TAIWAN AND THE GLOBAL SEMICONDUCTOR SUPPLY CHAIN: 2023 IN REVIEW

Edited by:
Chen-Yuan Tung, Ph.D.
Representative
Taipei Representative Office in Singapore

Table of Contents

List of Figures and Tables

FIGURES

TABLES

Please feel free to reach out to the Economic Division of the Taipei Representative Office in Singapore should you have any enquiries or are seeking partnership opportunities of investment or collaboration in the field of semiconductors in Taiwan.

Email: singapore@sa.moea.gov.tw
Telephone: +65 6500-0128

Published: Taipei Representative Office in Singapore
Address: 460 Alexandra Road, #23-00 mTower, Singapore 119963
Email: sgp@mofa.gov.tw
Telephone: +65 6500-0100

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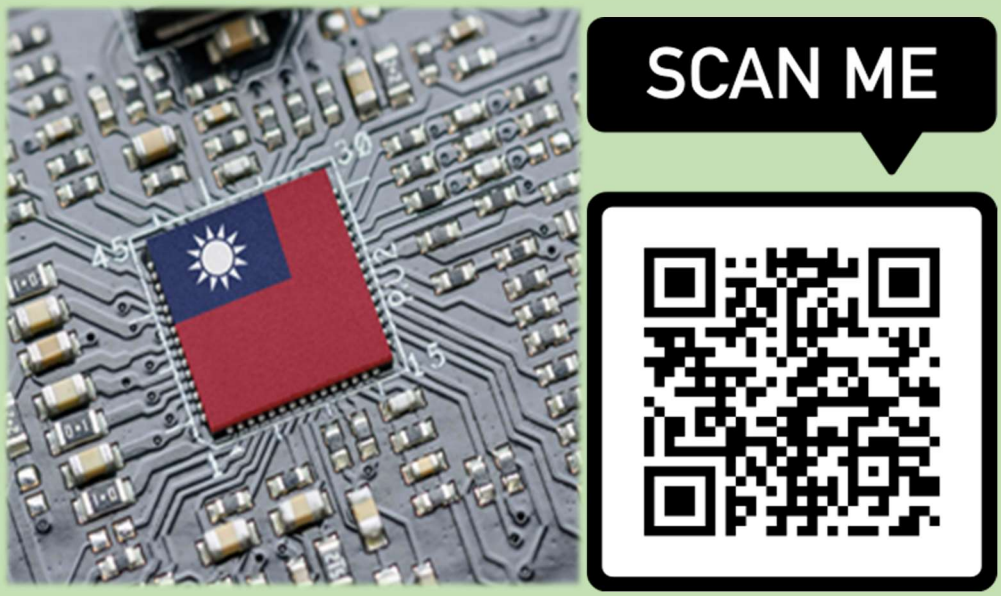

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1. Executive Summary

Semiconductors are the foundation of modern technology. As critical components of electronic products, semiconductors power the development of high-tech products and services, are a key force driving global economic development and technological innovation and are integral to applications in our daily lives and various industries. Today, leading-edge advanced semiconductors power the most sophisticated technology, including developing Artificial intelligence (AI) and building critical military capabilities.

Whilst the semiconductor industry had a challenging year in 2023, it is expected to rebound and recover in 2024. McKinsey reports that about 70% of the global semiconductor industry growth in the next decade is predicted to be driven by just three industries: automotive, computation and data storage, and wireless communications. More recently, the unprecedented success of OpenAI's ChatGPT has ushered generative AI to the mainstream, leading to an even greater appetite for advanced semiconductors.

Much of today's semiconductor supply capabilities are concentrated in Asia. The conflict between the U.S.A. and China over semiconductors has led to a reorientation of the global semiconductor supply chain. In particular, the U.S. CHIPS and Science Act and the on-going dispute between U.S.A. and China have significantly impacted the manufacturing and investment decisions of companies in and outside China. It has also spurred other countries to strengthen their semiconductor industries as they position themselves as an alternative to China in semiconductor production.

Recognizing the strategic importance of semiconductors, countries are also looking at ways to secure their semiconductor supply chains and to support their domestic semiconductor ecosystems amid increasing geopolitical tensions. The measures taken by countries – which take various forms from subsidies, regulations, investment incentives, friend-shoring and supporting research, development and innovation infrastructures – have significant impacts on the global semiconductor industry.

The escalating geopolitical tension and rapidly evolving global technology landscape call attention to the pivotal role Taiwan's semiconductor industry in the global semiconductor supply chain. Taiwan, a global semiconductor powerhouse, is home to some of the world's largest and most advanced semiconductor companies, including the Taiwan Semiconductor Manufacturing Company (TSMC) and ASE Technology Holding (ASEH) Company. It leads the world in wafer foundry and packaging and testing, two critical stages in the semiconductor manufacturing process, and is second globally in semiconductor design.

Taiwan's role in the global semiconductor industry makes it a natural and important partner for countries and global semiconductor companies. In view of the strategic importance of the semiconductor sector to Taiwan's economy and its global standing in technology, Taiwan's Ministry of Economic Affairs has outlined three areas of partnership, namely, 1) joining Taiwan's core cluster, 2) exploring the growing global market for semiconductor equipment and materials, and 3) establishing operations and research centers to tap into the fast-growing Asia market.

2. Background: Global Semiconductor Industry

A. Introduction

- **What Are Semiconductors**

Semiconductors, also known as integrated circuits (ICs) or chips, are tiny electronic devices (based primarily on silicon or germanium) composed of billions of components that can process, store, sense, and move data or signals.[1] They are the brains of modern electronic devices – from everyday consumer devices such as smartphones, household appliances and computers to specialized equipment in sectors such as healthcare, automotive, and defense. The availability of leading-edge semiconductors, in particular, is essential for advances in emerging technologies, such as AI, Internet of Things (IoT), 5G/6G communications and quantum computing.[2]

There are two major ways to categorize semiconductors: by type of integrated circuitry and by functionality. In terms of circuitry, a chip can be analog, digital, or mixed. The difference between analog and digital function has to do with the electric signals they process. In digital chips, the signals are binary. In analog chips, the signals are continuous, meaning they can take on any value within a given range, and they use more traditional circuit elements (resistors, capacitors and occasionally inductors).[3]

In terms of functionality, there are three broad categories of chips: logic chips, memory chips and DAO (discrete, analog and other).[4] Logic chips process and act as the 'brains' of electronic devices while memory chips are designed to store information. Both logic chips and memory chips are digital: they

[1] ASML, "The basics of microchips," 2024. https://www.asml.com/en/technology/all-about-microchips/microchip-basics.
[2] McKinsey & Company, "What is a semiconductor?" May 15, 2023.
[3] Ibid.
[4] ASML, "The basics of microchips," 2024. https://www.asml.com/en/technology/all-about-microchips/microchip-basics.

manipulate and store bits and bytes using transistors, and make it possible to create and use AI.[5] DAO chips, on the other hand, include optoelectronics and sensors, designed to transmit, receive and transform analog environmental inputs (such as sounds or images) into digital information.[6]

In recent years, advanced semiconductor packaging techniques, by enabling the integration of various components from different wafers into a single unit, have played a crucial role in the development of AI-specific chips such as Application-Specific Integrated Circuits (ASICs) and Systems-on-a-Chip (SoCs).[7]

ASICs are single-purpose chips used for performing repetitive processing routines such as scanning a barcode. SoCs, on the other hand, are essentially integrator chips that combine many chips and circuits in a single chip. As both ASICs and SoCs are designed from ground up for AI, they can perform more computations per unit of energy, resulting in faster processing speeds and lower energy consumption compared to general-purpose chips.[8]

There are also different nodes of semiconductors. Smaller nodes usually mean higher performance, lower power consumption, and higher density. The most advanced ones—below 7 nanometers (nm)— are the most sought after and most difficult to produce. Advanced semiconductors are often used for AI, high-performance computing, 5G/6G networks, and other emerging domains that require large amounts of data processing and computation.[9]

• Importance of Semiconductors

Due to their role in the fabrication of electronic devices across various industries, semiconductors stand at the forefront of modern technology. They are used in a wide range of applications, from consumer electronics to

[5] Ibid.

[6] Semiconductor Industry Association, "Comments of the Semiconductor Industry Association (SIA) on the Department of Energy "Notice of Request for Information (RFI) on Energy Sector Supply Chain Review," January 14, 2022.

[7] Ondrej Burkacky, Taeyoung Kim, and Inji Yeom, "Advanced chip packaging: How manufacturers can play to win," McKinsey, May 24, 2023.

[8] Saif M. Khan and Alexander Mann, Policy Brief: "AI Chips: What They Are and Why They Matter, An AI Chips Reference," Center for Security and Emerging Technology, April 2020.

[9] Antonio Varas, Raj Varadarajan, Ramiro Palma, Jimmy Goodrich, and Falan Yinug, "Strengthening the Global Semiconductor Supply Chain in an Uncertain Era," Boston Consulting Group, April 1, 2021.

industrial and medical equipment. Semiconductors are in devices such as smartphones and laptops, in communication infrastructures that form the backbone of the internet, enabling global connectivity, and in medical devices and equipment as well as implantable technology.[10]

As technology continues to evolve, we can expect to see even more innovative uses for semiconductor chips in the future. Notably, semiconductors form the basis of all advanced technologies, from wireless communication, IoT, AI, quantum computing and clean energy. When it comes to sustainability, semiconductors help advance methods for harnessing energy from renewable sources and can be found in wind turbines and solar farms. The constant evolution in semiconductor technology is paving the way for AI to expand its reach into various fields, increasing its impact on our daily lives.[11]

Analysis by the Global Semiconductor Alliance showed that the semiconductor industry helped create US$ 7 trillion in global economic activity and contributed US$ 2.7 trillion directly and indirectly to global GDP in 2012 — around 10% of global output.[12] Since then, semiconductors have further cemented their status as a foundational element of the modern and increasingly digitized world. The importance of semiconductors is particularly underscored by the drastic economic consequences of the semiconductor shortage in 2021. The U.S. Department of Commerce reported that the semiconductor shortage shaved an estimated US$ 240 billion off the country's GDP in 2021.[13] According to Deloitte, the semiconductor shortage contributed to lost revenue of more than US$ 500 billion worldwide, and US$ 210 billion in the auto industry in 2021 alone.[14]

Moreover, cutting-edge semiconductors are considered "dual-use goods," meaning they have applications in both civilian and military products.[15] They are key to critical infrastructure, such as energy and communications and are essential for innovation and advancement in internal and external security,

[10] Shiona McCallum, "What are semiconductors and how are they used?" BBC, August 4, 2023.
[11] Syed Alam, Timothy Chu, Michael Kurniawan, Jaya Shukla and Yanamadala Chowdary, "Unleashing the full potential of AI," Accenture, November 21, 2022.
[12] Global Semiconductor Alliance, "Why do Semiconductors Matter?" 2023. https://semismatter.com/why/
[13] U.S. Department of Commerce, Press Release: "Analysis for CHIPS Act and BIA Briefing," April 6, 2022.
[14] Gill Hofmeyr, "2022 semiconductor industry outlook," Deloitte, December 21, 2021.
[15] Matthew Schleich, DipNote: "Securing Semiconductors: How to Scale-up Global Semiconductor Production and Protect U.S. National Security at the Same Time," U.S. Department of State, May 15, 2023.

including defense and space.[16] In the case of military technology, for example, semiconductors and AI increasingly play a crucial role by enabling the development and operation of advanced communication systems, radar technology, weapons modeling systems, secure data encryption and modern warfighting technologies such as unmanned aerial vehicles (UAVs or drones) and cyber warfare. The U.S.A., for instance, has recognized the importance of maintaining a robust domestic semiconductor industry as a matter of national and economic security.[17]

• Semiconductor Industry Business Models

The semiconductor industry encompasses a diverse landscape of companies with varying business models. Because of high degrees of specialization and capital-intensive production processes, not many companies are involved in the design and production of chips.

According to Gartner, the 10 largest semiconductor vendors in 2023 cover 49.3% or almost half of the sales market share. Some companies, such as Intel, Samsung, SK Hynix, STMicroelectronics and Texas Instruments, are involved in all production stages, whereas others such as Qualcomm, Broadcom, NVIDIA, and Advanced Micro Devices, Inc. (AMD) are leading companies that focus on semiconductor design (see Table 1).

[16] Congressional Research Service, "Semiconductors and the Semiconductor Industry," April 19, 2023.

[17] The White House, Fact Sheet: "One Year after the CHIPS and Science Act, Biden-Harris Administration Marks Historic Progress in Bringing Semiconductor Supply Chains Home, Supporting Innovation, and Protecting National Security," August 9, 2023; National Institute of Science and Technology, U.S. Department of Commerce, "Chips for America: National Security," December 28, 2023.

Table 1: Top 10 Semiconductor Vendors by Revenue Worldwide: 2023

Unit: US$ Billion

Rank	Vendor	Revenue	Market Share (%)	Headquarter	Company Type
1	Intel	48.664	9.1	U.S.A.	IDM
2	Samsung Electronics	39.905	7.5	South Korea	IDM
3	Qualcomm	29.015	5.4	U.S.A.	Fabless
4	Broadcom	25.585	4.8	U.S.A.	Fabless
5	NVIDIA	23.983	4.5	U.S.A.	Fabless
6	SK Hynix	22.756	4.3	South Korea	IDM
7	AMD	22.305	4.2	U.S.A.	Fabless
8	STMicroelectronics	17.057	3.2	Switzerland	IDM
9	Apple	17.050	3.2	U.S.A.	NA
10	Texas Instruments	16.537	3.1	U.S.A.	IDM
	Others (Outside top 10)	268.853	50.7		
	Total Market	**533.025**	**100.0**		

Source: Gartner, "Gartner Says Worldwide Semiconductor Revenue Declined 11% in 2023," January 16, 2024.

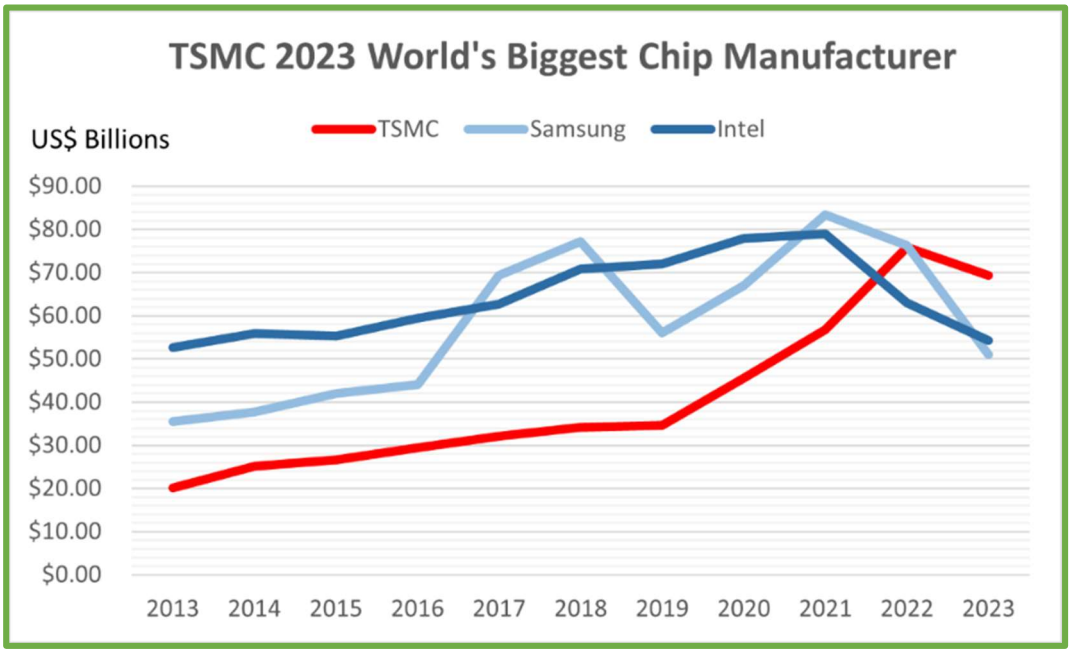
TSMC is a leading pure-play chip foundry serving fabless clients like Apple, AMD, NVIDIA, and Qualcomm. According to Taiwan-based analyst Dan Nystedt, TSMC generated US$ 69.3 billion in revenue last year (2023), surpassing Intel's US$ 54.23 billion and Samsung's US$ 50.99 billion semiconductor divisions (see Figure 1).[18] This propelled TSMC to become the world's largest semiconductor maker by revenue for the first time in 2023.[19] TSMC is usually not listed among the top 10 semiconductor firms since it is a supplier rather than a designer with chips under its brand name. Its leading-edge manufacturing services, however, has made TSMC an indispensable partner in producing advanced chips, fueling its rise to the top.[20]

[18] The difference in semiconductor vendor rankings could be due to various factors, such as the criteria used for ranking, the specific segments of revenue considered, or the timing of the data collection. Both compiled the numbers from calendar-year revenue figures but Gartner's results were published in January 2024 while Dan Nystedt's results were published in February 2024.

[19] Zo Ahmed, "TSMC earns $69.3 billion in 2023 becoming world's largest semiconductor company by revenue," Techspot, February 6, 2024.

[20] Keoni Everington, "Taiwan's TSMC becomes world's top chip maker by revenue for 1st time," Taiwan News, February 5, 2024.

Figure 1: World's Top Three Chip Manufacturers by Revenue: 2023



Source: Dan Nystedt, Twitter, February 4, 2024.

Depending on their level of integration and business model, semiconductor companies can be categorized into four main types: integrated device manufacturers (IDMs), fabless design firms, foundries and outsourced semiconductor assembly and test (OSAT) companies.[21] U.S.-headquartered companies such as Intel and Texas Instruments are leading IDMs while NVIDIA, Qualcomm, Broadcom and AMD are dominant fabless companies. Taiwan-headquartered companies such as TSMC and United Microelectronics Corporation (UMC) are key foundries while ASEH is a world leader in assembly, packaging, and testing of semiconductors (see Table 2).

[21] Antonio Varas, Raj Varadarajan, Ramiro Palma, Jimmy Goodrich, and Falan Yinug, "Strengthening the Global Semiconductor Supply Chain in an Uncertain Era," Boston Consulting Group, April 1, 2021.

Table 2: Type of Semiconductor Company by Business Model

TYPE	DESCRIPTION	EXAMPLES
IDMs	Companies that design, manufacture, and sell their own semiconductor products. They handle both the design and production processes in-house.	• Intel • Samsung • STMicroelectronics • Texas Instruments
Fabless companies	Companies focus solely on chip design and development and outsources the manufacturing (fabrication) process to external foundries.	• NVIDIA • Qualcomm • AMD • MediaTek
Foundries	Companies with specialized manufacturing facilities that produce semiconductor wafers based on designs provided by fabless companies. They offer fabrication (front-end manufacturing) services to multiple clients.	• TSMC • Samsung • UMC • GlobalFoundries
OSATs	Companies handle the assembly, packaging, and testing (back-end manufacturing) of semiconductor chips. They take the bare semiconductor dies (chips) and package them into final products (such as integrated circuits).	• ASE Technology Holding • Amkor Technology

- **Global Semiconductor Supply Chain**

The semiconductor manufacturing ecosystem is a global network characterized by its complexity and specialization. It involves a wide range of highly specialized companies and institutions that are geographically dispersed but interconnected through a supply chain encompassing the seven sectors, each with its own specialized role (see Table 3).[22] Each sector plays a crucial role in the semiconductor ecosystem, contributing to the advancement of technology and innovation.

[22] Antonio Varas, Raj Varadarajan, Ramiro Palma, Jimmy Goodrich, and Falan Yinug, "Strengthening the Global Semiconductor Supply Chain in an Uncertain Era," Boston Consulting Group, April 1, 2021.

Table 3: Sectors in Semiconductor Supply Chain

	SECTOR	DESCRIPTION
1.	**Research & Development (R&D)**	The research and development (R&D) sector determines the future capabilities and performance of semiconductor devices.
2.	**Design**	The blueprints for semiconductor devices, including the architecture and circuit design are created by engineers during this phase.
3.	**Front-End Manufacturing: Wafer Fabrication**	After the design stage, semiconductor chips are fabricated in facilities often referred to as fabs or foundries.
4.	**Back-End Manufacturing: Assembly, Testing and Packaging (ATP)**	After the wafers are fabricated, they are cut into individual chips, assembled into packages, tested for quality and functionality, and then prepared for shipment.
5.	**Electronic Design Automation (EDA) and Core Intellectual Property (IP)***	EDA refers to the software tools used for designing semiconductor devices. Core IP involves the essential designs and patents that are part of the semiconductor devices.
6.	**Equipment and Tools***	This sector provides the specialized machinery and tools required for semiconductor manufacturing, such as lithography equipment, etchers, and testers.
7.	**Materials***	Semiconductors require high-purity materials, including silicon, various gases, and chemicals used throughout the manufacturing process.

* These components are considered a specialized support ecosystem of chip manufacturing.

Semiconductor companies must invest heavily in people, facilities, and equipment. Due to the substantial capital expenditures required for research and development (R&D), design, and manufacturing processes, the semiconductor industry is characterized by its high barriers to entry. This means that even though demand for semiconductors is global, only a handful of countries and companies have the expertise, infrastructure and resources to produce them.

The U.S. semiconductor firms maintain a leading position in R&D. In 2022, total U.S. semiconductor industry investment in R&D was US$ 58.8 billion, while total R&D and capital expenditures by U.S. semiconductor firms,

including fabless companies, was US$ 109.6 billion.[23] Additionally, the "CHIPS for America" program, part of the broader "CHIPS and Science Act," which was signed into law on August 9, 2022, has an allocation of US$ 11 billion dedicated to advancing semiconductor R&D. The U.S.A. dominates the semiconductor design sector with companies like NVIDIA, Intel and Qualcomm.[24]

The U.S.A. also leads in design automation software known as electronic design automation (EDA), and reusable pieces of intellectual property (IP), called core IP. The top three EDA companies, namely, U.S.-based Cadence, Synopsys, and Mentor Graphics (a U.S.-based subsidiary of the German firm Siemens) control about 70% of the global EDA market. [25]

The precision and control required in wafer fabrication make it one of the most technology- and capital- intensive processes in manufacturing. In the wafer fabrication sector, Taiwan's TSMC holds the distinction of being both Taiwan's and the world's largest foundry.

Table 4 shows the ranking of the global top 10 foundries by revenue in the fourth quarter of 2023. TSMC had a global market share of 61.2%, increasing from 57.9% in the third quarter and 56.4% in the second quarter.[26] After TSMC, South Korea's Samsung Electronics Co. came in second in the fourth quarter with a market share of 11.3% after generating US$ 3.62 billion in sales, ahead of U.S.-based GlobalFoundries (US$ 1.85 billion in sales, 5.8% in market share). Taiwan's UMC ranked fourth, followed by China's Semiconductor Manufacturing International Corporation (SMIC) and Huahong Group. Israel's Tower Semiconductor Ltd., Taiwan's Powerchip Semiconductor Manufacturing Corporation (PSMC), China's Nexchip, and Taiwan's Vanguard International Semiconductor Corporation (VIS) rounded out the top ten (see Table 4).

[23] Semiconductor Industry Association, 2023 SIA Factbook, May 5, 2023.
[24] Matthew Fulco, "How Aerospace Can Improve Its Supply of Semiconductors," Aviation Week, June 13, 2023.
[25] Zeyi Yang, "Inside the software that will become the next battle front in US-China chip war," MIT Technology Review, August 18, 2022.
[26] TrendForce, Press Release: "Global Top 10 Foundries Q4 Revenue Up 7.9%, Annual Total Hits US$ 111.54 Billion in 2023, Says TrendForce," March 12, 2024.

Table 4: Ranking of Global Top 10 Foundries by Revenue: 2023Q4

Unit: US$ million

Ranking	Company	Revenue			Market Share	
		2023Q4	2023Q3	QoQ	2023Q4	2023Q3
1	TSMC (TW)	19,660	17,249	14.0%	61.2%	57.9%
2	Samsung (KR)	3,619	3,690	-1.9%	11.3%	12.4%
3	GlobalFoundries (USA)	1,854	1,852	0.1%	5.8%	6.2%
4	UMC (TW)	1,727	1,801	-4.1%	5.4%	6.0%
5	SMIC (CN)	1,678	1,620	3.6%	5.2%	5.4%
6	Huahong Group (CN)	657	766	-14.2%	2.0%	2.6%
7	Tower (IL)	352	358	-1.7%	1.1%	1.2%
8	PSMC (TW)	330	305	8.0%	1.0%	1.0%
9	Nexchip (CN)	308	283	9.1%	1.0%	1.0%
10	VIS (TW)	304	333	-8.7%	1.0%	1.1%
Total of Top 10		30,489	28,258	7.9%	95%	95%

Notes:
1. 2023Q4 USD: KRW= 1:1,321.85; USD: TWD= 1: 31.8177
2. Samsung's figures only include revenue from Samsung Foundry.
3. PSMC's revenue only derives from its foundry services.
4. Huahong Group's revenue includes revenue from Shanghai Huahong Grace Semiconductor Manufacturing Corporation and Shanghai Huali Microelectronics Corporation.
5. Huahong's 3Q23 revenue is an estimation from TrendForce.

