient and less prone to problems such as power shortages.

More than 100 companies compete in China's packaging and assembly market, including leading multinational companies and emerging domestic players. More than half of China's packaging companies are located in the Yangzi delta region, while midwestern China has emerged as a hotbed for packaging plants. Here are the main players in advanced packaging in China:

Figure 12



Source: Yole Développement, 2016

The more than RMB140 billion (US\$21.5 billion) accumulated by the National IC Fund, a critical component of the 2014 National Guideline to address China's semiconductor trade deficit, has spurred rapid gains throughout the region's IC supply chain. Semiconductors are China's largest import by revenue. Phase 2 of funding aims to raise another RMB150-200 billion (\$23.0-\$30.0 billion).

In September 2018, SEMI reported that China's IC packaging and test industry is moving up the value chain by enhancing its technology offerings through mergers and acquisitions and building advanced capabilities to entice international integrated device manufacturers. China's IC materials market, currently dominated by packaging materials, became the second largest regional market for materials in 2016, a position it solidified in 2017. China's materials market is expected to grow at a 10 percent CAGR from 2015 to 2019, driven primarily by the region's new fab capacity ramp in the coming years. Fab capacity will expand at a 14 percent CAGR during that period.

IC design remains the largest semiconductor sector in China for the second year in a row with \$31.9 billion in revenue in 2017, widening its lead over the long-dominant IC packaging and test sector. The ascent of China's IC Design sector comes as the region's equipment market is expected to claim the top spot in 2020 for the first time on the strength of the continuing development of its domestic manufacturing capability. China's maturing domestic fab sector is also benefiting domestic equipment and materials suppliers. Both groups continue to see gains in their product offerings and capabilities, particularly in silicon wafer production.

Figure 13



Source: ATREG Inc., 2019

But in 2019, the picture looks very different. We now know that facilities in China are not producing significant wafers as the country is struggling to complete all of its fab builds (eight to 10 facilities out of 30 are not yet built). Also a new major trend is starting to unfold. Advanced technology companies are getting increasingly concerned about having all their back-end facilities located there for a variety of reasons, including the ongoing trade war between China and the U.S. involving the introduction of 25 percent tariffs on phones, laptops, and tablets, IP protection, higher local labor costs, and the risk of overly centralizing production in just one location. Each country is coming to the realization that they should keep their fabs home. Here are just a few examples:

- Texas Instruments extending its existing 300mm fab in Richardson, TX
- Infineon investing €1.6 billion in a new 300mm wafer factory in Villach, Austria
- Bosch deciding to keep their investments in Dresden, Germany for a new 300mm fab
- STMicro announcing an expansion of existing sites in Europe
- Apple exploring moving 15 to 30% of its hardware production out of China

Nikkei recently reported that consumer electronics giant Apple is exploring moving between 15 and 30 percent of its hardware production out of China, even if this is bound to be a long and painful process over 18 months. They have apparently asked key manufacturing partners such as Foxconn, Pegatron, and Wistron to evaluate available options. This move would directly impact 10,000 Apple Chinese employees and indirectly about five million Chinese jobs thought to rely on Apple's manufacturing.

Apple i-Phone production is likely to move to South East Asia, e.g. India who has introduced a new National Policy on Electronics 2019 (NPE 2019) to develop its own electronics hardware manufacturing. If more than half the phones are assembled in India, taxes are waived. Vietnam is another alternative choice. The Vietnamese government is offering attractive subsidies to encourage foreign companies to set up shop there. For example, Intel has invested USD 1 billion in setting up its chip testing and assembly facility there. Even Samsung has mobile phones and other electronic manufacturing facilities located in Vietnam.

Another example is Google who has been moving some hardware production out of China, already shifting much of its production of U.S.-bound motherboards to Taiwan and some American-bound production of Nest devices to Taiwan and Malaysia. Moving operations outside of China is not solely due to the trade war and associated U.S. tariffs, since the rising cost of labor and meeting environmental regulations in China have also led to companies seeking cheaper production hubs over recent years.

VI. Spotlight on Automotive

Automotive is by far the most prominent application for test and packaging. French firm Yole Développement reports that smart automotive will represent a market value of USD 1,630 billion by 2021 (about 100 million vehicles).

Figure 14



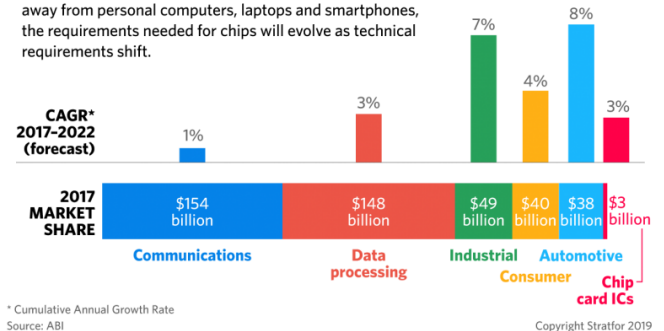
Source: Yole Développement, 2018

U.S.-TX-based Stratfor states that automotive is one of the key forces driving the growth in demand for semiconductor products with USD38 billion, as per the chart below.

