

Global wafer foundry industry, 2023 and beyond

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Introduction

Based on DIGITIMES Research's estimates, global foundry revenue is set to reach US\$137.2 billion in 2022, soaring 25.8%. The brilliant performance is a result of price hikes, customer long-term agreements (LTA) and capacity expansions. Going into 2023, amid macroeconomic uncertainties and rising US-China trade tensions, global foundry revenue will show a moderate on-year decline. However, driven by maturing 5G and high-performance computing (HPC) applications as well as increasing silicon content in electronics, global foundry revenue stands a chance of topping US\$200 billion by 2027.

DIGITIMES Research has observed that although end devices including mobile phones and notebooks have entered a period of inventory adjustment in 2022, global foundry revenue has still performed outstandingly thanks to price hikes and LTAs. Looking into 2023, end device inventory adjustment will extend into first-half 2023. A bleak economic outlook will take a toll on consumer spending. These factors will prolong end device inventory adjustment. As a result, 2023 global foundry revenue may fall back 2% to 3%.

In the mid-to-long term, with the recovery of semiconductor demand, 5G and HPC applications taking off, electronics and automobiles coming with increasing silicon contents, electronics brands and system integrators undertaking in-house chip R&D and IDMs continuing to outsource chip production, DIGITIMES Research projects global foundry revenue will grow at a CAGR of 8.3% for the period from 2022 through 2027, with the 2027 revenue to top US\$200 billion.

However, DIGITIMES Research also believes geopolitical uncertainties (especially the US-China tech war) will exert a big influence on global foundry industry developments. The restrictions on IC design or production or even the policies on semiconductor self-sufficiency will all have implications on the competition among leading foundry players and their strategic planning.

Key factors affecting the global wafer foundry industry

Demand

The global foundry industry's growth momentum started to weaken in second-half 2022 in the face of macroeconomic and geopolitical uncertainties on top of downstream product inventory adjustments. The situation is expected to extend into 2023.

The pandemic-induced demand for notebooks and tablets is gradually mitigating. Their mid-to-long-term growth momentum is expected to slow down.

Amid the escalating US-China tech war, the US government's latest export restrictions have blocked China from gaining access to high-end HPC chips or undertaking independent chip R&D. This has also held back China's progress on foundry technology development.

The US government's latest export controls announced on October 7 target the most advanced HPC chips while aiming to cripple China's ability to develop high-end chips.

The possibility of the US stepping up its efforts to suppress China is not to be ruled out.

Some of the demand for services from China's datacenters may be shifted to US datacenters.

Consumers cutting back their spending because of the bleak economic outlook will make electronics inventory digestion difficult and weaken foundry demand.

Emerging applications growing mature will drive up chip demand and device silicon content, spur a trend of independent chip development and prompt IDMs to increase outsourced production. These will support foundry demand for the short, medium and long term.

Table 1: Key factors affecting the global wafer foundry industry – demand

Demand side factor	2022	2023	2024-2027
Data processing and computing needs drive the demand for HPC chips including AI processors, CPU and GPU.	↑ ★★★	↑ ★	↑ ★★★★★
5G technologies spur smartphone and network infrastructure demand.	↑ ★	↑ ★	↑ ★★★★★
EV and ADAS fuel automotive semiconductor demand.	↑ ★	↑ ★	↑ ★★★★★
Electronics brands/system integrators/platform operators venture into in-house IC development.	↑ ★	↑ ★	↑ ★★★
IDMs have increasing need to outsource their production.	↑ ★	↑ ★	↑ ★
The demand for consumer electronics including notebooks and tablets is saturating and their growth momentum is decelerating.	↓ ★★★	↓ ★	↓ ★
Amid the escalating US-China tech war, the US imposes restrictions on HPC chip exports to China and prohibits China from using American technologies to manufacture high-end HPC chips.	↓ ★	↓ ★★★	–
Bleak economic outlook dampens consumer purchasing power and sets back electronics sales.	↓ ★	↓ ★★★★★	–

Note: The more stars, the higher the influence. ↓ indicates negative influence, ↑ indicates positive influence.