Source: TrendForce, Press Release: "Global Top 10 Foundries Q4 Revenue Up 7.9%, Annual Total Hits US$ 111.54 Billion in 2023, Says TrendForce," March 12, 2024.

Despite having a foundry market share of less than 1% in the fourth quarter of 2023, Intel aims to become the second-largest foundry by 2030. It announced its collaboration with UMC in January 2024, and is reportedly going for Samsung's customer base of tech companies and chip designers as it works towards its goal of overtaking the South Korean conglomerate.[27] Intel also revealed its plans to retake the mantle of making the world's fastest chips from TSMC later this year (2024) with what it calls Intel 18A manufacturing technology and to extend that lead into 2026 with Intel 14A manufacturing technology.[28]

[27] Intel Corp., Press Release: "Intel and UMC Announce New Foundry Collaboration," January 25, 2024.

[28] Stephen Nellis and Max A. Cherney, "Intel signs Microsoft as foundry customer, says on track to overtake TSMC," Reuters, February 22, 2024; Matthew Connatser, "Intel Foundry is trying to poach Samsung's South Korean customers in its bid to become world's second-biggest foundry: report," Tom's Hardware, March 4, 2024.

Table 5: Ranking and Market Share of Global Top 10 Foundries by Revenue: 2022Q1-2023Q4

Ranking	Company	Market Share							
		2023Q4	2023Q3	2023Q2	2023Q1	2022Q4	2022Q3	2022Q2	2022Q1
1	TSMC (TW)	61.2%	57.9%	56.4%	60.1%	58.5%	56.1%	53.4%	53.6%
2	Samsung (KR)	11.3%	12.4%	11.7%	12.4%	15.8%	15.5%	16.4%	16.3%
3	GlobalFoundries (USA)	5.8%	6.2%	6.7%	6.6%	6.2%	5.8%	5.9%	5.9%
4	UMC (TW)	5.4%	6.0%	6.6%	6.4%	6.3%	6.9%	7.2%	6.9%
5	SMIC (CN)	5.2%	5.4%	5.6%	5.3%	4.7%	5.3%	5.6%	5.6%
6	Huahong Group (CN)	2.0%	2.6%	3.0%	3.0%	2.6%	3.3%	3.1%	3.2%
7	Tower (IL)	1.1%	1.2%	1.3%	1.3%	1.2%	1.2%	1.3%	1.3%
8	PSMC (TW)	1.0%	1.0%	1.2%	1.2%	1.2%	1.6%	1.9%	2.0%
9	Nexchip (CN)	1.0%	1.0%	n.a.	n.a.	n.a.	1.0%	1.4%	1.4%
10	VIS (TW)	1.0%	1.1%	1.2%	1.0%	0.9%	1.2%	1.5%	1.5%
Total of Top 10		**95%**	**95%**	**94%**	**98%**	**98%**	**97%**	**98%**	**98%**

Source: TrendForce, Press Release, "Global Top 10 Foundries Q4 Revenue Up 7.9%, Annual Total Hits US$ 111.54 Billion in 2023, Says TrendForce," March 12, 2024. TrendForce, Press Release, "Top 10 Foundries Experience 7.9% QoQ Growth in 3Q23, with a Continued Upward Trend Predicted for Q4, Says TrendForce," December 6, 2023. TrendForce, Press Release, "Top 10 Foundries Report Nearly 20% QoQ Revenue Decline in 1Q23, Continued Slide Expected in Q2, Says TrendForce," June 12, 2023. TrendForce, Press Release," June 12, 2023. TrendForce, Press Release, "Global Top 10 Foundries' Total Revenue Grew by 6% QoQ for 3Q22, but Foundry Industry's Revenue Performance Will Enter Correction Period in 4Q22, Says TrendForce," December 8, 2022. TrendForce, Press Release, "Consumer Terminals Market Reverses as Tide of Shortages Recedes, 2Q22 Output Value Growth at Top 10 Foundries Falls to 3.9% QoQ, Says TrendForce," September 27, 2022.

Table 5 shows the ranking and market share of the global top 10 foundries by revenue from the first quarter of 2022 to the fourth quarter of 2023. The global foundry market is dominated by the top 10 foundries, which captured 98% of the market for the most part of 2022 and dropped to 95% in the fourth quarter of 2023. With the sole exception of TSMC, the global market share of all other top foundries took a nosedive in the fourth quarter of 2023.

According to TrendForce, TSMC's global market share has increased from an average of 55.4% in 2022 to 58.9% in 2023, and even hit a record high of 61.2% in the fourth quarter. As of the fourth quarter of last year, the company held a 61.2% market share in foundry, with Samsung trailing behind with 11.3%. GlobalFoundries and UMC each took third and fourth places with shares of 5.8% and 5.4%. SMIC was fifth with 5.2%. In contrast, the global market share of

TSMC's main rival, Samsung Electronics, has dropped significantly from an average of 16.0% in 2022 to 12.0% in 2023 (see Table 5).

Outside of leading foundries like TSMC, Samsung, and Intel, other foundries tend to focus on the production of less advanced semiconductors. The world's third, fourth, and fifth largest foundries— U.S.-based GlobalFoundries, Taiwan-based UMC, and China-based SMIC, are significant players in more mature processes (28nm and above). By comparison, TSMC reported in the fourth quarter of 2023 that 67% of its revenue was from processes at or under 7 nm, and 82% from those at or below 28 nm.[29] The rapid growth in the AI sector also contributed to the demand for TSMC's advanced chips, further boosting its performance in 2023.[30]

After front-end fabrication of the chips, wafers are typically sent to other facilities for back-end manufacturing activities such as assembly, testing, and packaging (collectively known as ATP). Semiconductor packaging and testing is largely a labor-intensive process involving precise handling, assembly, and inspection of tiny and delicate semiconductor devices. The global semiconductor packaging and testing industry is largely dominated by OSAT companies. These firms specialize in providing third-party IC packaging and testing services, including wafer bumping, wafer probing, IC packaging, and IC testing. To take advantage of lower wages and input costs, a significant portion of the world's assembly, testing, and packaging (ATP) production is located in Asia. The global top two OSAT companies are Taiwan's ASEH and US-headquartered Amkor Technology. [31]

Semiconductor production is supported by a broad network of materials, equipment, software design tools, and core intellectual property suppliers. For example, semiconductor manufacturing equipment (SME) vendors specialize in providing the machines necessary to produce chips. U.S.-headquartered firms lead in the producing of nearly all types of semiconductor manufacturing equipment except photolithography and wafer handling. Leading global equipment suppliers headquartered in the United States include Applied

[29] Taiwan Semiconductor Manufacturing Company Limited, TSMC Financial Results -2023Q4. https://investor.tsmc.com/english/encrypt/files/encrypt_file/reports/2024-01/3e43ab2cb1ddad664ef9fe09c6ae80fa69167eea/4Q23Presentation%28E%29.pdf

[30] Jane Lanhee Lee, "TSMC halts sales declines after AI demand offsets chip malaise," Bloomberg, January 10, 2024.

[31] TrendForce, "Chinese Semiconductor Design Industry Diverts to Malaysia to Evade U.S. Controls; Potential Advanced Packaging Orders Surge for ASE," December 19, 2023.

Materials, Lam Research, and KLA, which together control about 35% of the global market for semiconductor production tools.[32]

The Netherlands' ASML is the sole maker of a key technology - extreme ultraviolet (EUV) photolithography - needed to manufacture the most advanced chips.[33] Meanwhile, four Japanese companies—JSR, Tokyo Ohka Kogyo, Shin-Etsu Chemical, and Fujifilm Electronic Materials—control about three-quarters of the market for high-end photoresists used in photolithography and photoengraving of semiconductors. They also have a near-monopoly on EUV lithography photoresists.

The semiconductor industry's supply of silicon wafers, too, is dominated by a few key players, including Japan's Shin-Etsu Chemical and Sumco, and Taiwan's GlobalWafers.[34]

Each of the seven sectors across different countries must work in harmony to ensure a smooth supply chain, from the initial concept to the final product reaching the consumer. Disruptions in any part of this chain can have significant ripple effects across multiple industries.

B. Global Industry Trends

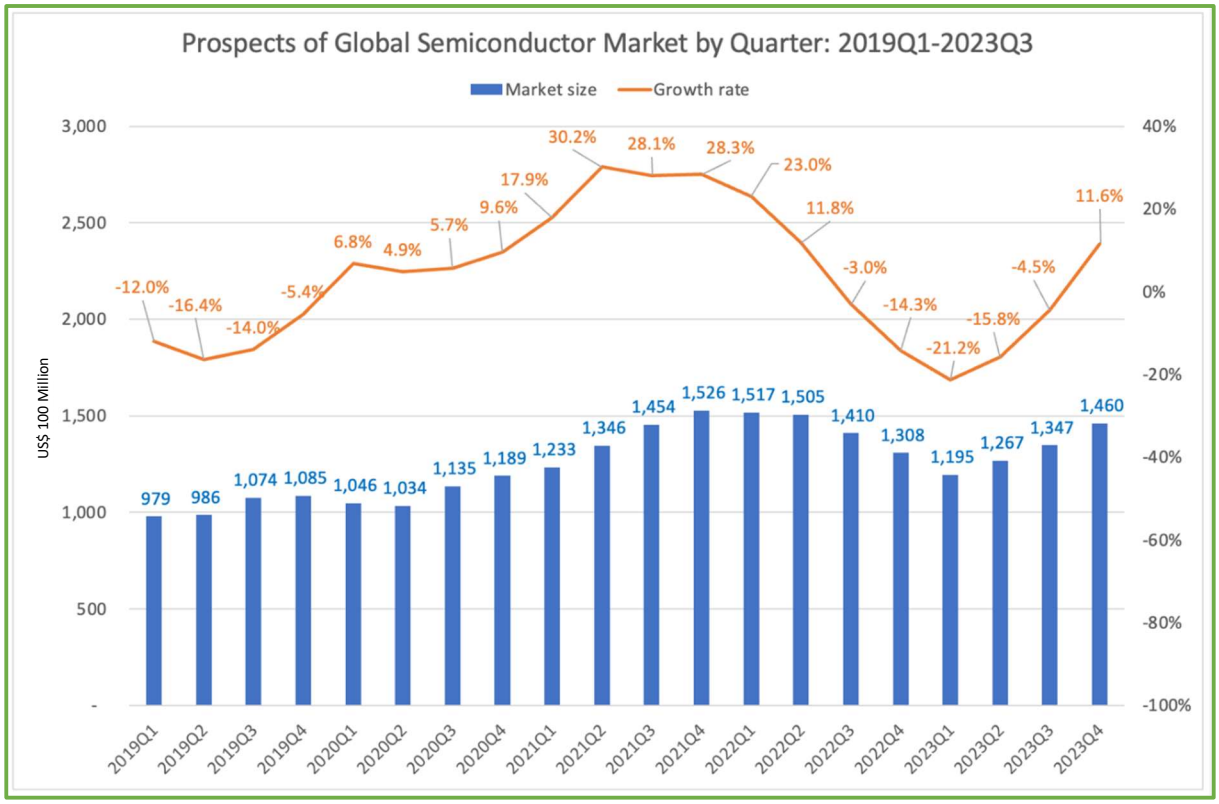
- **Market Growth**

With nearly US$ 1.5 trillion in annual trade flows by 2022, semiconductors are the world's 4th most traded product, after only crude oil, refined oil, and cars.[35] A vital and dynamic sector, the global semiconductor industry reported industry sales totaling US$ 526.8 billion in 2023.[36] Sales picked up during the second half of 2023. In fact, sales totaling US$ 146.0 billion in the fourth quarter of 2023 were 11.6% more than the total from the

[32] Lauly Li, "U.S. chip tool makers eye Southeast Asia as China business shrinks," Nikkei Asia, February 10, 2023.
[33] Toby Sterling, "ASML's next chip challenge: rollout of its new $350 mln 'High NA EUV' machine," Reuters, February 10, 2024.
[34] Yole Group, Press Release: "Globalwafers to mass produce advanced SiC wafers by 2025," October 27, 2023.
[35] Jennifer Meng, "Meeting of Semiconductor Associations from Around the World Underscores Importance of Global Chip Sector Collaboration," Semiconductor Industry Association, March 2, 2023.
[36] Semiconductor Industry Association, Press Release: "Global Semiconductor Sales Decreases 8.2% in 2023; Market Rebounds Late in Year," February 5, 2024.

fourth quarter of 2022 and 8.4% higher than the total from third quarter of 2023. As the industry recovers, a double-digit market growth is projected for 2024 (see Figure 2).

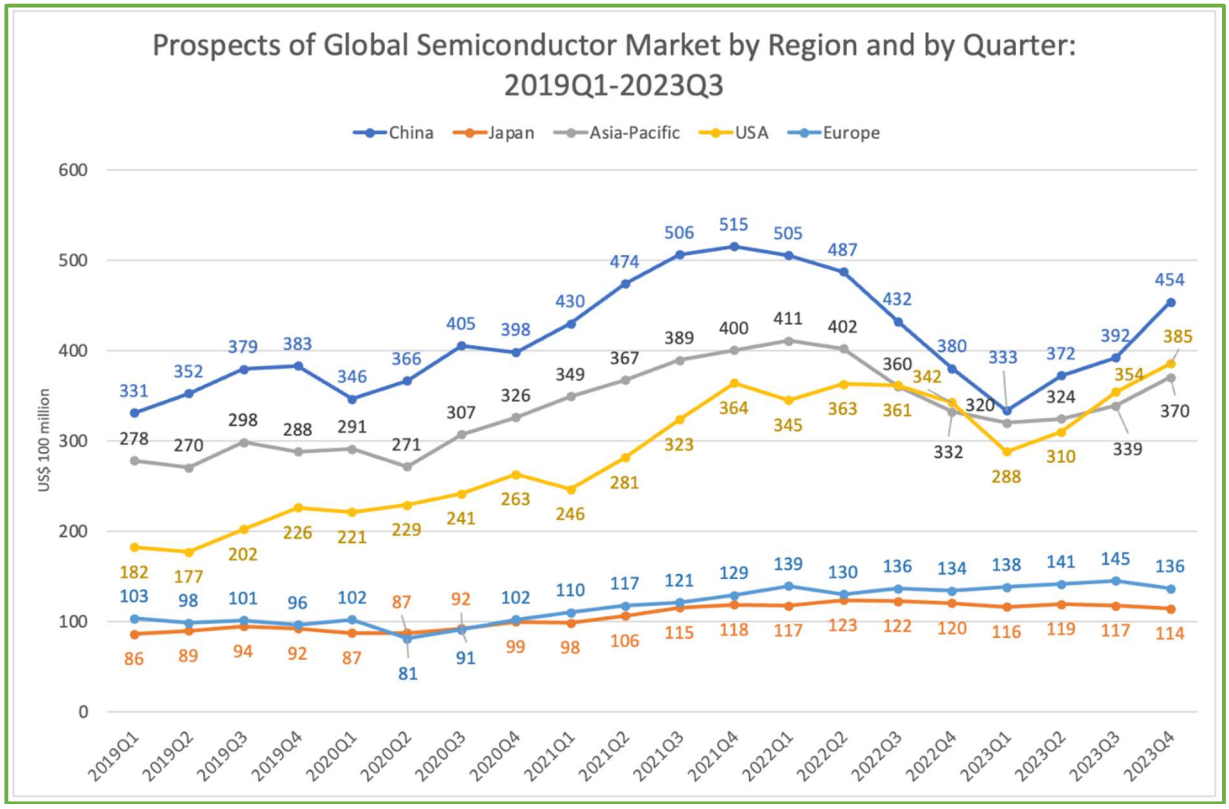
Figure 2: Prospects of Global Semiconductor Market by Quarter: 2019Q1-2023Q4



Source: Chia-Chen Lee, "Taiwan IC Industry Development in 2023Q4," IEK, ITRI, March 19, 2024, p. 2.

Figure 3 shows the prospects of the global semiconductor market by region and by quarter from the first quarter of 2019 to the fourth quarter of 2023. The global semiconductor market has experienced various shifts over the period. During the period from 2020 to 2022, the global semiconductor industry witnessed significant growth. In 2023, however, the semiconductor markets across the globe experienced a downturn in sales. This decline was influenced by various factors, including supply chain disruptions, geopolitical tensions, and fluctuations in demand.

Figure 3: Prospects of Global Semiconductor Market by Region and by Quarter: 2019Q1-2023Q4



Source: Chia-Chen Lee, "Taiwan IC Industry Development in 2023Q4," IEK, ITRI, March 19, 2024, p. 3.

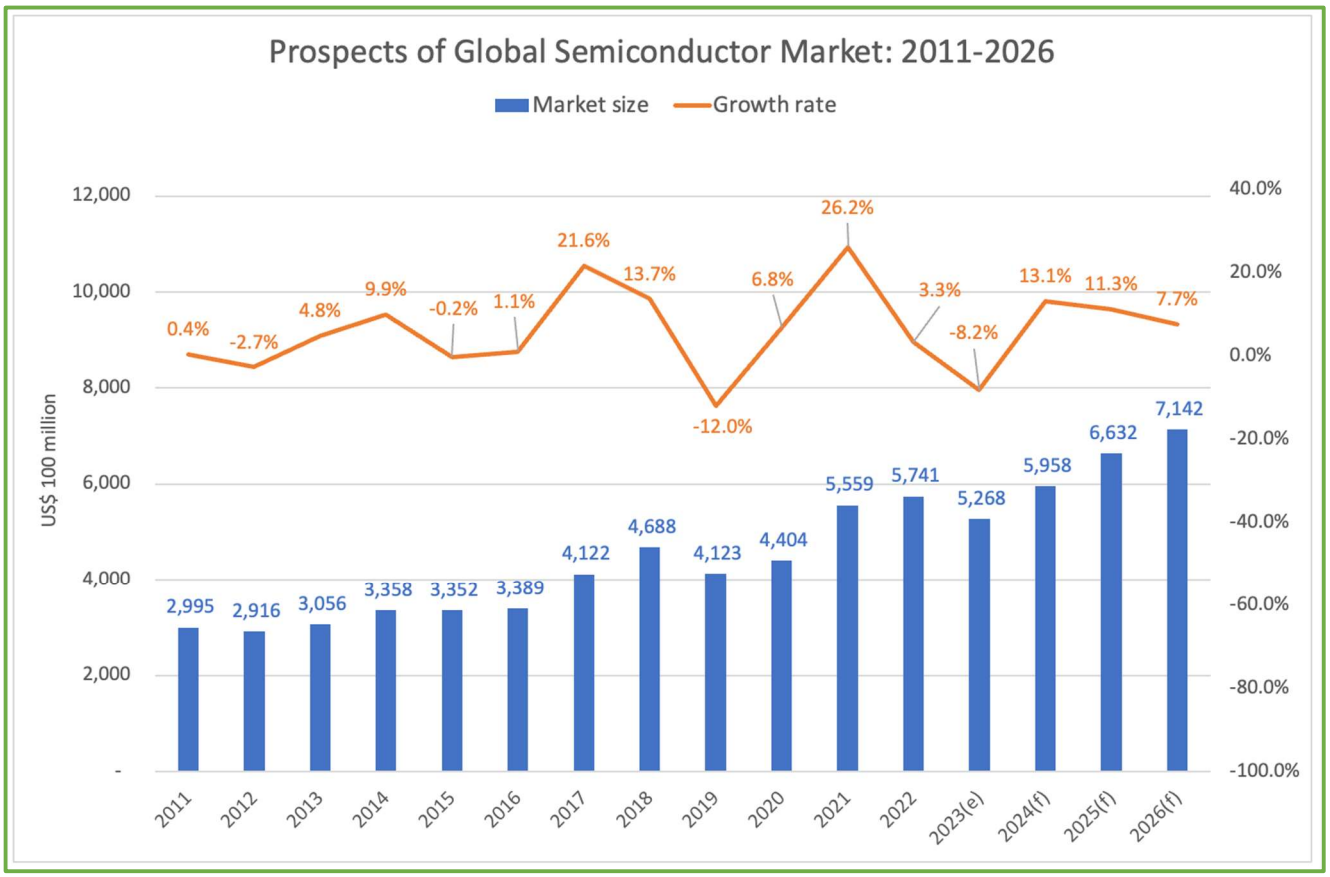
The semiconductor market in China faced significant challenges. The Chinese semiconductor industry reported peak sales of US$ 51.5 billion in the fourth quarter of 2021 but witnessed a sharp downturn in the first quarter of 2023, recording its lowest sales of US$ 33.3 billion since the first quarter of 2019. The U.S. government's increased restrictions on semiconductor exports to China, aimed at curbing the latter's technological advancements for national security reasons, have led to a sharp decline in China's semiconductor production and the lackluster market performance in the first quarter of 2023. Since then, however, the semiconductor market in China has shown signs of recovery and is expected to grow significantly in 2024 (see Figure 3).

Faced with demand fluctuations, supply chain disruptions, and geopolitical tensions, the semiconductor market in the Asia Pacific, the U.S.A and Japan similarly saw a significant fall in the first quarter of 2023. In the case of the semiconductor market in the U.S.A., sales dipped to a low of US$ 28.8 billion in the first quarter of 2023. Since then, the U.S. semiconductor market has seen steady growth in sales, from US$ 31.0 billion in the second quarter to

US$ 35.4 billion in the third quarter and then US$ 38.5 billion in the fourth quarter of 2023. This growth in sales is expected to continue in 2024. Like the U.S.A., the Asia Pacific and Japan are expected to rebound and recover in 2024.

Compared to other regions, the European semiconductor market saw less fluctuations in its sales and was the only region to experience growth in 2023. In the first quarter of 2023, its sales stood at US$ 13.8 billion, peaked at US$ 14.5 billion in the third quarter of 2023, and fell slightly to US$ 13.6 billion in the fourth quarter of 2023. The growth in the European semiconductor market is expected to continue in 2024.

Figure 4: Prospects of Global Semiconductor Market: 2011-2026



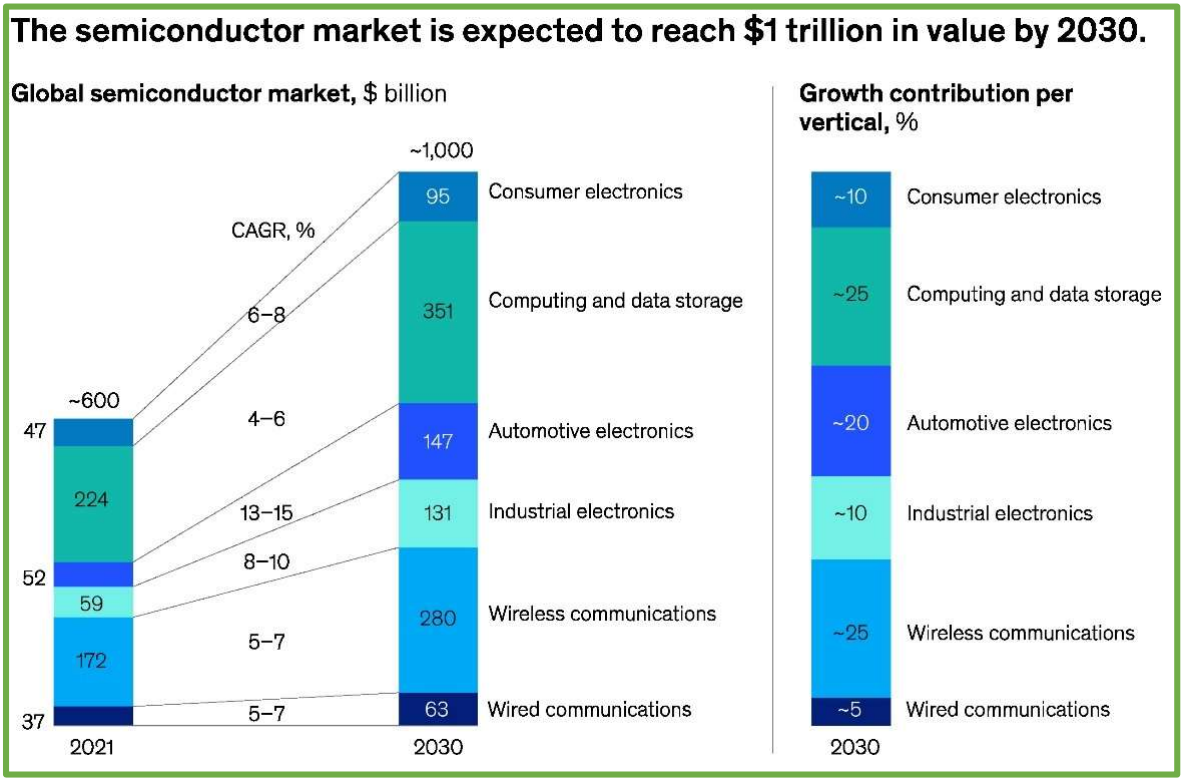
Source: Chia-Chen Lee, "Taiwan IC Industry Development in 2023Q4," IEK, ITRI, March 19, 2024, p. 4.

Figure 4 shows the prospects of global semiconductor market from 2011 to 2026. The global semiconductor market has witnessed significant growth over the past decade, driven by technological advancements, increasing demand for electronic devices, and emerging applications. In 2022, the

industry recorded its highest-ever annual total of US$ 574.1 billion. Compared to 2022, global semiconductor market shrank 8.2% in 2023, with sales totaling US$ 526.8 billion. In 2024, the global semiconductor market is projected to recover and continue this growth path in 2025 and 2026 (see Figure 4).