Figure 15

Projected Semiconductor Demand Growth by Segment

The "internet of things" and auto sector are driving the growth in demand for semiconductors. As demand moves away from personal computers, laptops and smartphones, the requirements needed for chips will evolve as technical requirements shift.



According to U.S. firm TechSearch International, here are some of the most indicative automotive packaging trends today:

- Increased connectivity, safety features, and automation mean an increasing use of sensors (3,500+ semiconductors in new cars), sensor fusion, computing power, and automotive network bandwidth needs
- Increased use of SiP (single inline package) solutions in a variety of package formats
- Co-design becomes increasingly important
- OSATs with automotive-qualified production lines include Amkor, ASE, Carsem, JCET (including STATS ChipPAC), Unisem, and UTAC

VII. Transaction Case Studies

This paper would not be complete without looking at a couple of real-world back-end fab transaction case studies as illustrations, namely Micron's Akita, Japan and Qualcomm's Longtan, Taiwan facilities.

Micron Technology needed to divest from its advanced operational 300mm assembly and test facility located in Akita, Japan featuring a 71,000-sq. ft. cleanroom. At the time, Micron was planning on shifting production from Japan to other facilities in Taiwan and had plans in place to close the Longtan facility. For the sale to be successful, Micron needed to greatly extend the length of the supply agreement and provide more flexibility on workforce issues. The facility was eventually sold to Taiwanese company Powertech Technology Inc. (PTI). The definitive agreement was announced in April 2017 with the deal closing in August 2017.

Qualcomm MEMS Technologies needed to dispose of its subsidiary Qualcomm Panel Manufacturing based in Longtan, Taiwan. The facility offered a one million-square feet newly built infrastructure-rich cleanroom equipped with a small pilot line for fourth-generation glass that was no longer compliant. Qualcomm had assumed the facility could only be used for similar technologies and was unsure if it could be converted to an alternative use.

The Qualcomm facility was exposed to a wide variety of potential buyers outside the fairly narrow field of users for its intended purpose, including LED, display, MEMS, and data center. At the time, TSMC had just laid the foundation of a new facility in Taiwan. Their strategy shifted to purchase the Longtan Qualcomm facility instead, saving them time and capital. TSMC now operates the fab as an advanced packaging facility to support the ramp-up of their InFO (Integrated Fan-out) process. Both companies signed the definitive agreement in October 2014 and the deal closed in April 2015.

VIII. Conclusion

In this unstable global context, the selection of a fab site is a crucial part of a sound manufacturing strategy for any advanced technology company. It should therefore be conducted with the utmost care after completing extensive global research to ensure the company's fab specifications are fully met. Here are some key considerations to ensure a successful fab site selection outcome:

- Gain corporate alignment between managers, executives, and the company board. Agree on a sound product strategy early on to ensure a viable business.
- Depending on your specific manufacturing needs, carefully weigh the pros and cons of greenfield vs. brownfield. Despite large amounts of incentives now available in various parts of the world to attract new fab construction, a sound, existing operational fab may be a better choice for your company in the long run and could ensure faster time-to-market.
- When considering purchasing a second-hand fab, don't get too hung up on the purchase price. Make sure you evaluate the opportunity cost, know all assumed liabilities, and understand all operating expenses. Negotiate a fair supply agreement for both parties to ensure continuity of supply.
- Don't underestimate your fab's local culture. Understand it well to get the most out of your local workforce.

Acknowledgment

ATREG, Inc. would like to thank IC Insights, SEMI, Yole Développement, Gartner, Stifel, and Stratfor for the use of their market data and statistics.

For More Information, Please Contact:

This paper is written by experts and practitioners at ATREG, Inc. We welcome your feedback and comments at info@atreg.com.

© 2019, ATREG, Inc. All rights reserved. ATREG and the ATREG logo are trademarks or registered trademarks of ATREG, Inc. All other product and company names mentioned herein may be trademarks of their respective companies.

This paper is not intended to be used as the basis for any transaction. Nothing herein shall be construed as legal, financial, accounting, investment, or other type of professional advice. If any such advice is required, the services of appropriate advisors should be sought. No part of this publication may be copied or redistributed in any form without the prior written permission of ATREG, Inc.

ATREG, Inc.
223 Yale Avenue North
Seattle, WA 98109
USA
+1.206.268.7800
info@atreg.com
www.atreg.com