Source: DIGITIMES Research, November 2022

US trade sanctions on China

DIGITIMES Research believes the US government's restrictions on semiconductor exports to China will affect foundry revenue from both advanced and mature processes, with TSMC sustaining the most significant influence but the impact will be to a limited extent.

AMD and Nvidia have been prohibited from supplying AI processors and GPUs exceeding the performance limit to China.

There is however a grace period within which US firms with operations in China can still have access to chip exports from the US (to non-Chinese companies).

Peripheral chips (made on mature processes) to HPC or supercomputer-related chips will also fall under the influence of the US government's export restrictions but to a small extent.

These chips are a niche market segment. The restrictions on their exports will have a limited impact on the foundry sector. Moreover, the production of HPC chips not subject to the restrictions can still be outsourced to TSMC and other foreign foundries (the end users and applications will need to be verified to ensure they do not belong to the entities and purposes identified in the restrictions).

China-based foundries are disabled from producing chips on 16/14nm or more advanced nodes.

The Foreign Direct Product Rule (FDPR) bans semiconductor production equipment made with American technologies (both software and hardware) for these process nodes from being supplied to China-based foundries.

Americans are barred from supporting the development or production of semiconductor process technologies and HPC chips in China.

Americans include US citizens, alien residents with green cards, US entities and corporate branches in the US

SMIC's ability to produce 14nm to N + 2 (similar to 7nm) chips is crippled. HLMC under Huahong Group is also unable to develop 14nm process technology.

DIGITIMES Research believes the US-China tech war will carry on regardless of which US political party is in charge. This will be a pivotal factor affecting the foundry industry going into the next five years.

Table 2: Effects of US trade sanctions on China semiconductor industry

Items	Contents	Effects
HPC chips	HPC and supercomputer chips with processing performance above 4,800 TOPS	-HPC chips are banned from being exported to China. Also, China's independent HPC chip development is crippled.
Advanced semiconductor process	Equipment and materials for 16/14nm and more advanced processes	-With this being a niche market segment, the impact will be limited.
End applications and users	-Supercomputer/military applications -28 Chinese firms added to the Entity List are involved in the development of supercomputers	-The production of HPC chips not specified in the restrictions is not affected. -China's progress on advanced semiconductor processes will grind to a halt. -Production of chips not subject to the restrictions can be outsourced to foreign manufacturers but end users and applications will have to be verified.

**Note: The table only includes contents and effects related to the wafer foundry industry.*

Source: DIGITIMES Research, November 2022

Supply

Going into 2023, in the wake of weakening chip demand, foundries may reduce their capital expenditure and scale back or put off their capacity expansion in anticipation of market recovery in 2024.

Special-purpose processes can still meet the demand from factory automation, automotive and radio frequency applications, which will be a strong pillar supporting foundry revenue.

TSMC can maintain revenue growth in 2023.

In 2023, only TSMC and Globalfoundries have plans to hike prices. The other foundries are not in a position to raise prices.

Advanced processes including the 5nm and 3nm nodes as well as advanced packaging processes are less susceptible to the boom and bust cycle so they are strong support for foundry revenue.

The US stepping up export controls against China will hinder China's progress on 16/14nm and more advanced processes. Foreign corporations with operations in China will be dealt with on an individual basis.

SMIC's sub-14nm node development and production will grind to a halt and so will HLMC's 14nm node development.

Applied Materials and Lam Research are pulling staff out of their sites in China.

Dutch company ASML has told its US employees to refrain from supporting semiconductor process business in China.

Whether ASML can ship 28nm process equipment to SMIC is something to be monitored.

Production equipment for these processes made with US technologies (including software) is prohibited from being exported to China.

US Department of Commerce has given TSMC permission to have 28nm and 16nm process equipment and parts shipped to its Nanjing plant for a year.