McKinsey projects the value of the global semiconductor market will nearly double, surpassing US$ 1 trillion by 2030.[37] Looking ahead, McKinsey reports that about 70% of the global semiconductor industry growth in the next decade is predicted to be driven by just three industries: automotive, computation and data storage, and wireless communications (see Figure 5).

Figure 5: McKinsey's Projection of the Global Semiconductor Market in 2030



Source: Ondrej Burkacky, Matteo Mancini, Mark Patel, Giulietta Poltronieri, and Taylor Roundtree, "Exploring new regions: The greenfield opportunity in semiconductors," McKinsey & Company, January 29, 2024.

Semiconductors are critical for the development of autonomous vehicles and advanced driver-assistance systems (ADAS), which emphasizes electrification, autonomous driving and connectivity.[38] From advanced lighting systems and adaptive headlights to lightweight electric vehicles,

[37] Ondrej Burkacky, Julia Dragon, and Nikolaus Lehmann, "The semiconductor decade: A trillion-dollar industry," McKinsey and Company, April 1, 2022.

[38] Infineon, "The future is now: how semiconductors are driving the evolution of mobility," Business Reporter, October 4, 2023.

semiconductors enable improved safety, efficiency and connectivity on the road, and drive the transformation to clean, safe and smart mobility.[39] According to the International Data Corporation (IDC), ADAS accounts for the largest share of the automotive semiconductor market, with a compound annual growth rate (CAGR) of 19.8% by 2027, accounting for 30% of the automotive semiconductor market in that year.[40] As more and more automotive electronics rely on chips, the demand for semiconductors will be long-term and steady.

In the realm of computing and data analytics, advanced semiconductors with feature sizes of 5nm and below play a pivotal role in enabling value creation and growth in storage, compute, memory, and networking.[41] When it comes to the production of advanced semiconductors with feature sizes of 5nm and below, Taiwan stands out as a global leader. Semiconductors power the algorithms and computations that underpin tasks driven by AI, including predictive analytics and natural language processing, enabling businesses and organizations to derive valuable insights from their data and make informed decisions. They also play a crucial role in innovations like in-memory processors and system-integrated memristor computing-in-memory chips, which are redefining energy efficiency in data processing.[42] In the longer term, there are forecasts suggesting that AI chips (mainly generative AI chips) could reach US$ 400 billion in sales by 2027.[43]

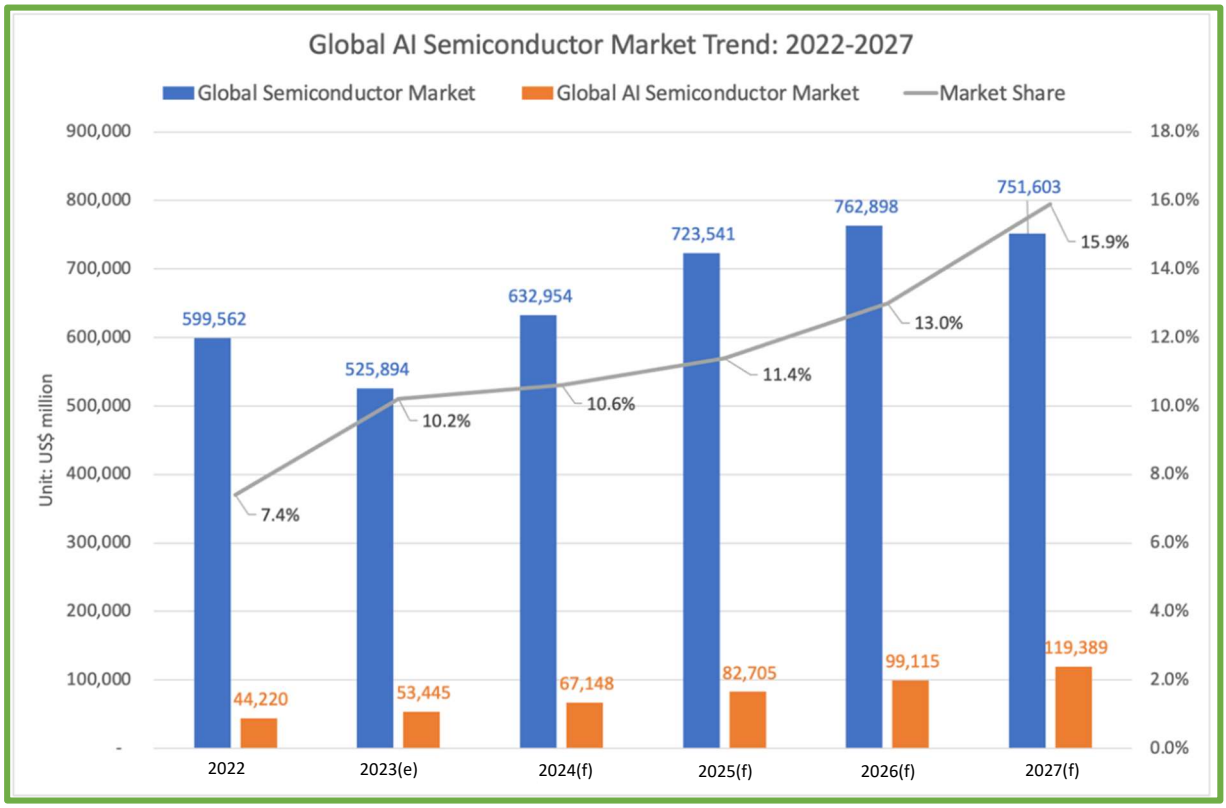
Additionally, semiconductors are essential in the development of wireless communication networks and devices, particularly for achieving high-frequency performance required for next-generation connectivity. Even before the maturity of 5G, research and development of next generation 6G technology is already underway. Market leader MediaTek, for example, released its "6G Vision White Paper" in January 2022.[44] With widespread

[39] Ibid.
[40] Miguel Carreon, Angel Wu and Helen Chiang, "The Semiconductor Market Will Recover in 2024 With an Annual Growth Rate of 20%, Says IDC," International Data Corporation, December 21, 2023.
[41] Chetan Arvind Patil, "AI Silicon Opportunity: Revolutionising Memory, Storage, Compute, And Networking," Electronicsforu, January 18, 2024.
[42] Jake Hertz, "International Researchers Move the Needle on Memristor Technology," All About Circuits, December 19, 2023.
[43] Christie Simons and Brandon Kulik, "2024 global semiconductor industry outlook," Deloitte, November 29, 2023.
[44] MediaTek, Press Release: "MediaTek Highlights How 6G Will Accelerate Digital Transformation in New White Paper," January 18, 2022.

rollout of 6G wireless technology projected to happen in 2030, semiconductors for wireless communications are expected to be a major growth engine.[45]

While the global semiconductor market size is expected to grow from US$ 633.0 billion in 2024 to US$ 762.9 billion in 2026, before falling to US$ 751.6 billion in 2027, the global AI semiconductor market size is expected to continue its strong growth trajectory from 2022 to 2027, with double-digit growth from 2023 to 2027. When the global semiconductor market declined 12.3% to US$ 525.9 billion in 2023, the AI semiconductor market was forecasted to grow from US$ 44.2 billion in 2022 to US$ 53.4 billion in 2023, an increase of 20.9% from 2022, according to Gartner. By 2027, AI chips revenue is expected to be more than double the size of the market in 2023, reaching US$ 119.4 billion. (see Figure 6 and Table 6).

Figure 6: Global AI Semiconductor Market Trend: 2022-2027



Source: Hsuan Chih Wang, "The AI Semiconductor Market Shows Strong Growth, with Emerging Consumer AI Applications," IEK, ITRI, October 2, 2023, p. 1.

[45] ASE Global, "5G/6G Wireless Communications," 2023. https://ase.aseglobal.com/applications/5g-6g/

Table 6: Global AI Semiconductor Market Growth Trend: 2023-2027

	2023	2024(e)	2025(f)	2026(f)	2027(f)
Global Semiconductor Market	-12.3%	20.4%	14.3%	5.4%	-1.5%
Global AI Semiconductor Market	20.9%	25.6%	23.2%	19.8%	20.5%

Source: Hsuan Chih Wang, "The AI Semiconductor Market Shows Strong Growth, with Emerging Consumer AI Applications," IEK, ITRI, October 2, 2023, p. 1.

The growing use of devices and applications with AI and other new technologies across the globe means that semiconductors are fundamental to the digital transformation shaping our world and the outlook is optimistic for the semiconductor industry.[46]

- ## Chip Miniaturization

The demand for smaller, more powerful, and energy-efficient chips continues to drive innovation in chip design. The transition to advanced semiconductor manufacturing processes allows for the creation of more densely packed transistors, resulting in chips that deliver higher performance while consuming less power.

TSMC, Samsung and Intel, collectively known as the "Big Three" in the industry, are recognized for their significant contributions to semiconductor manufacturing and technological advancements. Currently, TSMC and Samsung are producing 3 nanometer (nm) semiconductors while Intel is at the 5 nm mark. All three aim to begin mass production using the 2 nm process technology in 2025.[47] Intel unveiled its ambitious plan to collaborate with Microsoft in manufacturing 1.8 nm chips by the end of 2024, with the ultimate goal of surpassing Samsung Electronics and becoming the world's second-largest chipmaker through the successful production of 1.4 nm chips by 2027.[48] Samsung aims to achieve mass production at the 1.4 nm level by 2027, while TSMC is targeting 2027 to 2028, according to various media reports.[49]

[46] Parichart Jiravachara, "How semiconductor plays as a crucial element for economy," Deloitte, March 2022.
[47] Yifan Yu, "Intel joins 1.4-nanometer chip race against TSMC and Samsung," Nikkei Asia, February 22, 2024.
[48] Hyoun-Soo Kim, "Intel and Microsoft forge alliance to mass produce 1.8nm chip," Dong-a Ilbo, February. 23, 2024.
[49] Yifan Yu, "Intel joins 1.4-nanometer chip race against TSMC and Samsung," Nikkei Asia, February 22, 2024.

• Growth of Advanced Semiconductor Packaging

Advanced semiconductor packaging is not one specific packaging technique, but rather an array of technologies and capabilities that allow the combination of multiple chips and other components to form a highly integrated, multi-functional sub-system which can then be assembled onto laminates, panels, or circuit boards. Advanced packaging is categorized as front-end 3D which stacks chips or wafers vertically and back-end 2.5D Chip-on-Wafer-on-Substrate (CoWoS) that interconnects dies horizontally via a redistribution layer (RDL) or interposer.[50] Compared to conventionally packaged chips on a printed circuit board, advanced packaging achieves greater function, performance, and power savings.[51]

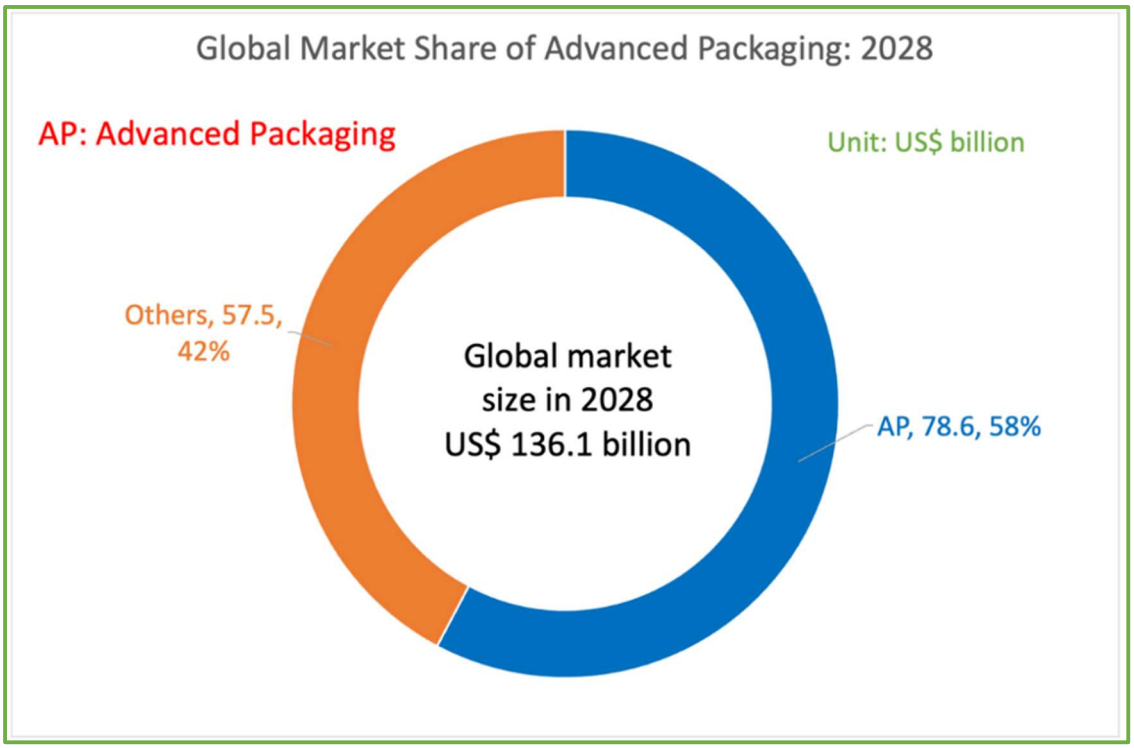
With Moore's Law becoming more challenging; demands of electronic products with smaller size, more powerful performance and lower cost growing; the need for improved connectivity rising; and a surge in the use of high-performance chips requiring better heat dissipation, there is a growing shift towards prioritizing advanced packaging. Moreover, advanced packaging offers a higher-value opportunity than traditional back-end packaging, and more players are jumping on the advanced semiconductor packaging bandwagon.[52]

Foundries like TSMC, IDMs such as Intel and Samsung, and OSAT companies are important players in the global semiconductor packaging and testing industry.[53] The global semiconductor packaging and testing industry is largely dominated by OSAT companies. These firms specialize in providing third-party IC packaging and testing services, including wafer bumping, wafer probing, IC packaging, and IC testing. The global top two OSAT companies are Taiwan’s Advanced Semiconductor Engineering (ASE) Technology Holding and US-headquartered Amkor Technology.[54]

[50] Counterpoint, “AI Chip Market: Advanced Packaging Capabilities Key Differentiating Factor,” July 24, 2023.
[51] National Institute of Standards and Technology, Department of Commerce, United States, “National Advanced Packaging Manufacturing Program”, November 20, 2023.
[52] Ondrej Burkacky, Taeyoung Kim, and Inji Yeom, “Advanced chip packaging: How manufacturers can play to win,” McKinsey & Company, May 24, 2023.
[53] TrendForce, “Chinese Semiconductor Design Industry Diverts to Malaysia to Evade U.S. Controls; Potential Advanced Packaging Orders Surge for ASE,” December 19, 2023.
[54] Ibid.

The AI boom has driven the development of high-performance computing chips (HPC) and sparked the demand for advanced semiconductor packaging technologies. Demand for advanced packaging by AI chipmakers, like NVIDIA and AMD, is skyrocketing as they seek to improve chip performance.[55] Consequently, the advanced packaging market is rapidly catching up with the traditional packaging market, and it is expected that the advanced packaging portion of the total semiconductor packaging market will increase from 47% in 2022 to 58% in 2028, with a compound annual growth rate (CAGR) of 10%. In fact, the whole semiconductor packaging market is expected to reach US$ 136.1 billion by 2028 (see Figure 7).

Figure 7: Global Market Share of Advanced Packaging: 2028



Source: Yunnie Chang, "The Sustainable Management of Semiconductor Packaging and Testing," IEK, ITRI, October 30, 2023, p.14.

Given the rapidly expanding demand for advanced packaging, it is unsurprising that leading chipmakers and OSAT companies are investing in new technologies and expanding their capabilities to meet the growing demand for advanced packaging solutions.

[55] Lucy Harley-McKeown, "How AI boom will benefit these nine chipmakers in 2024," Yahoo Finance, December 27, 2023.

- ## Development and Innovation of Various Day-to-day and Industrial Applications

By delivering new functionalities, better performance and lower cost with each generation, advances in chips have spawned new products and have had a profound impact on various fields. It is expected that more AI functions will be integrated into personal devices starting in 2024. AI smartphones, AI PCs, and AI wearable devices will be gradually launched into the market. This, in turn, will positively stimulate the increase in demand for semiconductors and advanced packaging.

Artificial Intelligence

2023 has been described as generative AI's breakout year.[56] Following the unprecedented success of OpenAI's ChatGPT when it was launched in November of 2022, other generative AI tools such as Google's Gemini and Microsoft's Copilot AI were introduced in quick succession. As the year progressed, numerous startups also emerged to innovate with generative AI, leading to the growing use of generative AI in data centers in the near term.[57]

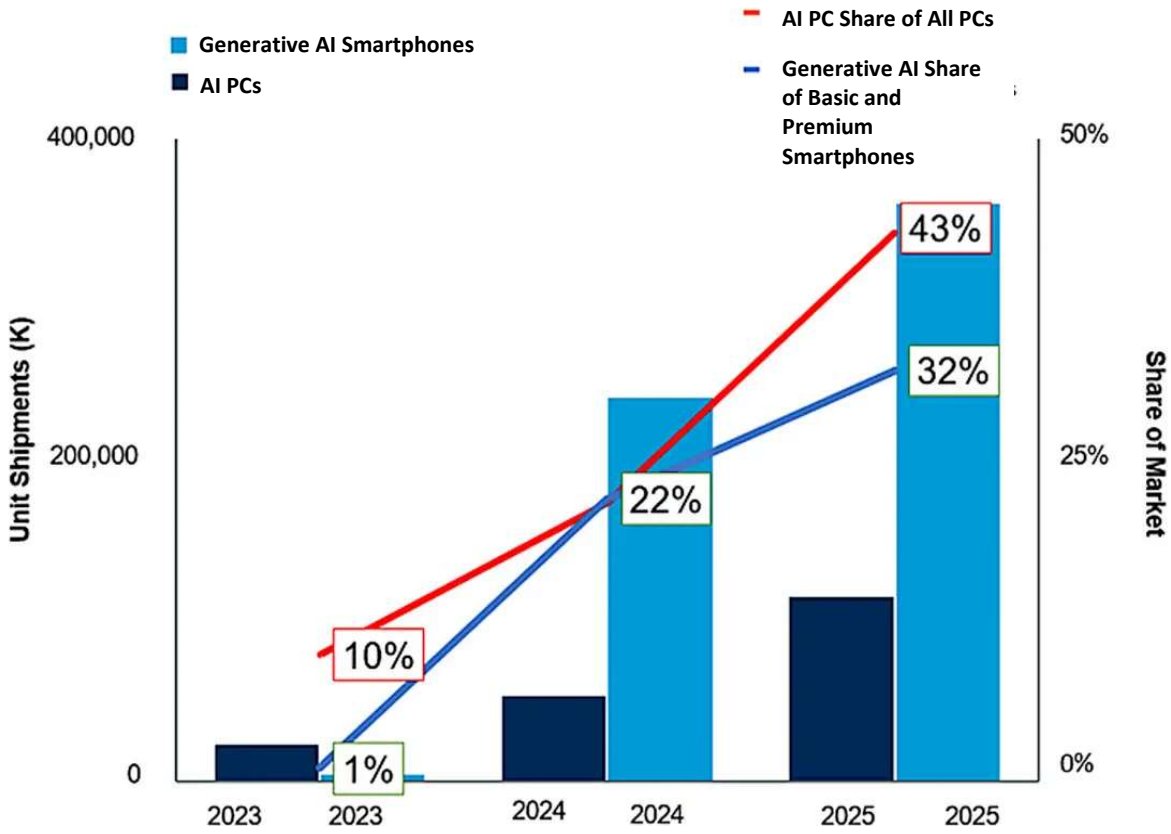
As generative AI is ushered to the mainstream, more users are experimenting directly with generative AI applications and the demand for consumer goods with AI applications amplifies across the globe.

With the increasing use of a wide range AI-based applications in data centers, edge infrastructure and endpoint devices, the demand for high-performance graphics processing units (GPUs) and optimized semiconductor devices is soaring. [58] In fact, worldwide shipments of AI PCs and generative AI smartphones are projected to total 295 million units by the end of 2024, up from 29 million units in 2023, according to a forecast from Gartner, Inc.[59] Gartner estimates 240 million generative AI smartphones and 54.5 million AI

[56] Alex Singla, Alexander Sukharevsky, Bryce Hall, Lareina Yee and Michael Chui, "The state of AI in 2023: Generative AI's breakout year," McKinsey, August 1, 2023.
[57] Lori Perri, "What's New in Artificial Intelligence from the 2023 Gartner Hype Cycle," Gartner, August 17, 2023.
[58] Alan Priestley, "Forecast: AI Semiconductors, Worldwide, 2021-2027, 3Q23 Update," Gartner Research, October 17, 2023.
[59] Gartner, Press Release: "Gartner Predicts Worldwide Shipments of AI PCs and GenAI Smartphones to Total 295 Million Units in 2024," February 7, 2024.

PCs will be shipped by the end of 2024 (see Figure 8). This will represent 22% of basic and premium smartphones and 22% of all PCs in 2024.

Figure 8: AI PCs and Generative AI Smartphones Market Share Worldwide: 2023-2025



Source: Gartner, Press Release: "Gartner Predicts Worldwide Shipments of AI PCs and GenAI Smartphones to Total 295 Million Units in 2024," February 7, 2024.

Top companies in the AI semiconductor market include NVIDIA, AMD and Intel Corporation. All three recognize the significant potential of AI-powered personal computers and are heavily investing in the AI PC market. At the recent CES 2024, all three unveiled processors specifically for AI PCs.[60] These chips feature a dedicated neural processing unit (NPU), offering enhanced data privacy, longer battery life, and expanded AI applications compared to regular PCs. However, in contrast to Gartner's optimistic outlook on AI PCs, AMD struck a more cautious tone, acknowledging that widespread consumer adoption of AI PCs may be slow, as the initial models will not differ

[60] Yifan Yu, "AMD and Intel bet on AI PCs to challenge Nvidia chip dominance," Nikkei Asia, January 11, 2024; NVIDIA, Press Release: "NVIDIA Brings Generative AI to Millions, With Tensor Core GPUs, LLMs, Tools for RTX PCs and Workstations," January 8, 2024.

significantly from traditional PCs until more AI-native applications are developed.[61]

Internet of Things (IoT)

IoT applications cannot work without sensors and integrated circuits, so all IoT devices will require semiconductors to allow for the seamless integration of physical objects into the digital world, enabling smart homes, smart cities, and industrial automation.

The potential economic value that the IoT could unlock is large and growing. By 2030, McKinsey estimates that it could enable US$ 5.5 trillion to US$ 12.6 trillion in value globally, including the value captured by customers of IoT products and services.[62]

Electric Vehicles (EVs)

In the automotive sector, semiconductors are key components in the electrification of vehicles. A typical car, with an internal combustion engine, today uses between 50 and 150 chips to run onboard electronics that manage lighting, fuel efficiency, and torque vectoring. When it comes to electric vehicles (EVs), where everything runs on electricity or a radio frequency signal that is managed by semiconductors, there is an exponential rise in the number of chips. Currently, some of the latest EVs use more than 3,000 chips.[63] In fact, the amount of silicon content in most cars is slated to exceed US$3,000 compared to US$ 300-350 a decade ago.[64] For high-end EVs, the chip price tag could go up to as much as US$ 6,000 per unit in the near future.[65] A report by the Rocky Mountain Institute (RMI) predicts that two thirds of global car sales

[61] Benzinga, "Nvidia Leads AI Chip Rivalry with New GPUs, While AMD and Intel Bet Big on AI PCs," Business Insider, January 11, 2024.
[62] Michael Chui, Mark Collins, and Mark Patel, "IoT value set to accelerate through 2030: Where and how to capture it," McKinsey & Company, November 9, 2021.
[63] Economic Development Board, Singapore, "Big hopes as Singapore gears up to ride EV microchip boom," February 6, 2024.
[64] Doug Parker and Christopher Thomas, "Winning Share in Automotive Semiconductors," McKinsey & Company, Autumn 2013; Third Bridge, "Automotive Chip Procurement – Silicon Content Per Vehicle and OEM Prioritisation," March 2022.
[65] Economic Development Board, Singapore, "Big hopes as Singapore gears up to ride EV microchip boom," February 6, 2024.

could be EVs by 2030.[66] On Semiconductor, Infineon, and STMicroelectronics are some of the IDMs that produce chips for Electric Vehicles (EVs).

C. Geo-politics and Policies in the Global Semiconductor Supply Chain

The onset of the trade war and technology war between the United States and China in 2018, the outbreak of the COVID-19 pandemic in 2020 and natural disasters such as earthquakes have exposed the vulnerabilities of a highly geographically concentrated global semiconductor supply chain. With the rise of AI, the connection between semiconductors and military, economic, and geopolitical strength has further intensified. Similar to the centrality of oil in the past century, semiconductors now occupy a central role in geopolitics, great-power rivalries, and trade, and have increasingly become a significant point of contention in the US-China relationship.

• U.S. – China conflict over Semiconductors

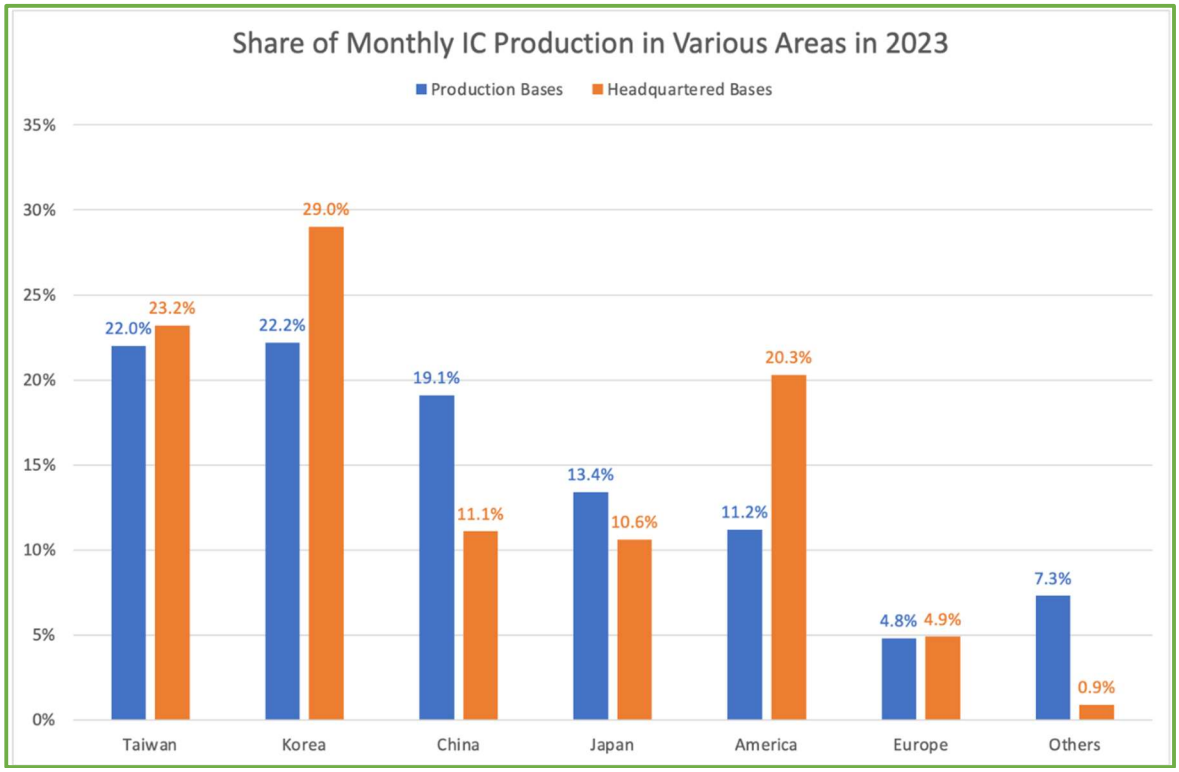
The United States is presently the global leader in the semiconductor industry. In 2022, the U.S.A. had a 48% (US$ 258 billion) market share, while South Korea had 19%, the E.U. and Japan each had 9%, Taiwan had 8%, and China accounted for 7% of the global chip sales (US$ $574 billion market).[67] Semiconductors were the fifth largest U.S. export; and the industry directly employed more than 300,000 people in the U.S. and supported nearly 1.8 million additional U.S. jobs in 2022.[68] However, the global share of semiconductors manufactured in the United States has declined from 37% in 1990 to about 12% in 2022.[69]

Recognizing the strategic importance of the semiconductor industry, countries like Taiwan, South Korea, Japan, China, India, Singapore, and

[66] Nick Carey, "As prices fall, two thirds of global car sales could be EVs by 2030, study says," Reuters, September 15, 2023.
[67] Semiconductor Industry Association, 2023 SIA Factbook, May 5, 2023. https://www.semiconductors.org/wp-content/uploads/2023/05/SIA-2023-Factbook_1.pdf. Accessed April 1, 2024.
[68] Semiconductor Industry Association, 2022 SIA Factbook, May 5, 2022. https://www.semiconductors.org/wpcontent/uploads/2022/05/SIA-2022-Factbook_May-2022.pdf. Accessed April 1, 2024.
[69] Semiconductor Industry Association, Press Release: "SIA Applauds Enactment of CHIPS Act," August 9, 2022.

Malaysia actively collaborate to drive innovation, foster talent, and secure their positions in the global market. Taiwan, for example, is home to TSMC, a world leader in semiconductor fabrication, South Korea is home to tech giants Samsung Electronics and SK Hynix, while Singapore hosts international semiconductor companies such as GlobalFoundries.[70]

Figure 9: Share of Monthly IC Production in Various Areas: 2023



Source: Chia-Chen Lee, "Policy-Driven Regional Semiconductor Manufacturing development," IEK, ITRI, March 20, 2024, p. 1.
Note: The above statistics encompass the entire global integrated circuit (IC) production, which includes not only pure-play foundries but also integrated device manufacturers (IDMs) and other types of semiconductor companies.

Figure 9 shows the global distribution of monthly production capacity of 8-inch equivalent integrated chips (ICs) from pure-play foundries, IDMs and other types of semiconductor companies in various areas in 2023. According to Knometa Research, the total global monthly production capacity of ICs (including image sensors) on 8-inch equivalent wafers in 2023 was approximately 23.2 million wafers, and this is expected to increase to 24.3 million units per month in 2024.

[70] Economic Development Board Singapore, Press Release: "GlobalFoundries officially opens US$4 billion expansion facility in Singapore, creating 1,000 new jobs," September 12, 2023.

In terms of production bases (include fabs of domestic and foreign-invested companies in the country), South Korea tops the list with its production of close to 5.2 million wafers per month, accounting for 22.2% of the global capacity. Taiwan ranks a close second with 5.1 million wafers per month, accounting for 22.0% of global capacity. Third-ranked China produces 4.4 million wafers per month, accounting for 19.1% of global capacity. Japan ranks fourth with 3.1 million wafers per month, accounting for 13.4% of global capacity. The Americas ranks fifth with almost 2.6 million wafers per month, accounting for 11.2% of global capacity. Sixth-ranked Europe produces 1.1 million wafers per month, accounting for 4.8% of global capacity. Other regions (including semiconductor fabs in Singapore, Israel, and Malaysia) have a combined capacity of nearly 1.7 million wafers per month, accounting for 7.3% of global capacity (see Figure 9).

In terms of headquartered bases (include fabs in home country and various host countries of multinational semiconductor companies), South Korea again tops the list with 6.7 million wafers per month, accounting for 29.0% of global capacity. Taiwan ranks second with 5.4 million wafers per month, accounting for 23.2% of global capacity. Third-ranked Americas produces 4.7 million wafers monthly (accounting for 20.3% of global capacity). China ranks fourth with 2.6 million wafers per month, accounting for 11.1% of global capacity. Fifth-ranked Japan produces 2.5 million wafers monthly, accounting for 10.6% of global capacity. Europe ranks sixth, with 1.138 million wafers per month, accounting for 4.9% of global capacity. Other regions have a combined capacity of 0.2 million wafers per month, accounting for 0.9% of global capacity (see Figure 9).

Both Taiwan and South Korea consistently lead in production capacity, whether in terms of production by only semiconductor fabs based in the country or including those at home and produced outside the country. Overall, Taiwan contributes 22.0% of global capacity, while South Korea boasts nearly 30% of the world's production capacity.

When a comparison is made between the countries where companies are headquartered and where wafer fabs are located, we can see a more pronounced difference in the capacity share of the Americas, China, and other regions under these two categories. As of 2023, although American companies

have 20.3% of the global capacity, only 11.2% of the global manufacturing capacity is in the Americas. This reflects the industry model in the Americas, which is mainly based on IC design, and the result of high operating costs faced by manufacturers setting up factories locally.

Meanwhile, China has 19.1% of the global capacity but the actual capacity owned by Chinese companies only accounts for 11.1% of the total global capacity (see Figure 9). Many foreign companies operate wafer fabs in China, such as SK Hynix owning NAND and DRAM fabs, Samsung Electronics owning NAND fabs, TSMC and UMC owning wafer foundries, and Texas Instruments having a manufacturing base in Chengdu.

The U.S.-China conflict over semiconductors has put chip design and manufacturing at the forefront. With both countries recognizing the strategic importance of semiconductor technology, competition in this sector is expected to intensify.

Citing national security, the Bureau of Industry and Security (BIS) of the United States's Department of Commerce implemented export controls on advanced chips to China. The export controls on semiconductors aimed at restricting China's ability to both purchase and manufacture certain high-end chips that could fuel breakthroughs in AI and give China a military advantage.[71] This is especially important in the face of China's military-civil fusion strategy that targets technologies such as quantum computing, semiconductors, 5G, nuclear technology, aerospace technology, gene editing and AI to achieve military dominance.[72] Furthermore, China has set 2030 as its target date to become a global leader in AI, with the subsequent goal of putting the People's Liberation Army on par with the U.S. military by 2035 — a goal the U.S. export controls intend to complicate.[73] The move by the U.S.A. has escalated tensions, with China accusing the United States of weaponizing trade and tech issues.

[71] U.S. Department of Commerce's Bureau of Industry and Security (BIS), Press Release: "Commerce Implements New Export Controls on Advanced Computing and Semiconductor Manufacturing Items to the People's Republic of China (PRC)," October 7, 2022; U.S. Department of Commerce's Bureau of Industry and Security (BIS), Press Release: "Commerce Strengthens Restrictions on Advanced Computing Semiconductors, Semiconductor Manufacturing Equipment, and Supercomputing Items to Countries of Concern," October 17, 2023.

[72] Nicholas R. Licata, "China's Military-Civil Fusion Strategy: A Blueprint for Technological Superiority," Foreign Policy Research Institute, December 19, 2023.

[73] Manya Koetse, "In the race for AI supremacy, China and the US are travelling on entirely different tracks," The Guardian, January 9, 2024.

In late January 2023, the United States also joined forces with the Netherlands and Japan to restrict China's acquisition of semiconductor equipment tools (including deep ultraviolet lithography systems and extreme ultraviolet lithography systems), materials, specialty chemicals, software (EDA and IP) capabilities.[74] Meanwhile, BIS has indicated that it is continually assessing the effectiveness of its advanced chips controls and signaled potential future updates are likely.[75]

In response to the U.S. export controls on semiconductors, China lodged a complaint with the World Trade Organization (WTO) on December 12, 2022,[76] banned the use of American Micron's chips in critical infrastructure projects on May 21, 2023,[77] and implemented export restrictions on germanium and gallium products from August 1, 2023.[78] With state support, the Chinese tech industry has also accelerated its push for semiconductor self-sufficiency and indigenous production.[79]

As part of its campaign to replace foreign technology with homegrown solutions, China's industry ministry issued stricter procurement guidelines in late December 2023. [80] In its statement were three separate lists of CPUs, operating systems and centralized database deemed "safe and reliable" for three years after the publication date, all from Chinese companies. These new guidelines will not only mean the phasing out of U.S. microprocessors from Intel and AMD from government personal computers and servers in China but would also sideline Microsoft's Windows operating system and foreign-made database software in favor of domestic Chinese options. Faced with sanctions and export controls imposed by other countries, the procurement revamp is

[74] Helen Chiang, "China's Three-Way Recipe for Semiconductor Autonomy and Global Industry Impact," International Data Corporation, February 26, 2024.

[75] Shearman & Sterling LLP, Perspectives: "U.S. Clarifies and Strengthens Restrictions on Semiconductor Exports to China, November 14, 2023.

[76] World Trade Organization, "China initiates WTO dispute complaint targeting US semiconductor chip measures," December 15, 2022.

[77] David Lawder, "US 'won't tolerate' China's ban on Micron chips, commerce secretary says," Reuters, May 28, 2023.

[78] Mia Nulimaimaiti, "China's gallium and germanium exports tumble as controls on shipments to the West take toll," South China Morning Post, January 21, 2024.

[79] Winston Mok, "For semiconductor self-sufficiency, China must collaborate, not just innovate," South China Morning Post, March 12, 2024. Refer to November 2023 issue of "Taiwan and the Global Semiconductor Supply Chain" for more details on the U.S.-China conflict over semiconductors.

[80] Akanksha Khushi, "China blocks use of Intel and AMD chips in government computers, FT reports," Reuters, March 24, 2024.

part of China's national strategy to empower local champions and foster technology self-sufficiency in the military, government, and state sectors.[81]

The strained relations between the United States and China have led to significant disruptions and a reorientation of the global semiconductor supply chain.[82] Several multinational semiconductor companies are diversifying their investments away from China to enhance their supply chain resilience.[83] The 2023 American Business in China White Paper published by the American Chamber of Commerce in China (AmCham China) in April 2023 finds 87% of U.S. firms expressing pessimism regarding the outlook for the relationship between the world's two largest economies.[84] In a survey released by the AmCham Shanghai in September 2023, some 40% of companies responded that they are moving investments elsewhere from China.[85]

• Semiconductor Policies of U.S.A., China, and India

The conflict over semiconductors between the U.S.A. and China has had far-reaching implications on the global semiconductor supply chain and the broader technology industry. This has prompted policy responses not only from the U.S.A. and China but also from other countries, including emerging players like India.

The U.S.A.

In response to China's growing semiconductor capabilities, the U.S.A. passed the "Creating Helpful Incentives to Produce Semiconductors (CHIPS) and Science Act". Signed into law on August 9, 2022, the CHIPS and Science Act aims at bolstering U.S. leadership in semiconductors, and provides US$ 52.7 billion for American semiconductor research, development, manufacturing, and workforce development. This includes US$ 39 billion in manufacturing incentives, including US$ 2 billion for the legacy chips used in automobiles and

[81] Ryan McMorrow, Nian Liu and Qianer Liu, "China blocks use of Intel and AMD chips in government computers: report," Financial Times, March 24, 2024.
[82] Jeremy Mark and Dexter Tiff Roberts, "United States–China semiconductor standoff: A supply chain under stress," Atlantic Council, February 23, 2023.
[83] Indo-Asian News Service (IANS), "New investments in semiconductor chips will remain in Asia but moving away from China: Moody's Analytics," February 29, 2024.
[84] Jeff Pao, "More US firms looking elsewhere: AmCham China," Asia Times, April 27, 2023.
[85] The Economist, "Business in China: Exit the Dragon," September 26, 2023.

defense systems, US$ 13.2 billion in R&D and workforce development, and US$ 500 million to provide for international information communications technology security and semiconductor supply chain activities. It also provides a 25% investment tax credit for capital expenses for the manufacturing of semiconductors and related equipment (see Table 7).

According to U.S. Secretary of Commerce Gina Raimondo, the CHIPS Act will ensure that the world's most advanced chips are manufactured on American soil by attracting investments, building up a robust semiconductor supplier and R&D ecosystem for innovating new process technologies, and drawing talented individuals to join the ecosystem.[86]

[86] The U.S. Department of Commerce, "Remarks by U.S. Secretary of Commerce Gina Raimondo: The CHIPS Act and a Long-term Vision for America's Technological Leadership", February 23, 2023.

Table 7: CHIPS and Science Act provides US$ 52.7 billion for U.S. semiconductor research, development, and manufacturing

Semiconductor Manufacturing and Research & Development

US$ 39 Billion Manufacturing Incentives:

- Build, expand, or modernize domestic facilities and equipment for semiconductor fabrication, assembly, testing, advanced packaging, or research and development, including US$ 2 billion specifically for mature semiconductors.

US$ 11 Billion for Research and Development (R&D):

- **DOC National Semiconductor Technology Center (NSTC):**
  - A public-private partnership to conduct advanced semiconductor manufacturing R&D and prototyping; invest in new technologies; and expand workforce training and development opportunities.
- **DOC National Advanced Packaging Manufacturing Program:**
  - A Federal R&D program to strengthen advanced assembly, test, and packaging (ATP) capabilities, in coordination with the NSTC.
- **DOC Manufacturing USA Semiconductor Institute:**
  - A partnership between government, industry, and academia to research virtualization of semiconductor machinery, develop ATP capabilities, and design and disseminate training.
- **DOC Microelectronics Metrology R&D:**
  - A National Institute of Standards and Technology (NIST) research program to advance measurement science, standards, material characterization, instrumentation, testing, and manufacturing capabilities.
- **DOC Economic Development Administration (EDA)'s Tech Hub Program**
  - Designation of Tech Hubs in regions across the country to drive regional innovation and job creation.
  - Award of Strategy Development Grants (SDG) to help communities significantly increase local coordination and planning activities.

Defense, Technology Security and Workforce Development

- **CHIPS for America Defense Fund:**
  - US$ 2 billion for the DOD to implement the Microelectronics Commons, a national network for onshore, university-based prototyping, lab-to-fab transition of semiconductor technologies—including DOD-unique applications—and semiconductor workforce training.
- **CHIPS for America International Technology Security and Innovation Fund:**
  - US$ 500 million for the Department of State, in coordination with the U.S. Agency for International Development, the Export-Import Bank, and the U.S. International Development Finance Corporation, to support international information and communications technology security and semiconductor supply chain activities, including supporting the development and adoption of secure and trusted telecommunications technologies, semiconductors, and other emerging technologies.
- **CHIPS for America Workforce and Education Fund:**
  - US$ 200 million to kick start development of the domestic semiconductor workforce, which faces near-term labor shortages, by leveraging activities of the National Science Foundation.

Source: US Department of Commerce, CHIPS and Science Act of 2022: Division A Summary - CHIPS and ORAN Investment, July 2022, and U.S. Economic Development Administration's Press Release: "Biden-Harris Administration Designates 31 Tech Hubs Across America", October 23, 2023.

To date, the following preliminary memorandums of terms (PMT) under the CHIPS and Science Act have been announced:

1. **BAE Systems Electronic Systems**: On December 11, 2023, the U.S. Administration announced US$ 35 million to support the modernization of the company's Microelectronics Center in Nashua, New Hampshire. This facility will produce chips that are essential to U.S. national security, including for use in F-35 fighter jets.[87]
2. **Microchip Technology Inc.**: On January 4, 2024, the U.S. Administration announced US$ 162 million for Microchip Technology to increase its production of microcontroller units and other specialty semiconductors, and to support the modernization and expansion of fabrication facilities in Colorado Springs, Colorado, and Gresham, Oregon.[88]
3. **GlobalFoundries**: In February 2024, the U.S. Administration announced US$ 1.5 billion for GlobalFoundries to support the development and expansion of facilities in Malta, New York, and Burlington, Vermont.[89]
4. **Intel**: On March 20, 2024, the White House announced that it would provide Intel with US$ 8.5 billion in funding and up to US$ 11 billion in loans through the CHIPS Act. Intel said the money would fund its projects in Ohio, Arizona and New Mexico, and its research and development facility in Oregon.[90]
5. **TSMC**: On April 8, 2024, the Biden administration announced the award of up to US$ 6.6 billion in direct funding and up to US$ 5 billion in loans to TSMC to build three greenfield leading-edge fabs in Phoenix, Arizona. The first fab will produce 3 nm process technologies, the second will produce the world's most advanced 2

[87] U.S. Department of Commerce, Press Release: "Biden-Harris Administration and BAE Systems, Inc., Announce CHIPS Preliminary Terms to Support Critical U.S. National Security Project in Nashua, New Hampshire," December, 11, 2023.

[88] U.S. Department of Commerce, Press Release: "Biden-Harris Administration Announces CHIPS Preliminary Terms with Microchip Technology to Strengthen Supply Chain Resilience for America's Automotive, Defense, and Aerospace Industries," January 4, 2024.

[89] U.S. Department of Commerce, Press Release: "Biden-Harris Administration Announces Preliminary Terms with GlobalFoundries to Strengthen Domestic Legacy Chip Supply for U.S. Auto and Defense Industries," February 19, 2024.

[90] The White House, Fact Sheet: "President Biden Announces Up To $8.5 Billion Preliminary Agreement with Intel under the CHIPS & Science Act," March 20, 2024; U.S. Department of Commerce, Press Release: "Biden-Harris Administration Announces Preliminary Terms with Intel to Support Investment in U.S. Semiconductor Technology Leadership and Create Tens of Thousands of Jobs," March 20, 2024.

nm nanosheet process technology while the third will produce 2 nm or more advanced process technologies depending on customer demand. In total, the package will support more than US$ 65 billion in investments at the three plants by TSMC.[91]

6. **Samsung**: On April 15, 2024, the Biden Administration announced it is awarding US$ 6.4 billion to Samsung for the construction of four facilities in Taylor, Texas. These facilities include two fabs, an advanced packaging facility and a research and development center.[92]

According to the U.S. Department of Commerce, a PMT is offered to an applicant on a non-binding basis after satisfactory completion of the merit review of a full application. The PMT outlines key terms for a CHIPS incentives award, including the amount and form of the award. The award amounts are subject to due diligence and negotiation of a long-form term sheet and award documents and are conditional on the achievement of certain milestones and remain subject to availability of funds.[93]

Companies that receive a CHIPS incentives award must abide by the following caveats: (1) not to expand material semiconductor manufacturing capacity in foreign countries of concern for ten years; and (2) not to undertake joint research or technology licensing efforts that relates to a technology or product that raises national security concerns with foreign entities of concern. The "countries of concern" include China and Russia, and the restrictions apply for 10 years after the date of award.[94] Companies affected the most by this rule include Intel and TSMC.

[91] U.S. Department of Commerce, Press Release: "Biden-Harris Administration Announces Preliminary Terms with TSMC, Expanded Investment from Company to Bring World's Most Advanced Leading-Edge Technology to the U.S.," April 8, 2024.

[92] U.S. Department of Commerce, Press Release: "Biden-Harris Administration Announces Preliminary Terms with Samsung Electronics to Establish Leading-Edge Semiconductor Ecosystem in Central Texas," April 15, 2024.

[93] U.S. Department of Commerce, Press Release: "Biden-Harris Administration Announces Preliminary Terms with Intel to Support Investment in U.S. Semiconductor Technology Leadership and Create Tens of Thousands of Jobs," March 20, 2024.

[94] U.S. Department of Commerce, Press Release: "Biden-Harris Administration Announces Final National Security Guardrails for CHIPS for America Incentives Program," September 22, 2023.

China

China's semiconductor industry consists of a wide spectrum of companies, from IDMs to pure-play foundries, fabless semiconductor companies and OSAT companies. It is currently the second-largest semiconductor application market in the world and has made significant strides in the fields of chip fabrication and OSAT.[95]

China's semiconductor industry, however, heavily relies on imported raw materials and components, and it also faces challenges in electronic design automation (EDA), and capital equipment.[96] The Chinese government's key policies, namely, the National Integrated Circuit Industry Investment Fund (IC Fund) and Made in China 2025 Plan aim to strengthen its semiconductor ecosystem, reduce dependence on imports, and foster homegrown innovation and champions (see Table 8).

[95] International Data Corporation, "China's Three-Way Recipe for Semiconductor Autonomy and Global Industry Impact," February 26, 2024.

[96] Mercy A. Kuo, "The State of China's Semiconductor Industry," The Diplomat, October 2, 2023.

Table 8: Chinese Semiconductor Industrial Policy

POLICY	DETAILS
National Integrated Circuit Industry Investment Fund (also known as The China Integrated Circuit Investment Fund or the Big Fund)	To bring China's semiconductor industry on par with leading international competitors, the Big Fund supports local semiconductor start-ups and research and development and helps to accelerate technology transfer through foreign direct investment and joint venture. This involves: • investing in indigenous semiconductor companies and research and development, • using the Big Fund for outbound foreign direct investment (FDI) to acquire foreign companies, • providing funds to facilitate inbound FDI such as greenfield investment and joint ventures with non-Chinese companies. The Big Fund is managed by Sino IC Capital, a company established by China Development Bank in 2014. The fund's shareholders include the Ministry of Finance, China Tobacco, China Telecom, and several local governments and investment funds. It operates as a corporate entity under the Ministry of Industry and Information Technology and the Ministry of Finance. The fund has three phases, each with different fundraising targets and investment focuses: • **Phase I (2014-2019)**: The fund raised RMB 138.7 billion yuan (equivalent to approximately US$ 19 billion) in 2014 and invested in 23 domestic semiconductor companies, mainly in chip manufacturing, design, and packaging. The fund also facilitated several mergers, acquisitions, and IPOs in the industry.[97] • **Phase II (2019-2024):** The fund raised RMB 200 billion yuan (US$ 27 billion) in 2019 and increased its focus on etching machines, film, test, and cleaning equipment, as well as new applications enabled by 5G and AI. The fund aimed to build an independent and controllable industrial chain for the Chinese IC industry.[98] • **Phase III (2023-2028):** The fund is reportedly raising US$ 40 billion in 2023 and is expected to invest in advanced nodes (7 nm or less), memory, and logic chips, as well as emerging technologies such as quantum computing and neuromorphic computing. The fund hopes to achieve global leadership in innovation and quality in the semiconductor industry.
Made in China 2025 (MIC 2025)	Formulated in 2015, the policy seeks to transform China's manufacturing sector by decreasing China's reliance on foreign technology imports and cementing its position in the global supply chains of critical technologies. MIC 2025 focuses on intelligent manufacturing in 10 strategic sectors: 1) advanced information technology; 2) automated machine tools and robotics; 3) aerospace and aeronautical equipment; 4) ocean engineering equipment and high-tech shipping; 5) modern rail transport equipment;

[97] Dashveenjit Kaur, "China is planning its biggest state-backed chip fund yet," TechHQ, September 6, 2023.
[98] Ibid.