Table 3: Key factors affecting the global wafer foundry industry – Supply

Supply side factor	2022	2023	2024-2027
Foundry price hikes	↑ ★★★★★	↑ ★	–
Continuing capacity expansions	↑ ★★★	↑ ★	↑ ★★★★★
Sub-5nm nodes fueling revenue growth momentum	↑ ★★★	↑ ★★★	↑ ★★★★★
Advanced packaging processes meeting customer requirements for high-end chips	↑ ★	↑ ★	↑ ★★★
Developing special-purpose processes to capture automotive and IoT market opportunities	↑ ★	↑ ★	↑ ★★★
US imposing restrictions on semiconductor material and equipment exports to China while prohibiting US persons from supporting China's advanced semiconductor process development	↓ ★	↓ ★★★	↓ ★★★

Note: The more stars, the higher the influence. ↓ indicates negative influence, ↑ indicates positive influence.

Source: DIGITIMES Research, November 2022

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Foundry capacity

Expansions

Table 4: Pure-play foundries capacity expansions in 2023

Company	Location	Manufacturing node	8-/12-inch	Added monthly capacity	Finishing schedule
TSMC	Tainan, Taiwan	3nm	12-inch	50k	2023
	Nanjing, China	28nm	12-inch	30k	1H23
Samsung	Hwaseong, S. Korea	3nm	12-inch	5-10k	2023
	Pyeongtaek, S. Korea	4/5nm	12-inch	~10k	2023
UMC	Tainan	28nm	12-inch	27.5k	2H23
Globalfoundries	Germany; New York	Special node	12-inch	Undisclosed	2023
	Singapore	Special node	12-inch	10-20k	1H23
SMIC	Shenzhen	28nm and above	12-inch	20k	2023
Huahong	Wuxi	12-inch special node	12-inch	10k	2023
VIS	Hsinchu, Taiwan	0.18 μ m and below	8-inch	20k	2H23

Source: Companies; compiled by DIGITIMES Research, November 2022

The foundries' capacity expansion will remain focused on 12-inch wafer production in 2023. Only VIS has a definite plan for 8-inch wafer capacity expansion.

TSMC is set to raise its 3nm capacity in 2023. Furthermore, the US Department of Commerce has exempted TSMC, allowing the 28nm production at its Nanjing plant to go according to schedule without a hitch.

Samsung will concentrate on adding sub-5nm capacity in 2023.

UMC will moderately increase its 28nm capacity at the Tainan factory.

Globalfoundries has plans to ramp up the capacity at its facilities in New York and Dresden, Germany in 2023 while its Singapore plant will kick off production in first-half 2023.

Subject to the US government's latest export restrictions, whether its Shenzhen plant can begin production without problems in 2023 remains to be seen.

It will hinge on whether SMIC can gain access to process equipment and technical support from the equipment suppliers.

Huahong's phase-1 facility in Wuxi is expected to ramp up to full capacity in 2023. Phase-2 facility planning and construction will depend on customers' mid-to-long-term demand.

VIS will defer its 8-inch wafer capacity expansion to second-half 2023 given weak market demand.

PSMC's new P5 fab in Tongluo was originally scheduled to begin production in second-half 2023 but the plan has been put off until 2024. The original target was to reach a monthly capacity of 35,000 12-inch wafers by 2024. The schedule has now been postponed as well.

Mature nodes

Table 5: Pure-play foundries mature nodes capacity expansions beyond 2023

Company	Location	Manufacturing node	8-/12-inch	Added monthly capacity	Finishing schedule
TSMC	Japan	12/16nm, 28nm	12-inch	40k, 15k	2024
	Kaohsiung, Taiwan	28nm	12-inch	20k	2024-2025
UMC	Tainan, Taiwan	28nm	12-inch	5k	2024
	Singapore	28nm	12-inch	30k	2024
PSMC	Miaoli, Taiwan	12nm special node	12-inch	100k (2-phase)	2024
Globalfoundries	France	FD-SOI	12-inch	30k	2024
SMIC	Beijing, China	28nm and above	12-inch	100k	2024
	Shanghai, China	28nm and above	12-inch	100k	Not decided
	Tianjin, China	28nm and above	12-inch	100k	Not decided
Tower	India	65nm	12-inch	Undisclosed	Not decided

Source: Companies; compiled by DIGITIMES Research, November 2022

Geopolitical factors prompt the foundries to distribute their investments in mature 12-inch wafer processes in different parts of the world.