POLICY	DETAILS
	6) energy saving and new energy vehicles; 7) power equipment; 8) new materials; 9) medicine and medical devices; and 10) agricultural equipment. MIC 2025 entails a 3-step strategy: • **Step 1 (2015-2025):** basic industrialization, progress made in smart and green manufacturing; • **Step 2 (2025-2035):** complete industrialization, tier-2 manufacturing leader with solid indigenous R&D, breakthrough in key sectors; and • **Step 3 (2035-2050):** Tier-1 manufacturing leader with advanced technology and industrial system. With reference to semiconductors, the goals are: 1) To develop the IC design industry, speed up the development of the IC manufacturing industry, upgrade the assembly, testing and packaging (ATP), and facilitate breakthroughs in the key equipment and materials of integrated circuits. 2) By 2020, China's semiconductor design and manufacturing should be one to two generations behind industry leaders and supported by a robust domestic supply chain of equipment, material and ATP service suppliers. 3) By 2030 the main segments of the IC industry should reach advanced international levels. The goal of raising local content of semiconductor chips to 40% by 2020 and 70% by 2025 was revised in 2019, with a new goal of reaching US$ 305 billion in output by 2030, and meeting 80% of domestic demand.

Source: Daxue Consulting, "China's semiconductor industry: Seeking for self-sufficiency amid tensions with Taiwan and the US chip export ban", September 28, 2022; The State Council, People's Republic of China, "Made in China 2025", March 30, 2017; Michael Settelen, "'Made in China 2025' And China's Evolving Industrial Policy," Switzerland Global Enterprise, January 3, 2023; State Council of the People's Republic of China, "Made in China 2025 Technical Roadmap," October 29, 2015; U.S. Chamber of Commerce, Made in China 2025, March 16, 2017, p. 65; Congressional Research Service, "China's New Semiconductor Policies: Issues for Congress," April 20, 2021.

Since 2014, the "China Integrated Circuit Industry Investment Fund" (Big Fund) has nurtured domestic champions such as SMIC, a producer of logic chips, and Yangtze Memory Technologies Company (YMTC), a manufacturer of memory chips for data storage.[99]

While China has mastered some chip technologies, its chip firms are notably absent in the market for high-end logic, advanced analog, and leading-edge memory products. When the U.S.A. restricted China's Huawei's access to

[99] Frédérique Carrier, "The chip industry's reshoring revolution," RBC Wealth Management, November 14, 2023.

American equipment and software, TSMC stopped producing HiSilicon chips for Huawei — its then second-largest customer, after Apple. The U.S. export restrictions to prevent China from getting advanced chips for military purposes, including AI applications, also cut off China as a market for the latest graphics processors from NVIDIA and AMD. The Chinese AI industry heavily relies on NVIDIA and AMD, making the ban on advanced AI chips from these companies a challenge to both China's AI industry and the semiconductor sector.[100]

Additionally, U.S. export controls have also led to a large number of company closures in the Chinese semiconductor industry. In 2022, as many as 5,746 Chinese chip companies were deregistered, a 68% increase from 3,420 in the previous year.[101] A record 10,900 chip-related companies lost their registration in 2023— a big jump from the 5,746 companies that folded in 2022, according to the report. That means an average of 30 Chinese chip-related companies closed their doors each day in 2023. [102]

While China still lags behind the top semiconductor foundries like Taiwan's TSMC and South Korea-based Samsung, which can currently make chips at 3 nm, the Huawei Mate 60 Pro smartphone, which features the 7 nm Kirin 9000s produced by China's SMIC, was hailed as a significant development in its semiconductor industry. Experts have said that given China's lack of access to more advanced equipment, it is costly to produce the 7 nm with limited quantity and that SMIC also faces the ceiling of 5 nm process node.[103] Although SMIC can theoretically produce advanced 7 nm chips using its existing DUV lithography systems, it is a considerable distance from reaching mass production. In the capital- and technology-intensive chipmaking industry, achieving mass production at a high yield rate is critical, as it can effectively lower the cost per chip.

[100] Daxue Consulting, "China's semiconductor industry: Seeking for self-sufficiency amid global political tensions," January 4, 2024.

[101] Manoj Gupta, "How US Sanctions Have Destroyed Thousands of Chinese Chip Companies, Impacting Their Confidence," CNN News18, February 23, 2023.

[102] Anton Shilov, "Chinese chip-related companies shutting down with record speed — 10,900, or around 30 per day, shut down in 2023," Tom's Hardware, December 14, 2023; 买明哲, "2023 年有 1.09 万家中国芯片公司消失，比去年增长近 90%," Fortune China, December 12,2023.

[103] Refer to the November issue of "Taiwan and the Global Semiconductor Supply Chain" published by the Taipei Representative Office in Singapore for more details.

As the United States scrambled to figure out how Huawei was able to produce an advanced 7 nm chip, it was revealed that despite U.S. export curbs, Chinese companies have been buying up U.S. chipmaking equipment for making advanced semiconductors by claiming that it is being used on an older production line.[104] According to Investor's Business Daily, China's tech companies, supported by generous state subsidies, had embarked on a frenzied buying spree on tons of chip equipment from Applied Materials, ASML, KLA and Lam Research— including some types the U.S. had hoped to prevent — before the export controls kick in.[105]

China's efforts to catch up, however, face major obstacles following the Biden administration's tightening of export controls to curb China's access to advanced chips, chip-making equipment and US talent. In fact, IC Insights predicts that by 2026, China-made integrated circuit manufacturing would be far from meeting the 70% self-sufficiency target set by the Chinese government, reaching only a self-sufficiency rate of 21.2%. But even this rate is supplemented by foreign companies (e.g., Samsung, SK Hynix, TSMC, etc.), which contribute to more than 50% of IC production in China. In a nutshell, China's self-sufficiency rate by China's headquartered companies might only be around 10% in 2026 (see Table 9).

Table 9: China's Self-sufficiency Rate on Semiconductor: 2009-2026

Unit: US$ billion

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2026(f)
Production	4.2	5.8	7.9	8.8	10.3	11.7	13.4	13	19.3	23.9	19.3	24.2	31.2	58.2
Market	41	57	62	63	69	77	83	94	118	150	131	146	187	274
Ratio (%)	10.2	10.2	12.7	14.0	14.9	15.2	16.1	13.8	16.4	15.9	14.7	16.6	16.7	21.2

Source: IC Insights Research Bulletin, "China-Based IC Production to Represent 21.2% of China IC Market in 2026," May 18, 2022, https://www.icinsights.com/data/articles/documents/1452.pdf.

As a matter of fact, only 6.6% of Chinese market demand was contributed by China-headquartered semiconductor companies in 2021. In that year, the size of China's semiconductor market was about US$ 186.5 billion, of which only US$ 31.2 billion worth of chips were manufactured in China, both by domestic and foreign-invested companies – a self-sufficiency rate of 16.7%. However, only US$ 12.3 billion worth of chips were

[104] Alexandra Alper, "China receives US equipment to make advanced chips despite new rules-report," Reuters, November 15, 2023.

[105] Patrick Seitz, "Why U.S. Chip Sanctions Against China Aren't Working," Investor's Business Daily, July 12, 2023.

manufactured by China-headquartered companies, accounting for merely 6.6% of domestic consumption. The figures of China's self-sufficiency rate by China's headquartered companies were 6.1% in 2019 and 5.8% in 2020, respectively (See Table 10).

Table 10: China's Self-Sufficiency Rate by China's Headquartered Companies: 2019-2021

Unit: US$ billion

	2019	2020	2021
China's IC Market	124.6	143.4	186.5
China-based IC Production	19.5	22.7	31.2
China-HQ IC Production	7.6	8.3	12.3
Self-Sufficiency Rate	15.7%	15.8%	16.7%
HQ Self-Sufficiency Rate	6.1%	5.8%	6.6%

Source: IC Insights Research Bulletin, "China-Based IC Production to Represent 21.2% of China IC Market in 2026," May 18, 2022, https://www.icinsights.com/data/articles/documents/1452.pdf. "IC Insights 预计中国芯片 2025 年 70%的自给率难以达成,"https://finance.sina.cn/tech/2021-01-08/detail-iiznctkf0880704.d.html?fromtech=1&from=wap . "IC Insights: there will be no significant progress in chip localization in China in the next 10 years," May 28, 2020, https://www.censtry.hk/article/10086.html.

Moreover, due to export restrictions limiting advanced equipment sales to China, domestic chipmakers are shifting gears to generate more mature process technology capacity. A study released in December 2023 by the U.S. Department of Commerce's BIS Office of Technology Valuation said the Chinese government had provided its chipmakers with about US$ 150 billion in subsidies in the past decade, which is likely to drive below-market pricing for legacy chips and create a non-level global playing field for the U.S.A. and other foreign competitors.[106]

According to market research firm TrendForce, China's share in global mature process capacity is anticipated to grow from 29% in 2023 to 33% in 2027 while Taiwan's share will fall from 49% to 42%. This expansion of mature process manufacturing share of more than one-third by 2027 could potentially cause a price war and increase the risk of consolidation.[107]

[106] Bureau of Industry and Security Office of Technology Valuation, U.S. Department of Commerce, "Assessment of The Status of The Microelectronics Industrial Base in The United States," December 21, 2023.

[107] Peter Brown, "China on track to grow mature process capacity share to 33% by 2027," Electronics 360, October, 20, 2023.

The Chinese government has also been working to convince domestic technology firms to source their inputs domestically rather than from U.S. suppliers.[108] According to a report from The Wall Street Journal in October 2023, major Chinese players like Alibaba, Tencent, Baidu and ByteDance are redirecting some advanced semiconductor orders to domestic companies and relying more on internally developed chips.[109]

The recent annual SEMICON China show in Shanghai provided a glimpse into the mood of the Chinese semiconductor industry. The U.S. sanctions have accelerated the trend of more Chinese manufacturing facilities using materials prescribed by Chinese firms. 'Buy local' and getting supply chains out of U.S. control was a clear focus of many at the show.[110] Chinese companies are rapidly closing the gap in material areas that do not require cutting-edge technology and are also gaining more orders against foreign rivals in the equipment sector. In response to government support and cost advantages, manufacturing facilities in China are increasingly prioritizing domestic firms for production lines in newly opened plants. In some cases, they also replace foreign equipment with domestic alternatives in older production lines.[111]

Although China has poured billions of U.S. dollars into the effort, the complexities and globally interconnected nature of the chip supply chain means that a big gap still exists in China's self-sufficiency drive.[112]

India

The "Make in India" initiative and the "Semicon India Programme" are two pivotal strategies by the Indian government to support the growth and transformation of India's semiconductor industry.

Launched in 2014, the "Make in India" initiative is a broad manufacturing initiative aimed at making the country a global manufacturing

[108] Brenda Goh and Katerina Ang, "China rushes to swap Western tech with domestic options as U.S. cracks down," Reuters, October 27, 2023.
[109] TrendForce, "Cooling Response to NVIDIA's Exclusive Chips for China, Lack of Interest in Downgraded Models by Customers," January 8, 2024.
[110] Brenda Goh and Yelin Mo, "At major China chip fair, firms ramp up call to buy domestic," Reuters, March 22, 2024.
[111] Ibid.
[112] Ibid.

hub and an integral part of the global supply chain by facilitating investment, fostering innovation, enhancing skill development, protecting intellectual property, and building best-in-class manufacturing infrastructure. [113]

To support the semiconductor industry in India, its Ministry of Electronics and Information Technology (MeitY) announced an initial outlay of US$ 10 billion investment in the India Semiconductor Mission (ISM).[114] The ISM's "Semicon India Program" aims to reduce reliance on imports and boost self-dependence.[115] The key schemes introduced under this program provide incentives for companies involved in semiconductor fabs, display fabs, compound semiconductors/ silicon photonics/ sensors (including micro-electromechanical systems [MEMS]) fabs, semiconductor packaging and semiconductor design (see Table 11).

Table 11: Schemes under the "Semicon India Programme"

Scheme	Details
Semiconductor Fabs	Fiscal support of up to 50% of project cost on pari-passu basis to the approved applicants.
Display Fabs	Fiscal support of up to 50% of project cost on pari-passu basis to the approved applicants.
Compound Semiconductors / Silicon Photonics / Sensors (including MEMS) Fabs / Discrete Semiconductors Fab and Semiconductor ATMP / OSAT Facilities	Fiscal support of 50% of capital expenditure to Compound Semiconductors / Silicon Photonics / Sensors (including MEMS [micro-electromechanical systems]) / Fabs and Semiconductor Packaging (including assembly testing marking and packing [ATMP] and outsourced semiconductor assembly and test [OSAT]) units.
Design Linked Incentive	Financial incentives as well as design infrastructure support across various stages of development and deployment of semiconductor design(s) for Integrated Circuits (ICs), Chipsets, System on Chips (SoCs), Systems & IP Cores and semiconductor linked design(s) over a period of 5 years.

Source: Adapted from India Semiconductor Mission Website, https://ism.gov.in/. Accessed April 1, 2024.

[113] Prime Minister's Office, Prime Minister of India, "Make in India," PM of India's Office, 2024, https://www.pmindia.gov.in/en/major_initiatives/make-in-india/. Accessed April 1, 2024.

[114] Naina Bhardwaj and Melissa Cyrill, "India Briefing: What is the Semicon India Program and How Does it Work?" Dezan Shira and Associates, February 21, 2022.

[115] Asia Pacific Foundation of Canada, "India Vies to Become Semiconductor 'Superpower' as FDI Pours In," September 20, 2023.

Like many countries, India is trying to seize the opportunities and fill the gaps in the global semiconductor supply chain that arise due to the strained relations between the United States and China.[116] Besides leveraging its strengths in chip design and offering government subsidies, India is also positioning itself as an alternative to China as a semiconductor investment and production location.[117]

A report by the Boston Consulting Group identified India as a future export manufacturing powerhouse.[118] Ajay Banga, the World Bank President, emphasizes that India has a limited window of three to four years to capitalize on becoming a manufacturing alternative to China. Some economists estimate the window will be open for up to 10 years.[119]

The Chinese authorities barred Micron from big infrastructure projects in May 2023 in what was seen as retaliation for the United States restricting China's access to key technology.[120] Taking advantage of global headwinds, the Indian government moved swiftly to approve and facilitate the setting up of Micron's new assembly and test facility in Gujarat in June 2023.[121] With the support from the Indian central government and from the state of Gujarat, the total investment in the facility will be US$ 2.75 billion. Of that total, 50% will come from the Indian central government and 20% from the state of Gujarat.[122] Micron said that its investment will be up to US$ 825 million.

The Indian government approved the establishment of three semiconductor units with investments of more than US$ 15 billion on February 29, 2024, namely:

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[116] Jeremy Mark and Dexter Tiff Roberts, "United States–China semiconductor standoff: A supply chain under stress," Atlantic Council, February 23, 2023.

[117] Stephen Ezell, "Assessing India's Readiness to Assume a Greater Role in Global Semiconductor Value Chains," Information Technology and Innovation Foundation, February 14, 2024.

[118] Jonathan Van Wyck, Kasey Phillips, Marc Gilbert, Michael McAdoo, Harrison Xue, Ravi Srivastava, Kristian Kuhlmann, and Gang Xu, "Harnessing the Tectonic Shifts in Global Manufacturing," Boston Consulting Group, September 21, 2023.

[119] Nirmala Ganapathy and Rohini Mohan, "'Make in India': Can South Asian giant surpass China and become world's biggest factory?" The Straits Times, March 9, 2024.

[120] Nirmala Ganapathy and Rohini Mohan, "'Make in India': Can South Asian giant surpass China and become world's biggest factory?" The Straits Times, March 9, 2024.

[121] Ministry of Electronics & IT, India, Press Release: "Micron's semiconductor project at Sanand in Gujarat on fast track," December 6, 2023.

[122] Micron, Press Release: "Micron Announces New Semiconductor Assembly and Test Facility in India," June 22, 2023.

1. A semiconductor fab by Tata Electronics Private Limited (TEPL) in partnership with Taiwan's Powerchip Semiconductor Manufacturing Corp (PSMC) in Dholera, Gujarat.
2. A semiconductor Assembly, Testing, Marking, and Packaging (ATMP) unit for specialized chips by Japan's Renesas Electronics Corporation and Thailand's Stars Microelectronics in Sanand, Gujarat.
3. A semiconductor ATMP unit by Tata Semiconductor Assembly and Test Pvt Ltd ("TSAT") in Morigaon, Assam.[123]

Besides India, Southeast Asian countries have also emerged as attractive options for companies looking at diversifying beyond China. Compared to India, countries like Vietnam, with its lower tariffs and membership in the ASEAN Free Trade Agreement and the Comprehensive and Progressive Agreement for Trans-Pacific Partnership, may appear as a more attractive choice.[124]

[123] Prime Minister's Office, Prime Minister of India, Press Release: "Giant leap for India Semiconductor Mission: Cabinet approves three more semiconductor units," February 29, 2024.

[124] Jonathan Van Wyck, Kasey Phillips, Marc Gilbert, Michael McAdoo, Harrison Xue, Ravi Srivastava, Kristian Kuhlmann, and Gang Xu, "Harnessing the Tectonic Shifts in Global Manufacturing," Boston Consulting Group, September 21, 2023.

3. Status of Semiconductor Industry in Taiwan

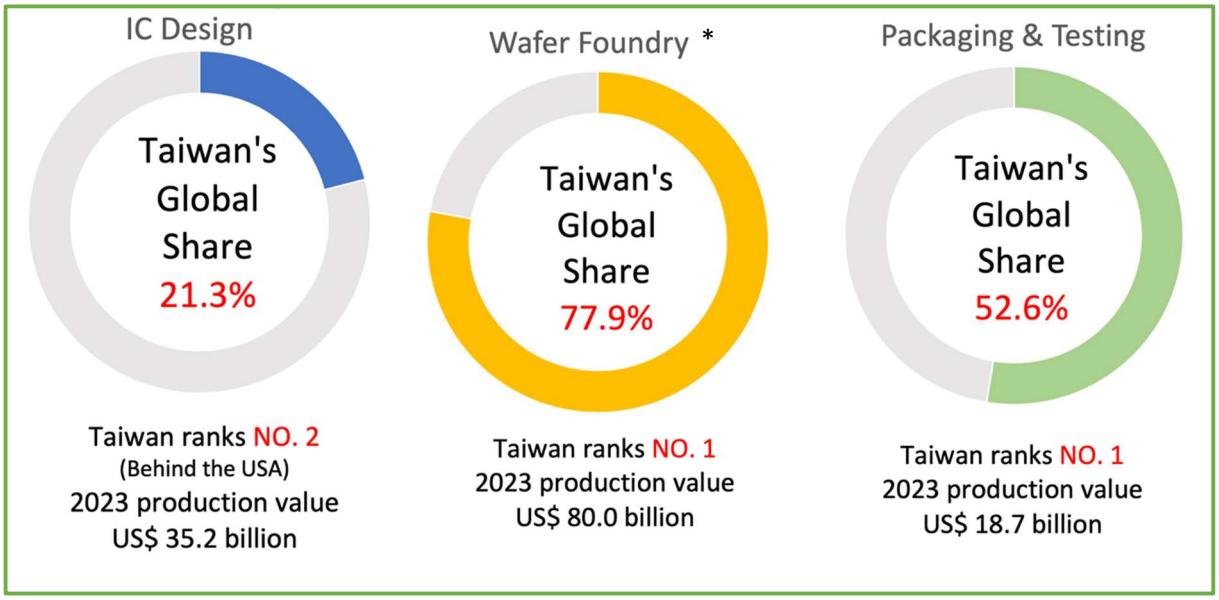
Taiwan's semiconductor industry is a global powerhouse, renowned both for its high-quality production and comprehensive ecosystem that encompasses the entire supply chain – from IC design, fabrication, assembly, packaging and testing to the equipment and materials industries needed for operations.

The success of Taiwan's semiconductor industry stems from decades of government support and investment. Its policy of establishing science and technology parks has fostered the growth of comprehensive and mature semiconductor industry clusters encompassing all key stages of the value chain while offering the advantage of one-day supply cycle time. This rapid cycle time provides an efficient and seamless support system for the semiconductor industry, from research and development to production and manufacturing.

Additionally, Taiwan's high-end talent pool, advanced technology, low cost, high production capacity, flexibility in customization, and the support by the science and research capabilities of the United States, Europe, Japan as well as its own research and development, have worked together to create a robust and resilient semiconductor ecosystem that can effectively and efficiently manage issues from semiconductor development to trial production and mass production, thereby accelerating the development of semiconductor process technologies.

Taiwan's complete semiconductor industrial chain has created a robust and efficient system that continues to grow, work closely with the global supply chain, and deepen collaborations with its partners. Its semiconductor industry has built close business ties with international tech giants, such as Apple, Google and NVIDIA, providing high-end chips used in advanced devices. The resilience and adaptability of Taiwan's semiconductor industry allows it to provide swift and close support to the global industry and have strengthened Taiwan's position as a critical player in the global supply chain for high-tech industries.

Figure 10: Rankings and Global Share of Taiwan's IC Industry in Terms of Production Value: 2023



Source: IEK, ITRI, March 4, 2024. Chia-Chen Lee, "Taiwan IC Industry Development in 2023Q4," IEK, ITRI, March 19, 2024, p. 7.

* "Wafer Foundry" refers to manufacturing-only (pure-play) foundries and does not include integrated device manufacturers (IDMs).

Figure 10 shows the ranking and global share of Taiwan's integrated circuit industry in 2023 in terms of production value. Taiwan continued to rank first by market share in both wafer foundry and packaging and testing, and second in the world in semiconductor design, just behind the United States.

Taiwan's IC design production value ranked second in the world and trailed only the United States in 2023. Its semiconductor companies accounted for a production value of US$ 35.2 billion, which translated to a global share of 21.3%. MediaTek and Novatek are two companies, among others, that help to solidify Taiwan's position as a leader in the global IC design sector. Their contributions are crucial in a highly competitive market that demands continuous innovation and quality.

Taiwan's foundry production value ranked first in the world in 2023. With a production value of US$ 80.0 billion, Taiwan accounted for 77.9% of global foundry production. TSMC and UMC are two of Taiwan's top semiconductor foundries, with the former a leader in developing cutting-edge 2 nm and below process technologies and the latter serving the steady

demand for legacy technology chips. Their combined efforts help maintain Taiwan's significant position in the semiconductor industry.

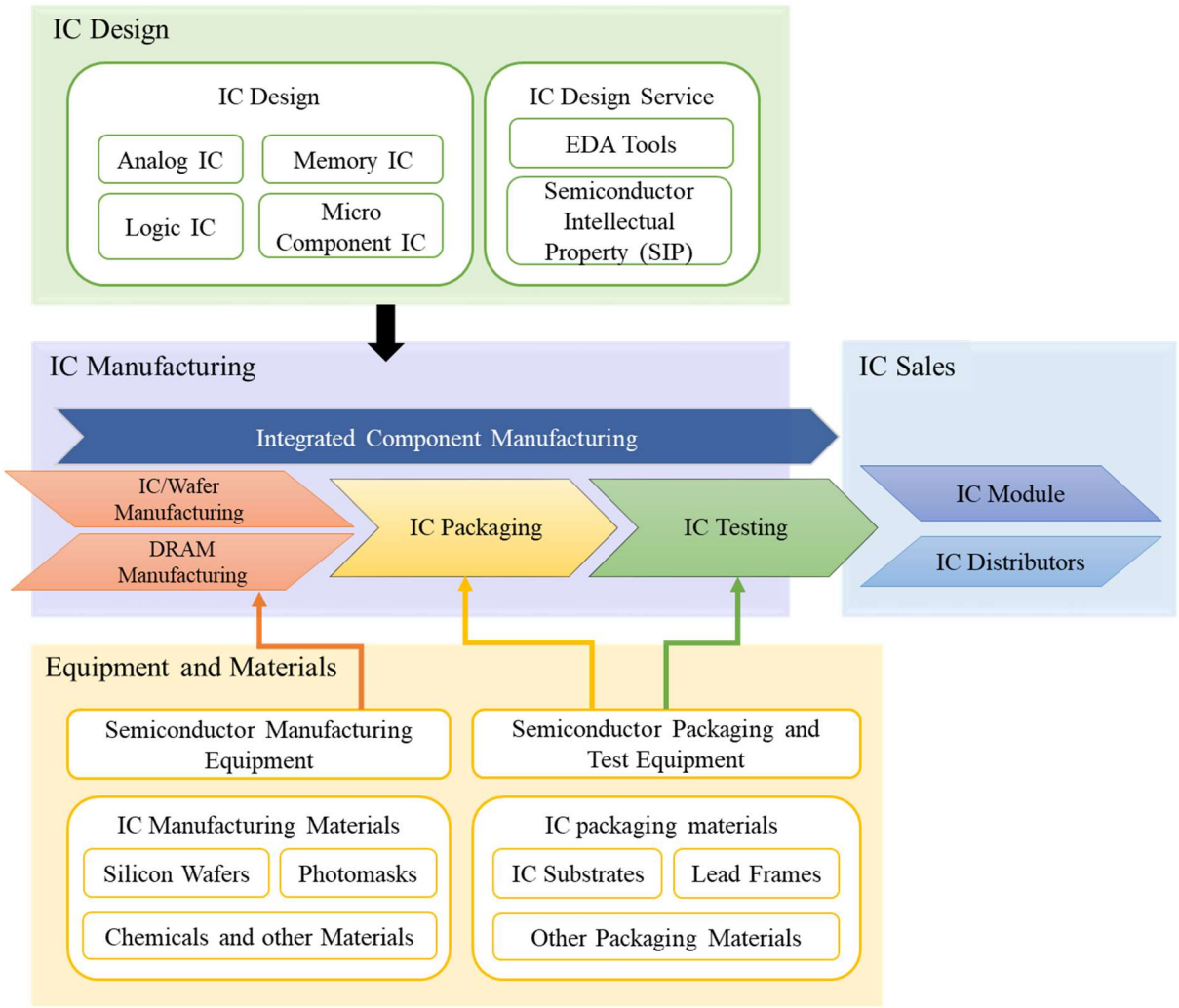
Taiwan's IC packaging and testing output value ranked first in the world in 2023. With a production value of US$ 18.7 billion, Taiwan accounted for 52.6% of the global production value. The country's top-ranking position in the IC packaging and testing sector reflects its advanced capabilities and the high value it brings to the semiconductor supply chain. Taiwan's ASEH and Powertech Technology Inc. (PTI) are leading providers of OSAT services, both in Taiwan and globally. ASEH, the world's largest OSAT provider, is renowned for its innovative approaches to advanced chip packaging. PowerTech Technology Inc., while not as large as ASEH, is also a prominent player in the industry, providing a range of services including chip probing, IC assembly, and final testing. Both ASEH and PTI's expertise and capacity in semiconductor packaging and testing services are crucial for the industry, supporting the global demand for advanced electronic products while meeting the complex and evolving needs of the semiconductor industry.