TSMC has announced its plan to build factories in Japan through joint ventures with Sony and Denso.

Globalfoundries and STMicroelectronics will together build production lines in France.

Tower Semiconductor will set up 65nm facilities in India.

The foundries will continue to expand their mature process capacity with a focus on special-purpose processes.

Globalfoundries will make efforts toward 20nm and 18nm fully depleted silicon-on-insular (FD-SOI) processes in France.

Dongbu HiTek has disclosed its plan to build new 8-inch SiC production lines in Korea, targeting the automotive semiconductor sector.

Despite its investments to establish plants in Beijing, Shanghai and Tianjin, SMIC's capacity expansion will hinge on its ability to obtain production equipment amid the US government's latest export restrictions.

EUV lithography equipment for 14nm processes can also be used to make 28nm chips so whether SMIC can gain access to such equipment will determine its capacity expansion plans.

If SMIC is unable to acquire 28nm production equipment, it should help alleviate the problem of having excess 28nm capacity worldwide.

Top-3 foundries advanced nodes

Table 6: Top-3 foundries advanced node capacity expansions

Company	Location	Manufacturing node	Added monthly capacity	Finishing schedule
TSMC	Arizona, US	5nm	20k	2024
	Hsinchu, Taiwan	2nm	>100k (4 fabs)	2025
Samsung	Pyeongtaek, S. Korea	4/5nm	Undisclosed	2023
	Texas, US	5nm and below	Undisclosed	2024
Intel	Israel	Undisclosed	Undisclosed	2023
	Ireland	Intel 4 and below	20k	2023
	Arizona, US	Intel 20A and below	40k (2 fabs)	2024
	Ohio, US	Intel 18A and below	40k (2 fabs)	2025
	Magdeburg, Germany	Intel 18A and below	40k (2 fabs)	2027

Source: Companies, DIGITIMES Research, November 2022

TSMC will adjust the 7/6nm production plans at its Kaohsiung factory due to decreasing customer demand but its 28nm production plan will stay on course.

Samsung will focus efforts on capacity expansion at its new Pyongtaek facility in 2023 while its new Texas plant is set to kick off production in 2024.

Samsung's Texas plant is targeted to produce sub-5nm chips starting in 2024, but the schedule may be pushed out due to weakening market demand.

In July 2022, Samsung announced the plan to invest US\$200 billion to build 11 fabs in Texas but has not disclosed further details so far.

According to supply chain sources, Samsung will build two fabs in Austin and nine in Taylor.

Intel will have its 20A and more advanced processes up and running starting in 2024.

Intel and Canada-based Brookfield Asset Management have agreed to jointly fund Intel's new fabrication facility in Arizona.

Roadmap

Table 7: Top-3 foundries advanced node roadmap

Company	2021	2022	2023	2024	2025	2026	2027
TSMC	N5P	N4P N3	N4X N3E	N3P	N3X N2	N2P*	N1.4*
	FinFET				GAAFET		
Samsung	5LPP 4LPX	4LPE, 4LPP 3GAE	5LPE-A 4LPP+	4HPC 3GAP	4LPA 3GAP+ 2GAP	2GAP+	1.4GAP
	FinFET				GAAFET		
Intel	Intel 7		Intel 4	Intel 3	Intel 20A	Intel 18A	Intel 14A*
	FinFET				GAAFET		

*Note: Nodes marked with * are temporary names.

Source: Companies, DIGITIMES Research, November 2022

DIGITIMES Research expects TSMC to gain a lead in the 3nm race in 2023.

Although Samsung launched 3nm production ahead of TSMC, the output and yield are inferior to TSMC's as of year-end 2022.

Samsung vowed to churn out 3nm chips in volume by the end of June 2022 while it could only reach small-volume production with limited yield.

The monthly capacity is estimated to be around 1,000 wafers and the yield is short of 50%.

Its monthly capacity is projected to reach 10,000 to 20,000 wafers by year-end 2023. Volume production is not expected to start until 2024.

TSMC's 3nm production is set to enter volume production in fourth-quarter 2022 and will continue to use FinFET.

For TSMC, DIGITIMES Research projects a monthly capacity of 20,000 to 30,000 12-inch wafers and a 60% to 70% yield. The monthly capacity will ramp up to 70,000 to 80,000 12-inch wafers by year-end 2023.

DIGITIMES Research believes Intel may defer the Intel 4 volume production to 2023.

Intel 4 only reached small-volume production in second-half 2022 with limited output and yield.

Meteor Lake CPU made on the Intel 4 process will be available in volume sometime second-half 2023.

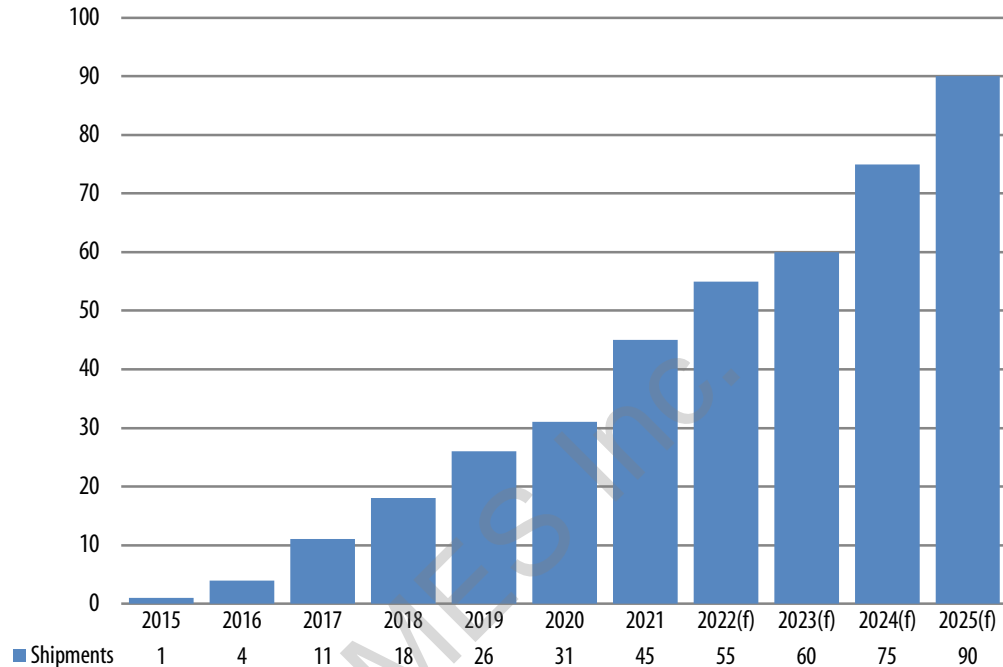
DIGITIMES Research expects the three leading foundries' 2nm processes to enter volume production in 2025 and their 1.4nm processes to launch in 2027.

All three foundries will adopt GAAFET for their sub-2nm nodes.

Their 1.4nm processes may not enter volume production until 2028.

Equipment

Chart 1: ASML EUV lithography equipment shipments, 2015-2025 (units)



Source: ASML; compiled by DIGITIMES Research, November 2022

EUV lithography equipment plays a critical role in foundry capacity expansion. TSMC, Samsung and Intel are all eagerly trying to acquire EUV lithography machines.

EUV lithography technology is one of the crucial elements driving the semiconductor process toward sub-7nm nodes.

DIGITIMES Research estimates that TSMC owns close to 100 EUV lithography equipment sets in 2022, while Samsung possesses no more than half of the quantity and Intel even fewer.

ASML will keep ramping up its EUV lithography equipment output, aiming to ship 60 units in 2023 and 90 in 2025.