Given Taiwan's crucial role in the global semiconductor supply chain, it is an important partner to countries seeking to diversify their semiconductor manufacturing capabilities. The escalating geopolitical tension and rapidly evolving global technology landscape further calls attention to Taiwan's semiconductor industry's integral role in the global semiconductor supply chain.

A. Taiwan's Ecosystem of Semiconductor Companies and Its Major Actors

Taiwan's semiconductor industry chain can be divided into three major sectors, namely, (1) upstream: IC or chip design and intellectual property (IP) design, (2) midstream: IC manufacturing, wafer fabrication, related production process testing equipment and components such as masks and chemicals, and (3) downstream: IC packaging and testing, related production process testing equipment, components (e.g., substrates and lead frames), IC modules, and IC channels (see Figure 11).

Figure 11: Upstream, Midstream, and Downstream Industry Chains in Taiwan's Semiconductor Industry



Source: Industry Value Chain Information Platform, compiled by Taiwan Stock Exchange Corporation, December 2023

To mitigate competition and create efficient collaboration, Taiwan's semiconductor industry leverages the professional division of labor between upstream, midstream, and downstream suppliers in the supply chain. After IC design companies complete the product design, a foundry or IDM (an integrated device manufacturer that provides all services from IC design to manufacturing, packaging, testing, and sales) is appointed to produce semi-finished wafer products. Following preliminary tests, the products are sent to a packaging manufacturer for cutting and packaging. The IC testing manufacturer then conducts final tests, and the finished products that pass the tests are sold to system manufacturers through sales channels for assembly and production of system products.

Table 12: Number of Taiwan's Semiconductor Companies: 2016-2023

	2016	2017	2018	2019	2020	2021	2022	2023
IC Design	240	240	238	238	238	250	262	262
IC Manufacturing	16	15	15	15	13	13	15	15
IC Packaging and Testing	37	37	37	37	37	37	37	37

Source: IEK, ITRI, March 4, 2024

Table 12 shows the number of Taiwan's semiconductor companies from 2016 to 2023. From 2016 to 2023, the number of IC design companies increased from 240 to 262, the number of IC manufacturing companies fell from 16 to 15 while the number of IC packaging and testing companies remain unchanged.

Table 13: Taiwan's Global Market Share of Semiconductor Sub-industries In Terms of Production Value: 2016-2023

Unit: %

	2016	2017	2018	2019	2020	2021	2022	2023
IC Design	19.4	18.0	17.0	18.8	20.1	22.0	20.8	21.3
Wafer Foundry*	70.7	73.2	75.6	74.6	77.3	79.7	77.6	77.9
IC Packaging and Testing	55.5	55.8	55.8	56.5	57.7	57.6	53.9	52.6

Source: IEK, ITRI, March 4, 2024.

* Only pure-play foundries, does not include integrated device manufacturers (IDMs).

Table 13 shows Taiwan's global market share in the IC design, wafer foundry and IC packaging and testing sub-industries in terms of production value from 2016 to 2023. The global market share of Taiwan's IC design and wafer foundry has grown from 2016 to 2023. Of significance are Taiwan's

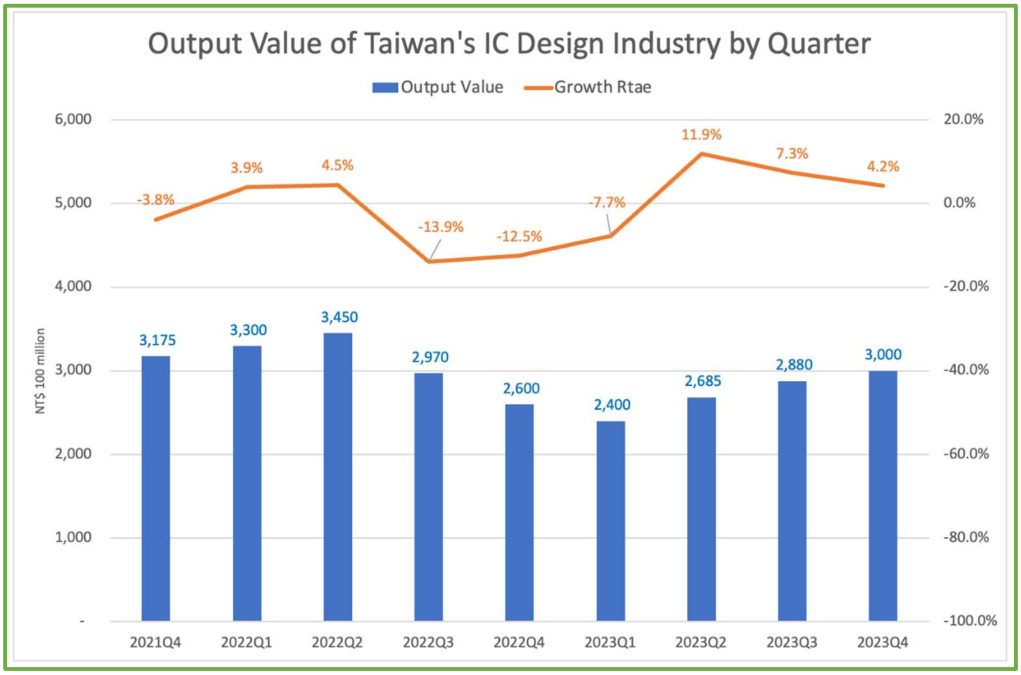
wafer foundry, which has held a global market share of over 70% and its IC packaging and testing, which has held a global market share of over 50% throughout the period. Taiwan's wafer foundry accounted for 77.9% of the global market share while its IC design and IC testing and packaging held 21.3% and 52.6% respectively in 2023.

I. Upstream: IC design

The upstream part of the semiconductor value chain includes IC design, IC design services (IP supply, electronic design automation or EDA, and design services), and other sub-industries. IC design serves as the foundation for all IC products. IC design companies use computer-aided design (CAD) and other IC design assistance tools developed by EDA companies to design the layout of transistors on the chip and the circuits that connect the transistors to create certain specifications and functions for chips.

Figure 12 shows the output value of Taiwan's IC design industry by quarter from the fourth quarter of 2021 to the fourth quarter of 2023. The output value of Taiwan's IC design industry experienced a downturn in the first quarter of 2023. However, there has been a recovery since then.

Figure 12: Output Value of Taiwan's IC Design Industry by Quarter: 2021Q4-2023Q4

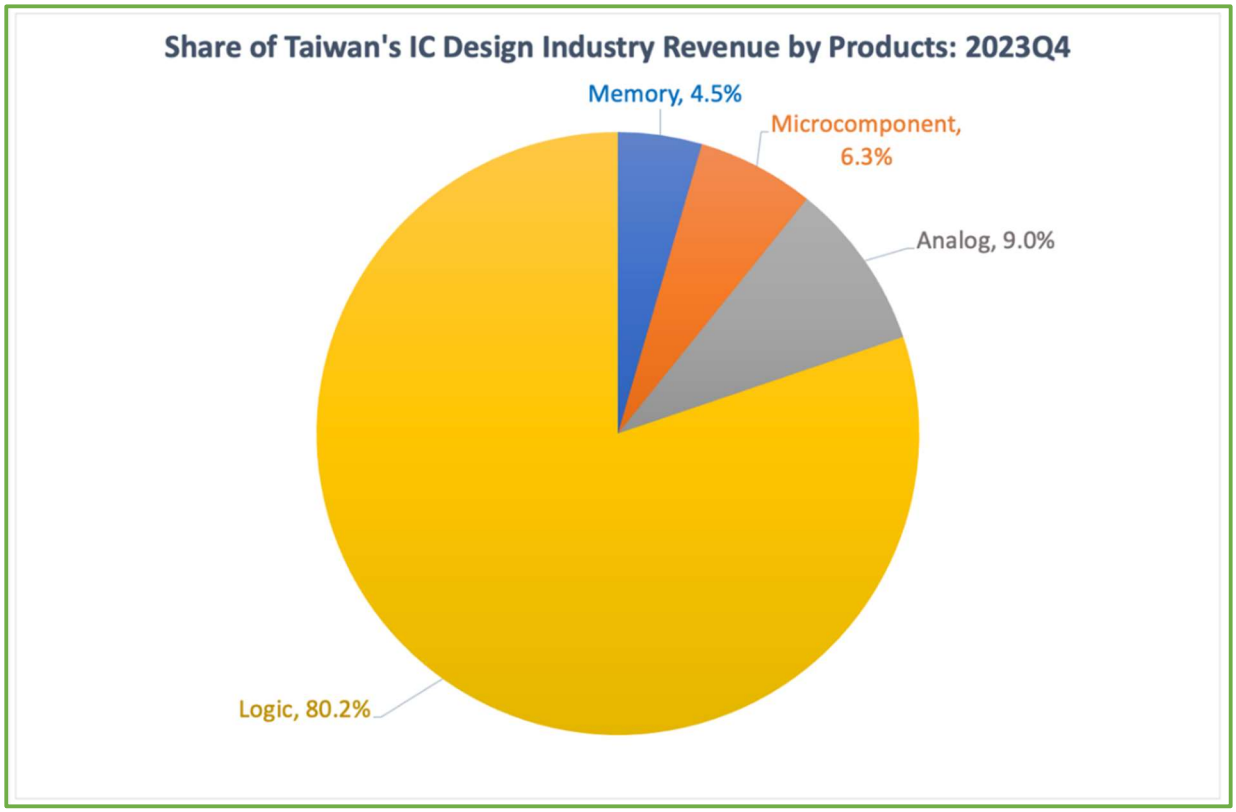


Source: Shu-Ting Chung," 2023 Q4 Industry Dynamics of IC design industry in Taiwan," IEK, ITRI, March 26, 2024, p. 1.

From the second quarter of 2023 onwards, Taiwan's IC design industry witnessed a surge in demand across various segments. The advanced features enabled by new mobile phone chips have significantly boosted the demand for high-end smartphones while the rise of AI in personal computers has also led to an increase in stocking of AI PCs. This trend is driven by consumer-focused AI applications like ChatGPT, which have become increasingly popular. The growth in AI PCs has, in turn, driven the demand for peripheral chips for enhancing the capabilities of AI PCs. Additionally, the launch of WiFi 7 is set to further boost demand. Equipment upgrades enabled the IC design industry to continue to maintain excellent performance in the fourth quarter. Overall, Taiwan's IC design industry showed an upward trend in the fourth quarter of 2023, with an output value of NT$ 300 billion (approximately US$ 9.4 billion), an increase of 4.3% from the third quarter.

Taiwan's IC design industry is dominated by logic chips, which are a fundamental component of many types of electronic devices. Logic chips, also known as logic ICs, are used to perform digital computations and processing. They are essential in applications ranging from consumer electronics to industrial machinery. In the fourth quarter of 2023, logic chips accounted for 80.2% of Taiwan's IC design industry revenue, followed by 9% share by analog chips, 6.3% by microcomponent chips and 4.5% by memory chips (see Figure 13).

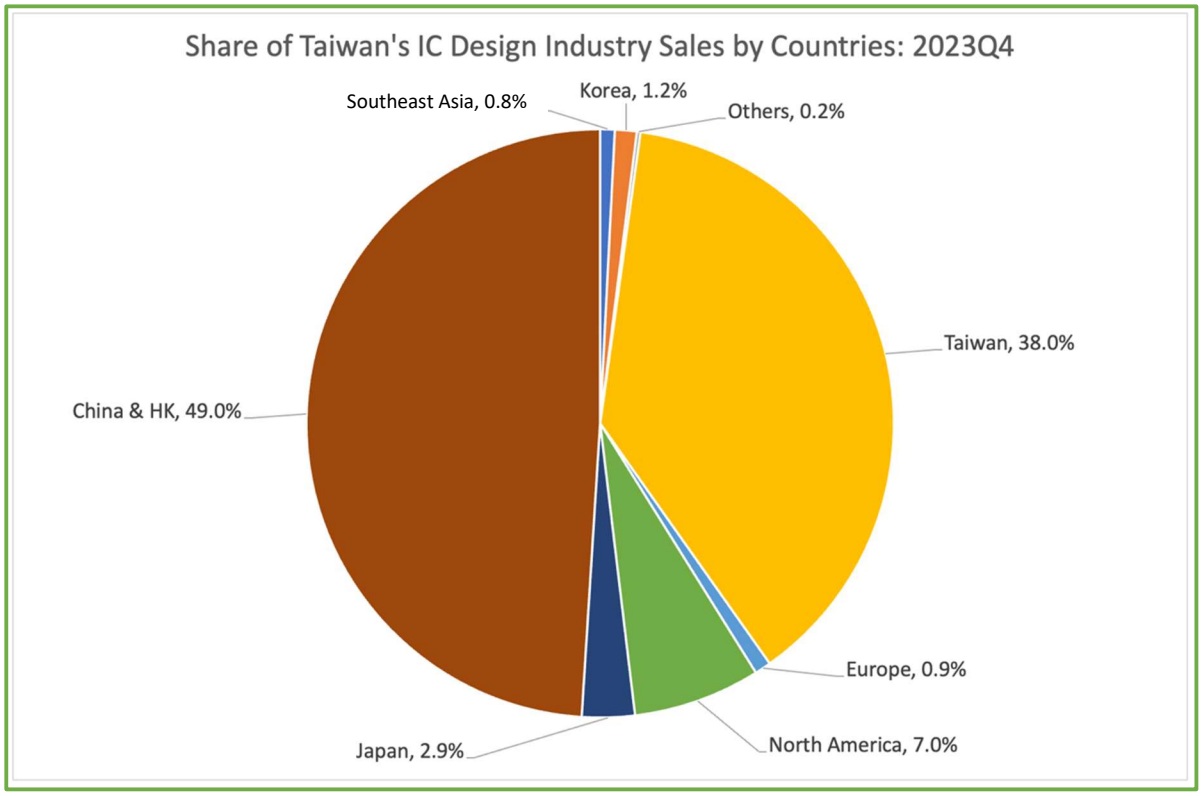
Figure 13: Share of Taiwan's IC Design Industry Revenue by Products: 2023Q4



Source: Shu-Ting Chung," 2023 Q4 Industry Dynamics of IC design industry in Taiwan," IEK, ITRI, March 26, 2024, p. 2.

In the fourth quarter of 2023, Taiwan's IC design industry's largest market was that of "China & Hong Kong", which accounted for 49.0% all sales. Domestic demand is the second largest market, accounting for 38.0%. Chips sold to customers in North America and Japan accounted for 7.0% and 2.9% respectively (see Figure 14).

Figure 14: Share of Taiwan's IC Design Industry Sales by Regions: 2023Q4



Source: Shu-Ting Chung," 2023 Q4 Industry Dynamics of IC design industry in Taiwan," IEK, ITRI, March 26, 2024, p. 3.

II. Midstream: IC manufacturing

After the IC design company designs the IC circuit layout, it is transferred to the foundry for IC manufacturing. The manufacturing process requires the transfer of the circuit and circuit components onto the wafer with a photomask, and the wafer is manufactured through oxidization, diffusion, chemical vapor deposition (CVD), etching, and ion implantation. As the IC circuit design has several layers, the process requires complex procedures, including the use of several photomasks and pattern creations to form circuits and components before a complete integrated circuit is produced. Consequently, both the technical and capital requirements of IC manufacturing are high.

IC manufacturing can be divided into two broad categories, namely foundries that specialize in producing data processing and computing IC, and memory manufacturers that produce memory IC. Taiwan’s IC manufacturing industry focuses mainly on semiconductor foundries, which account for more than 90% of the output value of Taiwan’s IC manufacturing industry.

Taiwan adopted a business model of specialized division of labor in both the upstream and downstream sections of the industry chain, and has developed a unique foundry contract manufacturing business. By focusing on specific areas of the semiconductor manufacturing process, Taiwanese semiconductor companies have achieved both superior yield performance with mature manufacturing processes due to their technological lead and cost savings in production processes. They also offer diverse manufacturing processes and capacity options to satisfy market demand. Being at the forefront of technology and having built a reputation for reliability and quality, most of the semiconductor companies in Taiwan have formed strategic partnerships with major tech companies, allowing them to sign long-term contracts with customers to generate stable profits.

Taiwan's foundries also focus on the development of advanced processes. Companies such as TSMC have contributed to the technological innovation and capital investment in Taiwan's overall IC manufacturing industry, and in the process, extended Taiwan's lead in advanced processes. In 2023, Taiwan maintained its lead across the board from 0.18 micrometers (μm) to 20 nm and sub-10 nm processes in the global IC manufacturing industry (see Table 14). TSMC announced in 2023 that mass production will begin for the 2 nm process by 2025 (see Table 15). The market expects that tech giants, such as AMD, NVIDIA, Qualcomm, MediaTek, Broadcom, and Intel, will begin using TSMC's 3 nm processes in the second half of 2023 to 2024.

Table 14: Overview of Global Capacity of Process Technologies: 2023

	Over 0.18μm	0.18μm to 40nm	40nm to 20nm	20nm to 10nm	Under 10nm	Total*
Taiwan	16.8%	29.4%	29.5%	9.9%	62.6%	21.4%
South Korea	6.8%	9.6%	27.3%	29.3%	36.7%	20.4%
Japan	17.1%	13.5%	-	23.6%	-	15.8%
China	20.5%	15.6%	15.4%	14.8%	-	15.3%
North America	16.0%	12.5%	17.0%	11.6%	0.7%	12.6%
Europe	12.1%	7.2%	6.8%	1.7%	-	5.7%

Source: Taiwan Industry Economics (TIE) Database, Taiwan Institute of Economic Research, June 2023

* Only pure-play foundries, does not include integrated device manufacturers (IDMs).

Table 15: Global Foundry Advanced Process Mass Production Timeline: 2021-2025

	2021	2022	2023	2024 (F)	2025 (F)
2 nm					TSMC, Samsung
3 nm+			TSMC		
3 nm, 3 nmGAA		TSMC, Samsung			
4 nm	TSMC, Samsung				
5 nm+, Intel 18A				Intel	
5 nm, Intel 20A				Intel	
7 nm+, Intel3			Intel		
7 nm, Intel4			Intel		
10 nm, Intel7		Intel			

Source: Taiwan Industry Economics (TIE) Database, Taiwan Institute of Economic Research, October 2023

According to estimates, Taiwan's mature process capacity will account for 43% of the global capacity by 2025, and advanced process capacity will account for 69% of the global capacity. Through its continuous innovation, investment and strategic planning, Taiwan's foundry industry is expected to maintain its lead in the medium to long-term development.

III. Downstream: IC packaging and testing

IC packaging refers to the covering of a processed wafer with plastic, ceramic, or metal coating after the die is cut in order to protect the die from contamination, increase the ease of assembly, enhance the electrical connection between the chip and the electronic system and to allow for heat dissipation. IC testing can be divided into two stages. The first is the wafer test before packaging to test the chip's electrical properties. The second is the IC finished product test, which is mainly implemented to test whether the IC functions as intended, including the testing of its electrical properties and heat dissipation capacity to ensure quality.

Taiwan's IC packaging and testing industry ranks first in the world. With the rise of IoT applications, Taiwan's IC packaging and testing companies have continued to develop high-end packaging and heterogeneous integration technologies, significantly increasing their lead over their competitors.

In 2023, five Taiwanese companies were ranked among the top ten global IC packaging and testing companies, including the world's largest packaging and testing company, Advanced Semiconductor Engineering Technology Holdings (ASE or ASEH), which boasted a market share of nearly 30%. The top ten IC packaging and testing companies accounted for about 88% of the global market share. Of the companies in the ranking, five Taiwanese companies – ASEH, Powertech Technology Inc (PTI), King Yuan Electronics Co (KYEC), ChipMOS Technology, Chipbond Technology Corporation– accounted for around 42% of the market share (see Table 16).

Table 16: Ranking of Main Global IC Packaging and Testing Companies by Revenue: 2023

Unit: US$ billion

2023 Ranking	Company Name	Headquarter	2023 Revenue	2023 Market Share
1	**ASE (ASEH)**	**TW**	**10.1**	**29%**
2	Amkor	US	6.5	19%
3	JCET	CN	4.0	12%
4	TFMC	CN	3.1	9%
5	**Powertech (PTI)**	**TW**	**2.3**	**6%**
6	HUATIAN	CN	1.6	5%
7	**KYEC**	**TW**	**1.1**	**3%**
8	Hana Micron	KR	0.7	2%
9	**Chipmos**	**TW**	**0.7**	**2%**
10	**Chipbond**	**TW**	**0.6**	**2%**
Market share of the world's top ten companies				88%
Total market share of Taiwanese companies				**42%**

Note: Only revenue from packaging and testing is included for ASE (ASEH).
Source: Companies, TechInsights, Market Intelligence & Consulting Institute (MIC) of the Institute for Information Industry

Table 17 shows the ranking of the top ten Taiwanese IC packaging and testing companies in 2023 by revenue. For the Taiwanese IC packaging and testing companies included in the ranking, the main products include computing IC and memory IC testing, demonstrating the diversity and comprehensiveness of Taiwan's IC packaging and testing industry.

Table 17: Ranking of Main Taiwanese IC Packaging and Testing Companies by Revenue: 2023

Unit: US$ billion

2023 Ranking	Company Name	2023 Revenue	Main Products
1	ASE (ASEH)	10.0	Logic IC packaging and testing, mixed-signal IC packaging and testing
2	Powertech (PTI)	2.3	Memory packaging and testing, logic IC packaging and testing
3	KYEC	1.1	Wafer probing, IC product testing
4	ChipMOS	0.7	Driver IC packaging and testing, memory packaging and testing
5	Chipbond	0.6	Driver IC packaging and testing, gold bumping
6	OSE	0.5	Memory packaging and testing
7	Sigurd	0.5	Mixed-signal IC, RF, power semiconductor packaging and testing
8	Ardentec	0.5	Memory wafer testing, digital and mixed-signal IC testing
9	FATC	0.2	Memory packaging and testing
10	WALTON	0.2	Memory packaging and testing

Note: Only revenue from packaging and testing is included for ASE (ASEH).
Source: Companies, Market Intelligence & Consulting Institute (MIC) of the Institute for Information Industry

IV. IC equipment and other supply chains

According to SEMI's report, Taiwan will continue to maintain its lead in expenditures on global foundry equipment in 2024, with a total of US$ 24.9 billion.[125] However, nearly 80% of the expenditures consist of purchases of foreign equipment, which shows that there is significant room for growth for domestic equipment manufacturers.

Taiwan's government has actively implemented a policy for domestic production of semiconductor equipment in recent years. It integrated national and industry resources, and encouraged companies to invest in semiconductor equipment development with the aim of attaining local production of foreign company equipment, and domestic production of advanced packaging and testing equipment to increase the use of domestic equipment by Taiwan's

[125] SEMI, Press Release: "Global Fab Equipment Spending On Track For 2024 Recovery After 2023 Slowdown, Semi Reports," March 21, 2023.

semiconductor companies.[126] The government also seeks to connect the entire industry to jointly support the upgrade of Taiwan's semiconductor equipment industry and enhance the international competitiveness of Taiwan's semiconductor equipment industry. Its goal is to make Taiwan a "high-end manufacturing center in Asia" and "center of advanced semiconductor processes."[127]

Table 18 shows the main listed companies in Taiwan's semiconductor equipment manufacturing and materials/substrates/chemicals sector. Some of the IC equipment and support materials companies in the midstream of the semiconductor supply chain include United Integrated Services (UIS), which helps clients build manufacturing facilities and install clean rooms; Marketech International Corporation, which produces wafer manufacturing equipment; Taiwan Mask Shop (TMC) which produces photomasks; and companies such as Eternal, Topco and Wahlee that produce chemicals and photoresist.

Downstream in the semiconductor supply chain, companies such as Chroma and Scientech produce packaging and testing equipment while Chang Wah Technology Co., Ltd., SDI Corporation, and Jih Lin Technology Co., Ltd. produce lead frames among other products for the semiconductor industry. Additionally, Unimicron, Nan Ya PCB (N.P.C), and Kinsus are all involved in the production of substrates for the semiconductor industry.

Both the companies in the upstream and downstream of the semiconductor supply chain play a crucial role in the semiconductor industry by providing the equipment and components to help ensure the smooth operation of the semiconductor supply chain.

[126] William Hetherington, "Tsai pushes local chip equipment production," Taipei Times, January 18, 2022.
[127] Department of Information Services, Executive Yuan, Republic of China (Taiwan), "Making Taiwan a high-end production hub for Asia and an advanced semiconductor manufacturing center," August 30, 2022.

Table 18: Main Listed Companies in Taiwan's Semiconductor Equipment Manufacturing And Materials/Substrates/Chemicals Sector

Supply Chain		Supply Chain Companies
Midstream	Wafer plant construction and system integration	UIS, L&K
	Wafer manufacturing equipment	MIC, Fiti
	Silicon wafer manufacturing	FST
	Photomasks	TMC
	Chemicals, photoresist	Eternal, Topco, Wahlee
Downstream	Packaging and testing equipment	Chroma, Scientech
	Substrates	Unimicron, NanYaPCB (N.P.C), Kinsus
	Lead frames	ChangWah, SDI, JihLin

Source: Compiled by the Taiwan Stock Exchange Corporation, January 2024.

V. IC distributors

IC distributors are only responsible for IC trading and sales and are not involved in the production. Their business model mainly consists of procurement from upstream semiconductor design companies or manufacturers, and the supply of key components or materials to downstream electronics industry manufacturers. They play the role of an intermediary in the entire semiconductor industry.

Distributors are indispensable for the success of Taiwan's semiconductor industry as they provide marketing channels and networks for upstream component suppliers. Due to the reach of distributors and high market sensitivity, they can quickly obtain market information and recommend new technologies to downstream manufacturers. They also leverage their integration and price negotiation capability for procurement from upstream suppliers to provide favorable prices for manufacturers. The most significant difference between semiconductor distributors and other distributors is that the former help original manufacturers with sales, technology, and warehousing management, resolve customer issues in design and mass production, and help customers shorten the time-to-market for new products.

In 2022, four Taiwanese companies, namely, WPG Holdings (WPG), WT Microelectronics (WT), Supreme Electronics and Edom Technology, were

ranked among the top ten global IC distributors (see Table 19). The IC distributor industry favors large companies, which tend to retain their lead. As 30% to 40% of IC industry products are sold through distributors, there is limited room for market growth and the intermediary service providers have margins of only 3% to 5%. Moreover, distributors generally rely on economies of scale, so mergers and acquisitions become an important means for distributors to expand their range of suppliers and customers.

Table 19: Ranking of Main Global IC Distributors by Revenue: 2023

Unit: US$ billion

Ranking	Company Name	Headquarter	Revenue	Market Share
1	Arrow	US	21.7	11%
2	Avnet	US	19.9	10%
3	**WPG**	**TW**	**19.2**	**10%**
4	**WT**	**TW**	**18.9**	**10%**
5	Macnica	JP	6.7	4%
6	Toyota Tsusho	JP	4.6	2%
7	**Supreme**	**TW**	**4.5**	**2%**
8	CECport	CN	4.5	2%
9	Future Electronics	CA	4.3	2%
10	Digi-key	US	3.4	2%
Market share of the world's top ten companies				55%
Total market share of Taiwanese companies in top 10 list				**22%**

Source: Gartner, "Market Share: Semiconductor Distributors, Worldwide, 2023," March 12, 2024

In recent years, Taiwanese IC distributors such as WPG and WT have continuously expanded their businesses through mergers and acquisitions. They have also used horizontal partnerships to increase synergy in operations. WT completed its acquisition of Future Electronics, creating a global electronic components distribution powerhouse, dual-headquartered in Taipei and Montreal for an enterprise value of US$ 3.8 billion on April 2, 2024.[128] This is expected to make WT one of the top three IC distributors in the world and increase its competitiveness in future development. Among the four Taiwanese IC distributors, WPG ranked first in terms of revenue, followed by WT, Supreme and Edom (see Table 20).

[128] Future Electronics, Press Release: "WT Microelectronics Completes Acquisition of Future Electronics," April 2, 2024.

Table 20: Ranking of Main Taiwanese IC Distributors by Revenue and Products Distributed: 2023

Unit: US$ billion

2023 Ranking	Company Name	Securities Market	2023 Revenue	Main Products
1	WPG	TWSE	24.5	Core components, memory components, discrete and logic components, analog and mixed-signal components, optical and sensor components; brands distributed include: AMD, Broadcom, Infineon, Intel, Kioxia, MediaTek, Micron, Nanya, Novatek, Nuvoton, NXP, Phison, Qualcomm, Realtek, Samsung, ST Micro, Willsemi, and Winbond
2	WT	TWSE	19.1	Analog IC, microcontrollers, memory IC, microprocessors, application specific IC; brands distributed include: Broadcom, ESMT, Intel, Marvell, MediaTek, Micron, Nanya, NXP, Nuvoton, Qualcomm, Realtek, and ST Micro
3	Supreme	TWSE	4.7	Memory components; brands distributed include: Samsung, MediaTek, Novatek, and CIRRUS LOGIC
4	Edom	TWSE	3.3	Integrated circuits, electronic components, memory

Data Source: WPG, Press Release: **"**WPG (TWSE:3702) Reports Fourth Quarter Sales of NT$183.38 Billion Exceeding High Range Forecast," January 10, 2024; WT, Press Release: "WT Microelectronics Announced Financial Results for the Fourth Quarter of 2023," January 31, 2024; Supreme Group 2023 Financial Report, March 11, 2024; Edom Technology, Press Release: "2023 Monthly Sales (Unit: Thousand NT$)," January 2024, Taiwan Stock Exchange, January 2024.

Taiwan's IC Market

The semiconductor industry is a key pillar of Taiwan's economic growth. It is one of its most important industries in terms of output value and share of exports.

Table 21 shows the output value of Taiwan's semiconductor industry from 2016 to 2023. Taiwan's semiconductor industry has grown across the board from 2016 to 2023, reaching a peak in 2022. IC manufacturing (includes wafers from foundries, memory chips and other semiconductor devices) was the largest contributor with an output value of NT$ 2,662.6 billion (US$ 85.3 billion) in 2023. This was followed by IC design (US$ 35.2 billion), IC packaging (US$ 12.6 billion) and IC testing (US$ 6.1 billion).

Table 21: Output Value of Taiwan's Semiconductor Industry: 2016-2023

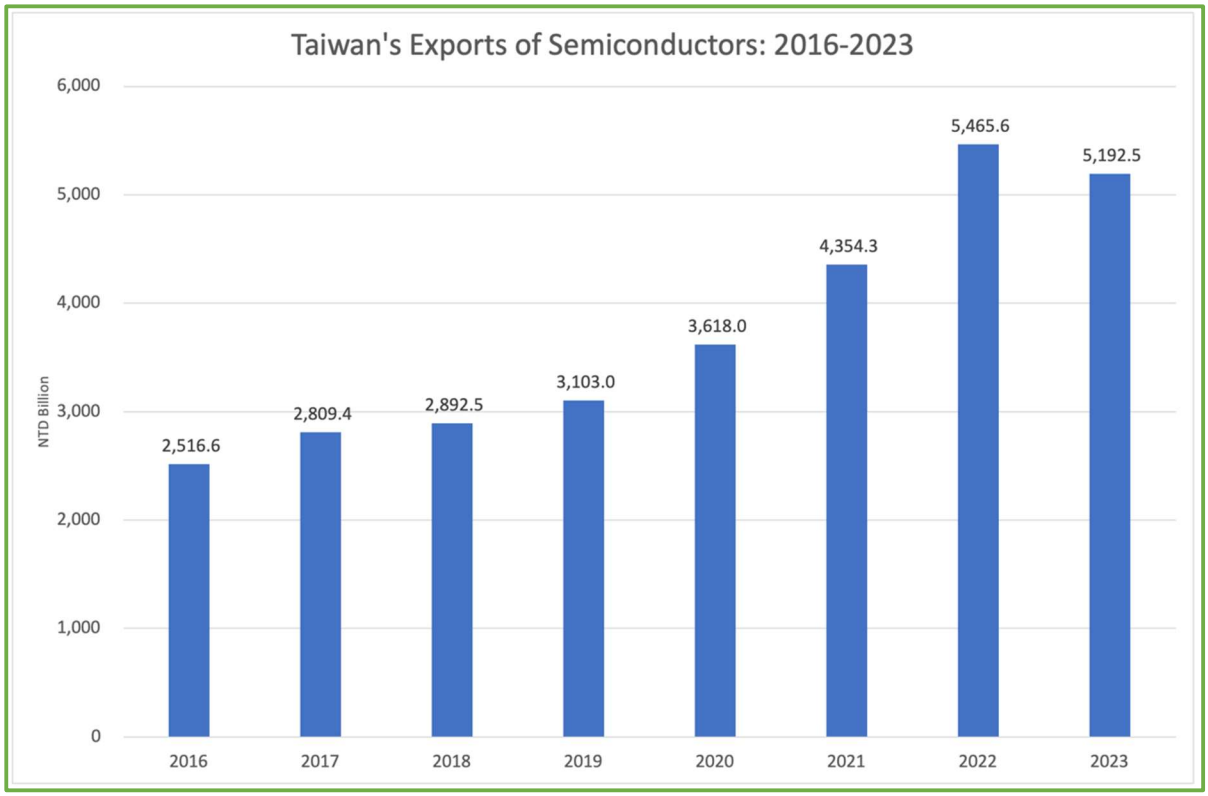
Unit: NT$ Billion

	2016	2017	2018	2019	2020	2021	2022	2023
IC Design	653.1	617.1	641.3	692.8	852.9	1,214.7	1,232.0	1,096.5
IC Manufacturing	1,332.4	1,368.2	1,485.6	1,472.1	1,820.3	2,228.9	2,920.3	2,662.6
IC Packaging	323.8	333.0	344.5	346.3	377.5	435.4	466.0	393.1
IC Testing	140.0	144.0	148.5	154.4	171.5	203.0	218.7	190.6

Source: IEK, ITRI, March 4, 2024.

Figure 15 shows Taiwan's semiconductor exports from 2016 to 2023. Taiwan's exports of semiconductors rose from NT$ 2,516.6 billion (US$ 80.7 billion) in 2016 to NT$ 5,465.6 billion (US$ 175.2 billion) in 2022 and then fell to NT$ 5,192.5 billion (US$ 166.4 billion) in 2023.

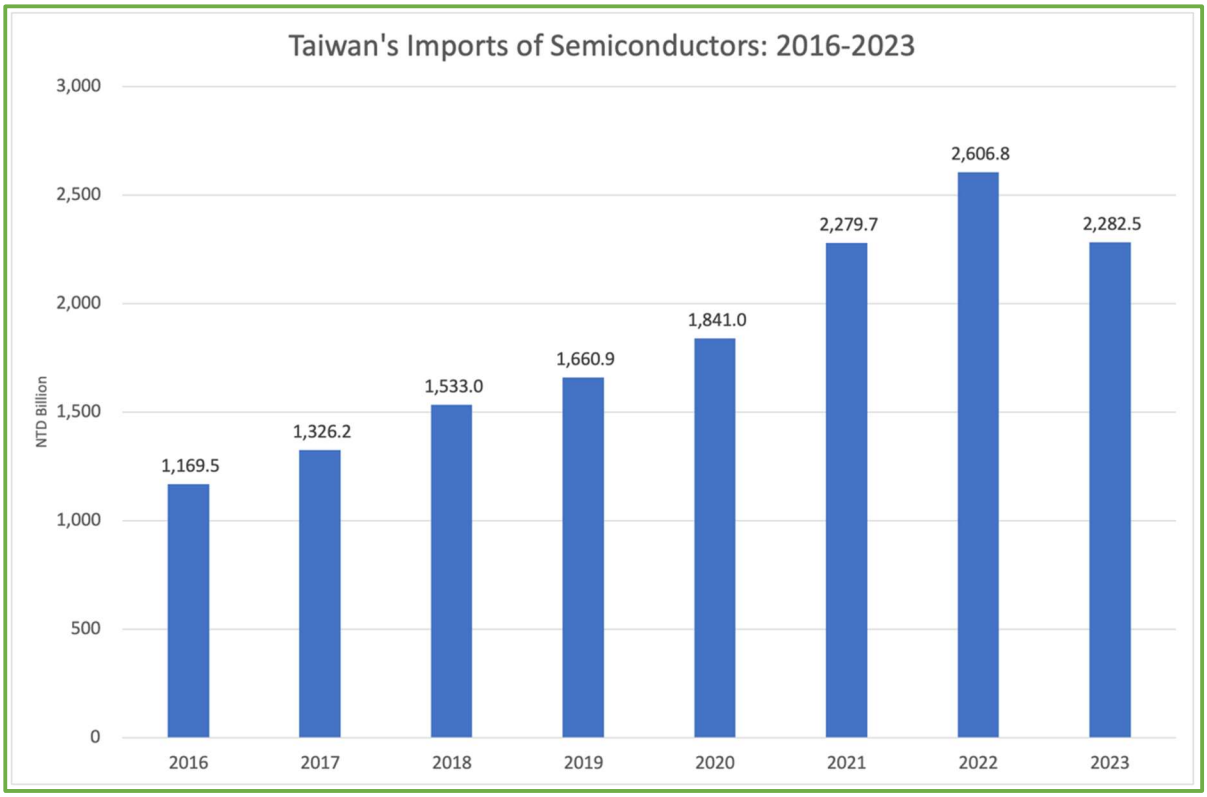
Figure 15: Taiwan's Exports of Semiconductors: 2016-2023



Source: IEK, ITRI, March 4, 2024.

Meanwhile, Taiwan's imports of semiconductors also rose from NT$ 1,169.5 billion (US$ 36.4 billion) in 2016 to NT$ 2,606.8 billion (US$ 81.1 billion) in 2022 and then fell to NT$ 2,282.5 (US$ 71.0 billion) in 2023 (see Figure 16).

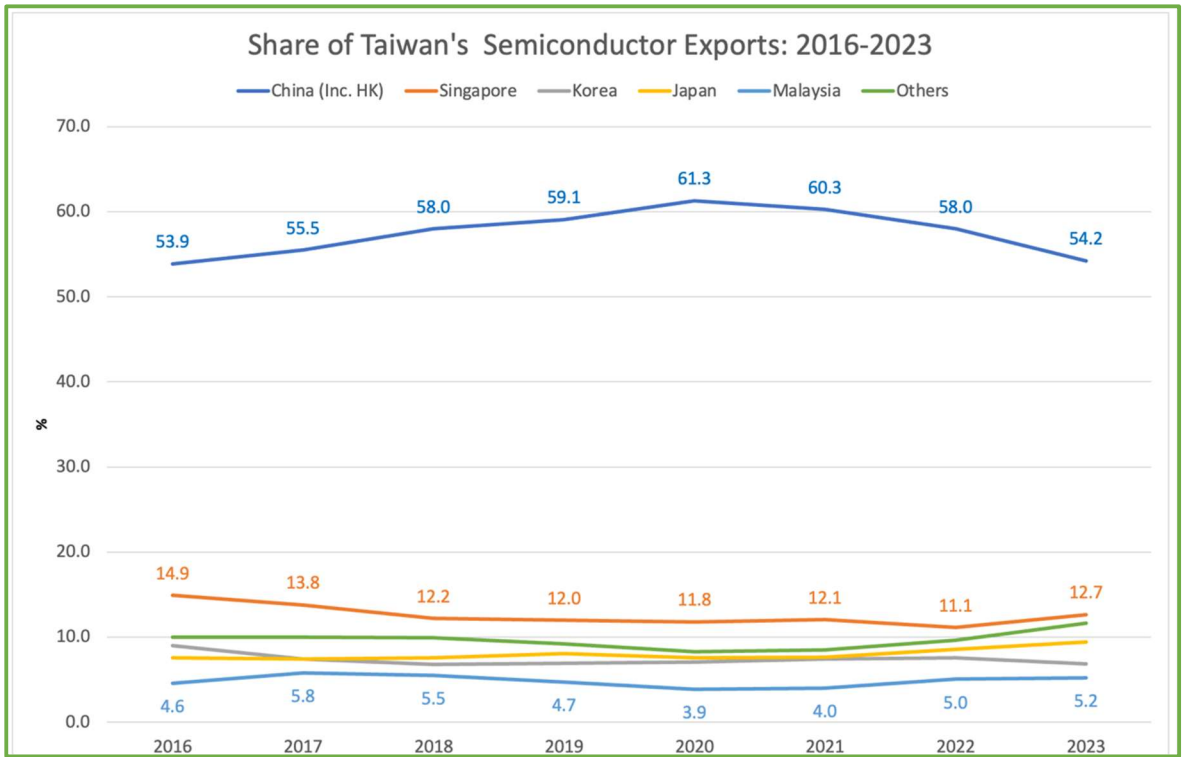
Figure 16: Taiwan's Imports of Semiconductors: 2016-2023



Source: IEK, ITRI, March 4, 2024.

Figure 17 and Table 22 show the main countries where Taiwan's semiconductors were exported from 2016 to 2023. Taiwan's top five export destinations included China, Singapore, Korea, Japan and Malaysia. Throughout the period, the largest share of amounting to more than 50% of Taiwan's semiconductor exports, were to China. The share of exports to China reached its peak at 61.3% share in 2020 and has been falling since. In 2023, the share of exports to China was 54.2%. In contrast, the share of Taiwan's semiconductor exports to countries like Singapore and Malaysia has been increasing since 2020. The share of Taiwan's semiconductor exports to Singapore increased from 11.8% in 2020 to 12.7% in 2023 and that to Malaysia increased from 3.9% in 2020 to 5.2% in 2023.

Figure 17: Share of Taiwan's Semiconductor Exports by Countries: 2016-2023



Source: IEK, ITRI, March 4, 2024.

Table 22: Share of Taiwan's Semiconductor Export by Countries: 2016-2023

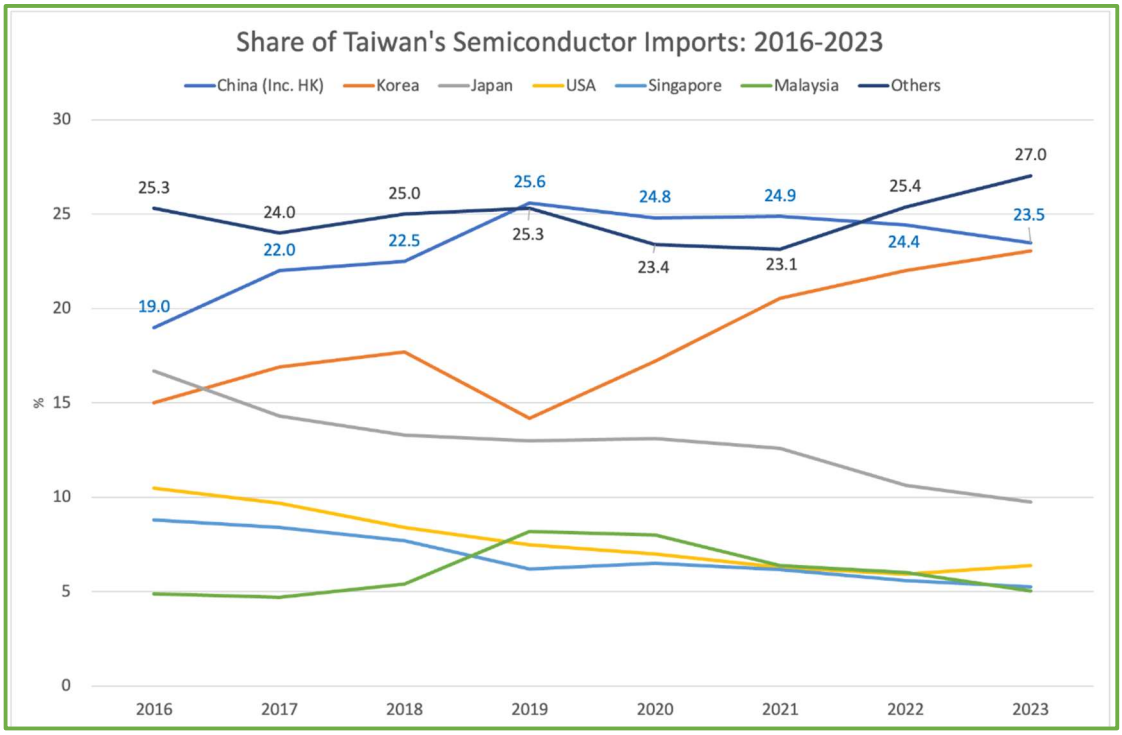
Unit: %

	2016	2017	2018	2019	2020	2021	2022	2023
China (Inc. HK)	53.9	55.5	58.0	59.1	61.3	60.3	58.0	54.2
Singapore	14.9	13.8	12.2	12.0	11.8	12.1	11.1	12.7
Korea	9.0	7.4	6.8	6.9	7.1	7.5	7.6	6.8
Japan	7.6	7.4	7.6	8.1	7.6	7.6	8.6	9.4
Malaysia	4.6	5.8	5.5	4.7	3.9	4.0	5.0	5.2
Others	10.0	10.0	9.9	9.2	8.3	8.5	9.7	11.6

Source: IEK, ITRI, March 4, 2024.

Figure 18 and Table 23 show the main countries where Taiwan's semiconductors were imported from 2016 to 2023. Taiwan's top five import sources included China, Korea, Japan, the U.S.A., and Singapore. In 2023, Taiwan imported the most from China (including Hong Kong) (23.5%) followed by South Korea (23%), Japan (9.8%), the U.S.A. (6.4%), and Singapore (5.3%). Other countries combined stood for 27% of imports.

Figure 18: Share of Taiwan's Semiconductor Imports by Countries: 2016-2023



Source: IEK, ITRI, March 4, 2024.

Table 23: Share of Taiwan's Semiconductor Imports by Countries: 2016-2023

Unit: %

	2016	2017	2018	2019	2020	2021	2022	2023
China (Inc. HK)	19.0	22.0	22.5	25.6	24.8	24.9	24.4	23.5
Korea	15.0	16.9	17.7	14.2	17.2	20.5	22.0	23.0
Japan	16.7	14.3	13.3	13.0	13.1	12.6	10.6	9.8
USA	10.5	9.7	8.4	7.5	7.0	6.3	5.9	6.4
Singapore	8.8	8.4	7.7	6.2	6.5	6.2	5.6	5.3
Malaysia	4.9	4.7	5.4	8.2	8.0	6.4	6.0	5.0
Others	25.3	24.0	25.0	25.3	23.4	23.1	25.4	27.0

Source: IEK, ITRI, March 4, 2024.

Table 24 shows Taiwan's semiconductor sub-industries value-add to the country's national income. As the pillar of Taiwan's economy, the semiconductor industry has been growing rapidly, with its value-add increasing from NT$ 1,275.4 billion (US$ 39.7 billion) in 2016 to US$ 81.6 billion in 2023. Among Taiwan's semiconductor sub-industries, IC manufacturing made the highest value-added contribution. In 2023, IC manufacturing's value-added contribution was NT$ 1,904.4 (US$ 59.2 billion) while that of IC design and IC packaging and testing were US$ 13.9 billion and US$ 8.4 billion respectively.

Table 24: Value-added Contribution of Taiwan's Semiconductor Sub-industries: 2016-2023

Unit: NT$ Billion

	2016	2017	2018	2019	2020	2021	2022	2023
IC Design	163.9	158.9	179.6	218.9	270.4	483.5	515.0	448.2
IC Manufacturing	888.4	932.7	1,022.1	973.4	1,286.1	1,590.9	2,141.7	1,904.4
IC Packaging and Testing	223.1	228.0	232.7	237.8	262.4	309.6	334.1	270.7
IC Industry	1,275.4	1,319.6	1,434.4	1,430.1	1,818.9	2,384.0	2,990.8	2,623.3

Source: IEK, ITRI, March 4, 2024.

Table 25 shows the value-added ratio of Taiwan's semiconductor sub-industries from 2016 to 2023. The value-added ratio of Taiwan's semiconductor industry and its various sub-industries have increased from 2016 to 2023. In 2023, the value-added ratio stood at 61.7% for the industry while that of the IC design, IC manufacturing and IC packaging and testing sub-industries stood at 41.5%, 73.1% and 47.7% respectively.