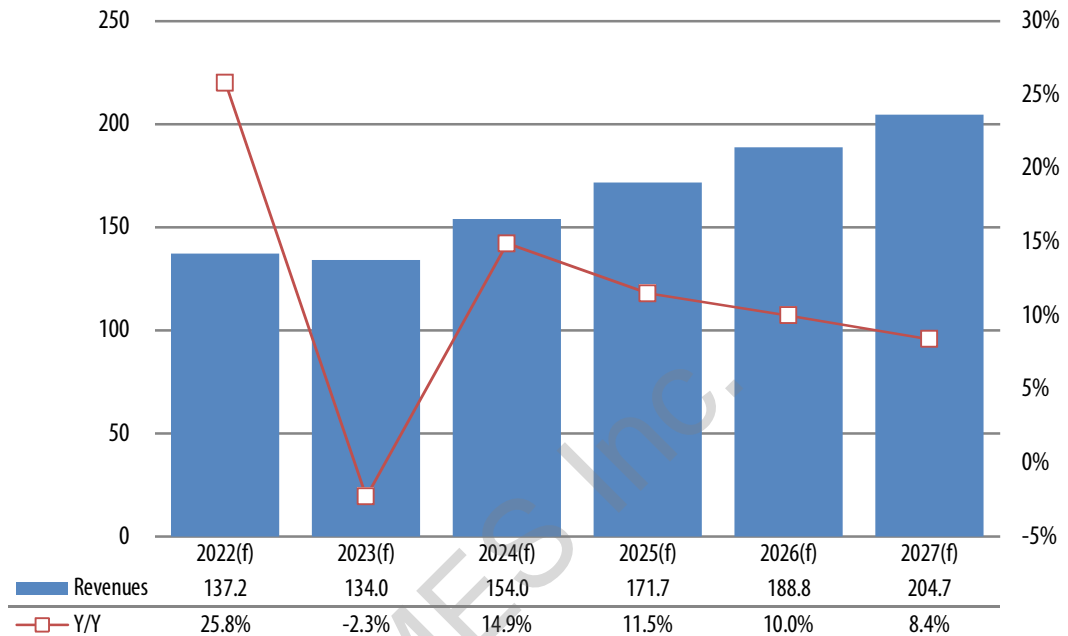
ASML is set to start shipping 0.55 high-NA EUV lithography equipment in 2024.

The equipment will be available in a small quantity in 2024 mainly for customers to perform R&D and pilot production. They will be shipped in volume in 2025.

DIGITIMES Research believes TSMC, Samsung and Intel will get these new systems around the same time but TSMC will still receive more high-NA EUV lithography equipment than its competitors.

Revenues

Chart 2: Global foundry services revenues, 2020-2027 (b units)



*Note: The amounts include those from Samsung SLSI, but not from Intel.

Source: DIGITIMES Research, November 2022

Based on DIGITIMES Research's projections, 2022 global foundry revenue is set to reach US\$137.2 billion, soaring 25.8% from a year ago, thanks to customer LTAs, price hikes and capacity expansion.

DIGITIMES Research expects 2023 global foundry revenue to edge downward 2.3% to US\$134 billion.

The US-China tech war dragging on plays a crucial role in the development of the foundry industry.

A bleak economic outlook taking a toll on consumer spending may slow down foundry customers' inventory depletion.

DIGITIMES Research expects global foundry revenue to grow at a CAGR of 8.3% from 2022 through 2027.

Applications including 5G, HPC and EV will drive mid-to-long-term foundry demand while IDMs stay the course of increasing outsourced production.

Global foundry revenue has a chance of topping US\$200 billion in 2027.

In light of uncertainties including the US government's latest export restrictions against China and end device inventory adjustments, DIGITIMES Research has lowered the forecast on the four leading Taiwan-based foundries' 2023 revenue performance to a 1.6% on-year decline.

The forecast given in October 2022 was a 6% on-year growth in their 2023 revenue.

Even with the downward adjustment, the Taiwan-based foundries will still outperform the global foundry industry.