Table 25: Value-added Ratio of Taiwan's Semiconductor Sub-industries: 2016-2023

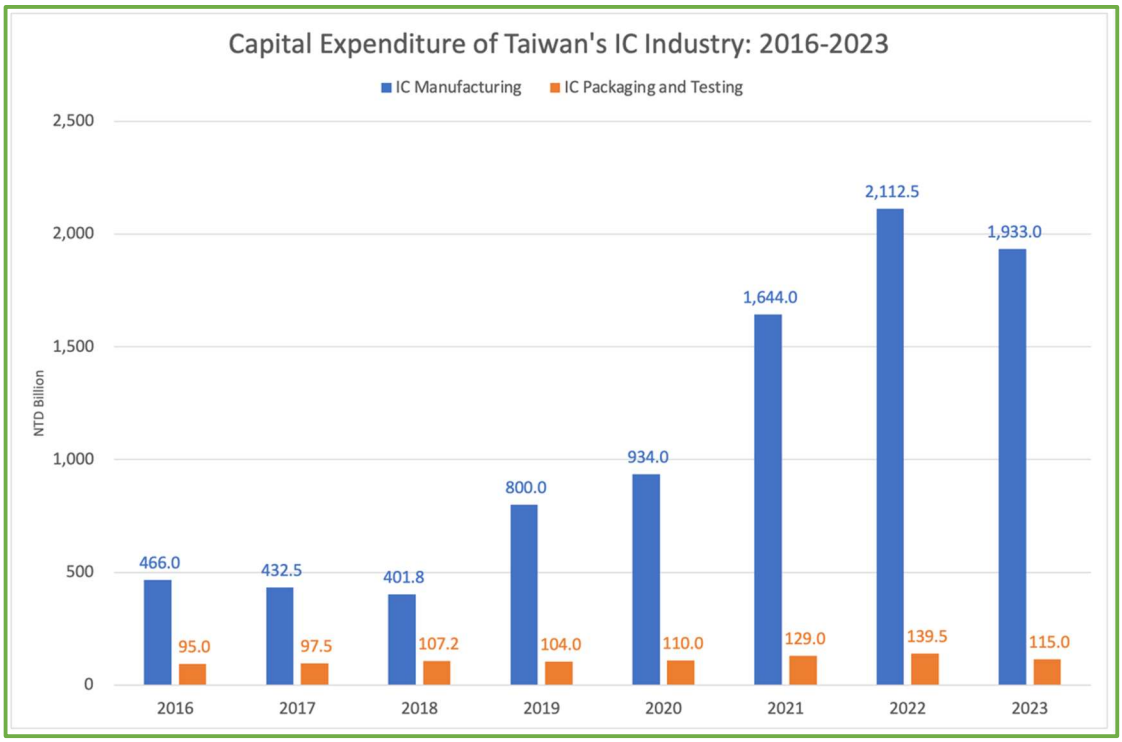
Unit: %

	2016	2017	2018	2019	2020	2021	2022	2023
IC Design	25.1	25.7	28.0	31.6	31.7	39.8	41.8	41.5
IC Manufacturing	66.7	68.2	68.8	66.1	70.7	71.4	73.3	73.1
IC Packaging and Testing	48.1	47.8	47.2	47.5	47.8	48.5	48.8	47.7
IC Industry	52.1	53.6	54.8	53.7	56.4	58.4	61.8	61.7

Source: IEK, ITRI, March 4, 2024.

B. Capital Expenditure

Figure 19: Capital Expenditure of Taiwan's IC Industry: 2016-2023



Source: IEK, ITRI, March 4, 2024.

Despite the challenges posed by global economic conditions, Taiwan's semiconductor industry remains resilient and committed to advancing its capabilities. The industry's capital spending continues to rise, reflecting its strategic importance and dedication to innovation. Capital expenditure in IC manufacturing and IC packaging and testing has increased from 2016 to 2023. In 2023, Taiwan's IC manufacturing recorded a capital expenditure of NT$ 1,933 billion (US$ 60.1 billion) while its IC testing and packaging hit a capital expenditure of US$ 3.6 billion (see Figure 19).

C. Employment, R&D Expenditure and Researchers

Table 26 shows the research and development (R&D) expenditure of Taiwan's semiconductor industry from 2016 to 2023. Due to its economic importance, Taiwan's semiconductor industry's total R&D spending has

increased from NT$ 259.6 billion (US$ 8.1 billion) to NT$ 433.4 billion (US$ 13.5 billion) in 2023, with IC manufacturing leading in R&D spending. In 2023, IC manufacturing spent NT$ 217.4 billion (US$ 6.8 billion) on R&D, followed by IC design (US$ 6.2 billion), and IC packaging and testing (US$ 0.6 billion).

Table 26: Research and Development Expenditure of Taiwan's Semiconductor Industry: 2016-2023

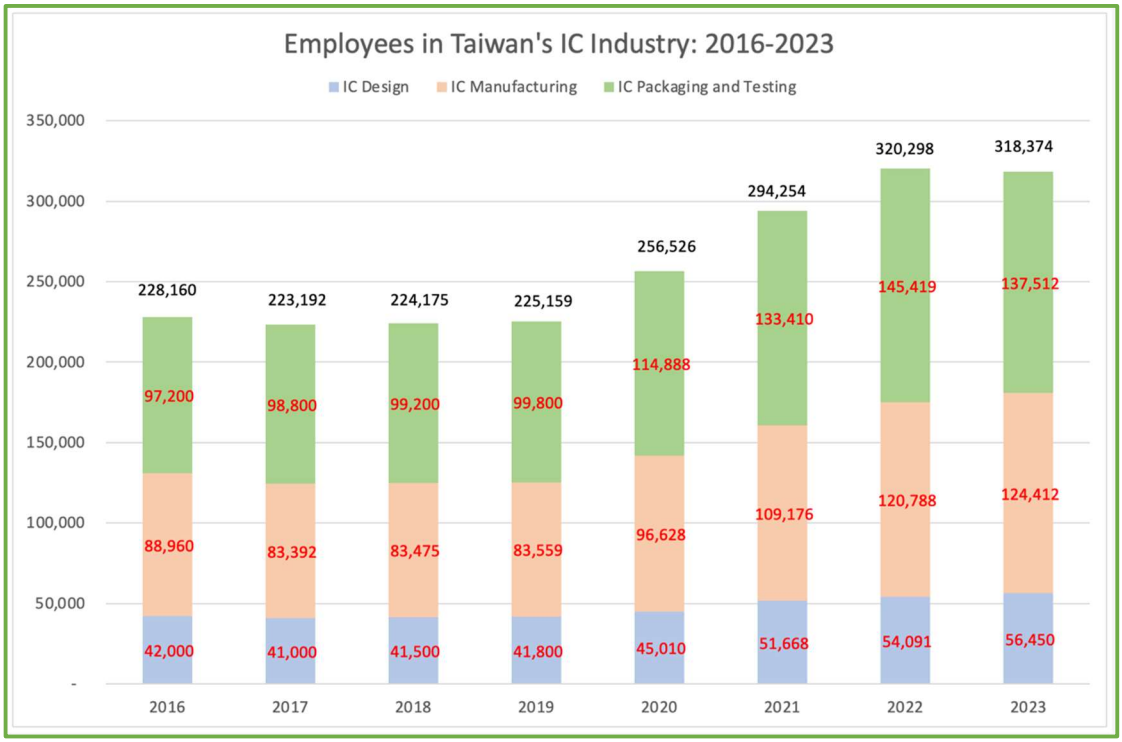
Unit: NT$ Billion

	2016	2017	2018	2019	2020	2021	2022	2023
IC Design	109.0	108.0	115.5	125.5	157.8	220.5	232.0	198.0
IC Manufacturing	135.4	116.4	117.3	118.7	142.5	168.1	205.1	217.4
IC Packaging and Testing	15.2	15.5	15.7	16.5	16.7	19.9	22.0	18.0
IC Industry	259.6	239.9	248.5	260.7	317.0	408.5	459.1	433.4

Source: IEK, ITRI, March 4, 2024.

Taiwan's semiconductor industry continues to thrive, attracting talent and driving technological advancements. Figure 20 shows the workforce trends in Taiwan's IC industry from 2016 to 2023. The number of persons employed in the semiconductor industry rose from 228,160 in 2016 to 318,374 in 2023. Of the semiconductor sub-industries, IC packaging and testing has the largest number of employees, followed by IC manufacturing and IC design. This is because the IC packaging and testing phase in the semiconductor industry tends to be more labor-intensive compared to IC manufacturing (wafer foundry). In 2023, the number of persons employed in IC design, IC manufacturing and IC packaging and testing were 56,450; 124,412; and 137,512 respectively.

Figure 20: Number of Employees in Taiwan's IC Industry: 2016-2023



Source: IEK, ITRI, March 4, 2024.

D. Global Expansion of Taiwan's Leading Semiconductor Companies

Taiwan's leading semiconductor companies are expanding globally, investing heavily to strengthen their positions in the global IC market. As various countries actively develop their semiconductor industries, Taiwan's foundries, including the TSMC, UMC, and PSMC, are becoming prime targets for local manufacturing facilities. As foundries expand their operations overseas, a number of their Taiwanese suppliers are also expanding their presence in these regions to provide more timely and efficient services. Leading IC design companies such as MediaTek as well as packaging and testing companies such as ASEH are also expnding globally, contributing to the robust growth of the semiconductor industry worldwide.

- **TSMC**

TSMC is the world's largest contract chipmaker and plays an important role in the global semiconductor supply chain.

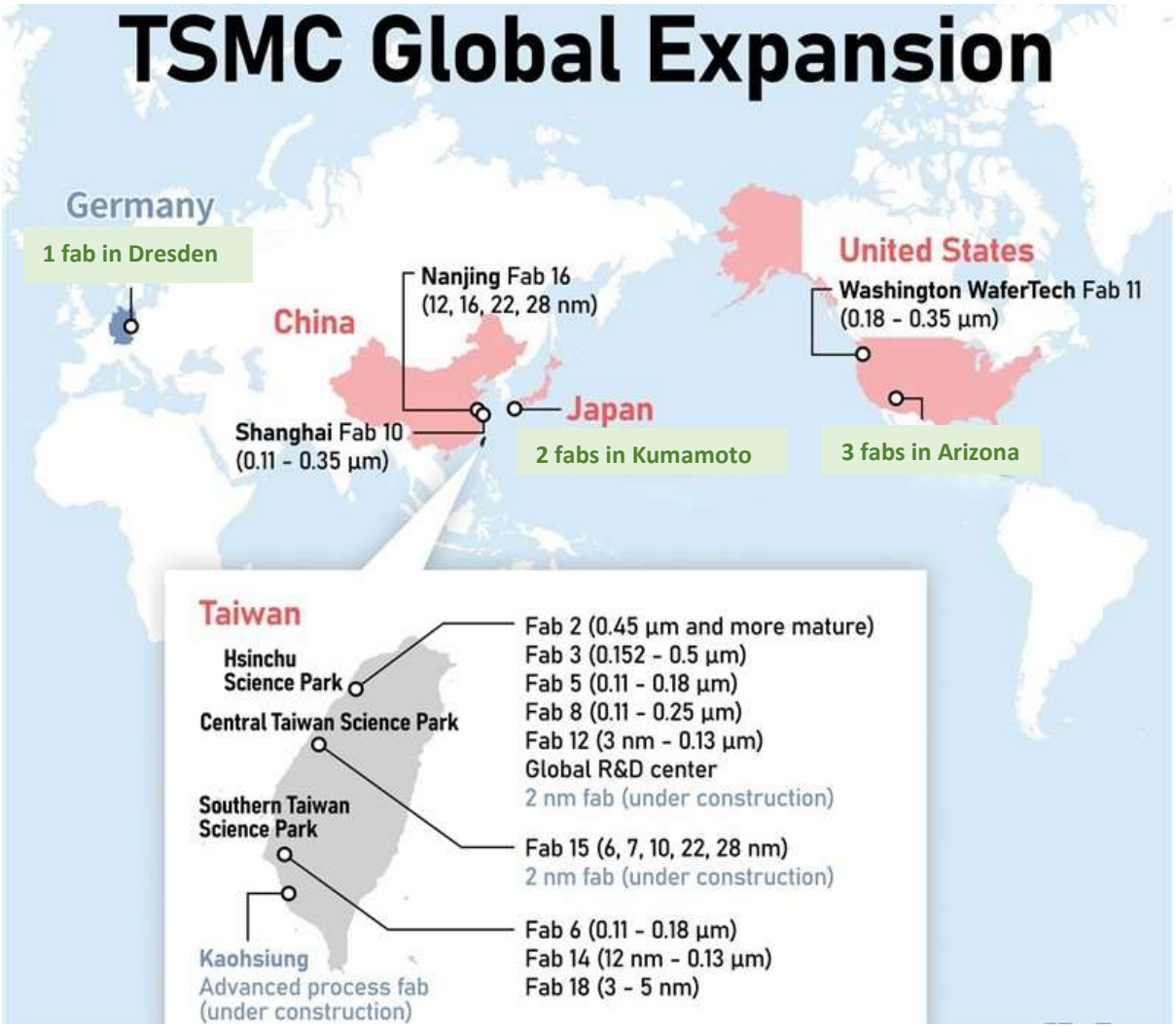
Despite the massive April 3, 2024, earthquake in Taiwan, TSMC announced that its full-year revenue would not be impacted, allaying concerns of a hit to the global semiconductor supply.[129] Apart from certain production lines in areas that experienced greater impact, equipment in TSMC and other Taiwan fabs such as UMC, Vanguard International Semiconductor and Powerchip Semiconductor Manufacturing have largely been fully recovered by April 5, 2024.

Over its more than thirty years of existence, TSMC has established deep roots in Taiwan, employing a large workforce of engineers, research and development scientists, technicians, and production workers. TSMC currently has a global R&D center and operates four 12-inch wafer GIGAFAB® fabs, four 8-inch wafer fabs, and one 6-inch wafer fab – all in Taiwan – as well as one 12-inch wafer fab at a wholly owned subsidiary, TSMC Nanjing Company Limited in China, and two 8-inch wafer fabs at wholly owned subsidiaries, TSMC Washington in the United States, and TSMC China Company Limited in Shanghai, China. [130]

With the semiconductor industry's recovery this year (2024) and the high demand for AI chips, expansion efforts in the north, central, and southern regions have become more active. In April 2024, first tool-in will be commenced at the Baoshan 2 nm plant (Fab 20) in the Hsinchu Science Park. Meanwhile, a 2 nm plant (Fab 22) in Kaohsiung is under construction, with plans for a third plant underway. TSMC's 2 nanometer process is scheduled for mass production in 2025.[131] Concurrently, TSMC has been actively expanding its global manufacturing footprint, with plans for new fabs in the United States, Japan, and Germany (see Figure 21).

[129] Yuvraj Malik, "TSMC retains 2024 revenue view in sign of limited impact of earthquake," Reuters, April 5, 2024.
[130] TSMC, TSMC Fabs, https://www.tsmc.com/english/aboutTSMC/TSMC_Fabs. Accessed on April 16, 2024.
[131] TrendForce, Press Release: "TSMC to Expand Production with New Facilities Across Taiwan in April," March 7, 2024.

Figure 21: TSMC's Global Expansion



Source: Figure adapted from Central News Agency (CNA) graphic, August 8, 2023.

The expansion of TSMC to Japan, the U.S.A. and Germany is a major event in the global semiconductor industry. It is a sign of the growing demand for semiconductors and is also seen as a key to strengthening the resilience of the global semiconductor supply chain.

1. **Phoenix, Arizona**: TSMC Arizona's first fab is on track to begin production leveraging 4nm technology in first half of 2025. The second fab will produce the world's most advanced 2 nm process technology with next-generation nanosheet transistors in addition to the previously announced 3 nm technology, with production beginning in 2028. The third fab will produce chips using 2 nm or more advanced processes, with production beginning by the end of the decade. TSMC's total capital

expenditure for the 3 fabs in the Phoenix, Arizona site is more than US$ 65 billion, making the site the largest foreign direct investment in Arizona history, and the largest foreign direct investments in a greenfield project in U.S. history.[132]

2. **Kumamoto, Japan**: TSMC celebrated the opening of its majority-owned subsidiary Japan Advanced Semiconductor Manufacturing, Inc. (JASM) in Kumamoto Prefecture, Japan, on February 24, 2024. A second Japanese plant is scheduled to begin operation by the end of 2027, bringing the total investment in its Japan venture to more than US$ 20 billion with the support of the Japanese government. With both fabs, JASM's Kumamoto site is expected to offer a total production capacity of more than 100,000 12-inch wafers per month, starting from various nanometer process technologies for different applications.[133]

3. **Dresden, Germany**: TSMC, along with Bosch, Infineon, and NXP, established a joint venture to bring advanced semiconductor manufacturing to Europe. The joint venture, European Semiconductor Manufacturing Company (ESMC) GmbH, is planned under the framework of the European Chips Act. The fab is expected to have a monthly production capacity of 40,000 12-inch wafers on TSMC's 28/22 and 16/12 nanometer process technology. Construction is aimed to begin in the second half of 2024, with production targeted to start by the end of 2027. Total investments are expected to exceed EU€ 10 billion (US$ 10.6 billion), with significant support from the European Union and German government.[134]

At its home base in Taiwan, TSMC sits at the center of a web of factories, suppliers and engineering firms. As TSMC expands its operations overseas, many of its Taiwanese suppliers are also expanding their presence in these regions to maintain close proximity and provide timely services to TSMC.[135] For

[132] Taiwan Semiconductor Manufacturing Company (TSMC), Press Release: "TSMC Arizona and U.S. Department of Commerce Announce up to US$6.6 Billion in Proposed CHIPS Act Direct Funding, the Company Plans Third Leading-Edge Fab in Phoenix," April 8, 2024.

[133] Taiwan Semiconductor Manufacturing Company (TSMC), Press Release: "JASM Set to Expand in Kumamoto Japan," February 6, 2024; TSMC, Press Release: "TSMC Celebrates the Opening of JASM in Kumamoto, Japan," February 24, 2024.

[134] Huang Ya-shih and Alison Hsiao, "Smaller city near Dresden hopes for boost following TSMC's arrival," Focus Taiwan, March 2, 2024.

[135] Taipei Times, "Chip firms to invest US$210bn globally," November 26, 2023.

instance, Marketech International Corp, a facility monitor control system provider for TSMC, has set up a team in the U.S.A. and is planning to expand its presence there due to TSMC's Arizona project. Likewise, Mirle Automation Corporation, which provides intelligent automation system solutions to TSMC, has expressed its intention to stay geographically close to TSMC while IC packaging and testing services provider ASEH is studying possible investments in the U.S.A. so that it could continue to support TSMC's operations.[136] These expansions highlight the interconnected nature of the semiconductor supply chain and the importance of maintaining close relationships between manufacturers and their suppliers.

- **UMC and PSMC**

Taiwan's second largest foundry, UMC, has fabs spread across Taiwan, Singapore, China, and Japan.[137] Meanwhile, PSMC, Taiwan's third largest foundry, has established joint ventures to set up semiconductor fabs in several countries, including China, India, and Japan.[138] According to PSMC Chairman Frank Huang, PSMC is the go-to option for countries seeking guidance in semiconductor manufacturing as South Korea, the United States and Taiwan's TSMC and UMC are unwilling to teach others how to make semiconductors.[139]

- **MediaTek**

Chip designer MediaTek, for example, has offices in countries, including the United States, China, Dubai, Finland, Germany, India, Japan, Korea, Singapore, Sweden, and the United Kingdom on top of its operations in Taiwan.[140] Meanwhile, semiconductor testing and packaging giant ASE has manufacturing locations spanning the globe, with facilities in Taiwan, China, South Korea, Japan, Singapore, Malaysia, Vietnam, Mexico, United States, Poland, France, United Kingdom, Germany, Tunisia and the Czech Republic.[141]

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136 Ibid.

137 United Microelectronics Corporation, "Overview," https://www.umc.com/en/StaticPage/about_overview

138 Powerchip Semiconductor Manufacturing Corporation (PSMC), Press Releases: "Taiwan and Japan join hands to build JSMC's first fab in Miyagi Prefecture," October 31, 2023; "Tata joins hands with PSMC to build India's first 12-inch fab," February 29, 2024.

139 TrendForce, Press Release: "TSMC and PSMC Face Dilemma as Overseas Foundry Costs Skyrocket 2.5 to 4 Times," January 12, 2024.

140 MediaTek, "Office Locations." https://corp.mediatek.com/about/office-locations. Accessed April 10, 2024.

141 ASE Holdings, "About the Company." https://www.aseglobal.com/. Accessed April 10, 2024.

4. Opportunities and Prospects of Taiwan's Semiconductor Industry

A. Taiwan's Stock Market

The Semiconductor Industry Association (SIA) of the United States stated in 2021 that if Taiwan was unable to produce chips for an entire year, the revenue of the global electronics industry would fall by nearly US$ 500 billion. Besides its pivotal role in the global semiconductor industry, the robust international competitiveness of Taiwan's semiconductor companies is also an important engine of growth for Taiwan's capital market.

As of December 2023, the total market value of semiconductor companies listed on the Taiwan Stock Exchange Corporation (TWSE) accounted for approximately 40% of the market value of all listed companies in Taiwan. The semiconductor industry plus other ICT-related industry accounted for 60% of the total market value. Their operations include IC design, foundry, and packaging and testing. The upstream, midstream, and downstream sections of the industry form comprehensive semiconductor industry clusters which play a crucial role in Taiwan's economic growth and technological advancement.

Taiwan's stock market offers advantages in terms of low price-earnings ratio and high yields. Its transaction value and turnover rate are some of the highest among Asian markets, which demonstrate that Taiwanese stock prices are relatively reasonable and highly liquid, and that investors can obtain stable cash dividends. In addition, more than 50% of foreign capital investments in Taiwan's capital market are invested in semiconductor stocks, which demonstrates the indispensable role of Taiwan's semiconductor industry in the global capital market (see Table 27).

Going forward, the TWSE will continue to help Taiwan's semiconductor companies leverage the power of the capital market and national industrial policies and resources to consolidate the key role of Taiwan's semiconductor industry in the global semiconductor industrial chain while expanding its lead over its competitors.

Table 27: Basic Information of Main Listed Companies of Taiwan's IC Industry

Unit: Capital, revenue, market value: US$ billion

Industry Chain	Stock Code	Short Name of the Company in English	Short Name of the Company in Chinese	Listing Date	Capital	2022 Revenue	Revenue in the First Three Quarters of 2023	Market Value	PB Ratio	PE Ratio	Dividend Yield	Company Website
IC design	2454	MTK	聯發科	2001/07/23	0.51	18.39	9.82	48.37	3.83	21.55	8.04%	www.mediatek.com
	2379	RT	瑞昱	1998/10/26	0.16	3.75	2.35	7.38	5.43	25.31	6.01%	www.realtek.com
	3034	NOVATEK	聯詠	2002/08/26	0.19	3.68	2.69	9.95	5.04	14.11	7.24%	www.novatek.com.tw
	3592	Raydium	瑞鼎	2022/01/07	0.02	0.76	0.43	0.98	2.83	21.43	10.19%	www.rad-ic.com
	4961	FITIPOWER	天鈺	2018/10/17	0.04	0.66	0.40	1.10	2.03	17.42	3.01%	www.fitipower.com
	8016	Sitronix	矽創	2003/12/25	0.04	0.60	0.39	1.11	3.33	19.23	7.61%	www.sitronix.com.tw
	3006	ESMT	晶豪科	2002/03/04	0.09	0.54	0.28	0.87	2.48	-	1.90%	www.esmt.com.tw
IC design service	3661	Alchip	世芯-KY	2014/10/28	0.02	0.46	0.69	7.39	13.14	84.72	0.42%	www.alchip.com
	3443	GUC	創意	2006/11/03	0.04	0.81	0.64	7.07	24.6	53.38	0.85%	www.guc-asic.com
	3035	Faraday	智原	2002/08/26	0.08	0.44	0.30	3.07	10.66	53.39	1.30%	www.faraday-tech.com
Foundry	2330	TSMC	台積電	1994/09/05	8.30	75.84	49.63	478.73	4.47	16.71	1.91%	www.tsmc.com
	2303	UMC	聯電	1985/07/16	4.00	9.34	5.41	19.56	1.75	9.14	7.36%	www.umc.com
	6770	PSMC	力積電	2021/12/06	1.30	2.55	1.06	3.92	1.28	51.02	3.42%	www.powerchip.com
	4919	NTC	新唐	2010/09/27	0.13	1.40	0.87	1.99	3.88	25.69	4.71%	www.nuvoton.com
Memory	2408	NTC	南亞科	2000/08/17	0.99	1.91	0.68	7.43	1.35	-	2.84%	www.nanya.com
	2344	WEC	華邦電	1995/10/18	1.34	3.17	1.80	3.79	1.3	-	3.53%	www.winbond.com
	2337	Macronix	旺宏	1995/03/15	0.59	1.46	0.70	1.71	1.09	-	6.25%	www.macronix.com
IC packaging and testing	3711	ASEH	日月光投控	2018/04/30	1.40	22.48	13.61	17.94	1.87	14.48	6.87%	www.aseglobal.com
	6239	PTI	力成	2004/11/08	0.24	2.81	1.66	2.72	1.64	15.51	6.25%	www.pti.com.tw
	2449	KYEC	京元電子	2001/05/09	0.39	1.23	0.79	3.24	2.72	17.54	4.23%	www.kyec.com.tw
	8150	ChipMOS	南茂	2014/04/11	0.23	0.79	0.50	0.95	1.21	18.98	5.64%	www.chipmos.com

Industry Chain	Stock Code	Short Name of the Company in English	Short Name of the Company in Chinese	Listing Date	Capital	2022 Revenue	Revenue in the First Three Quarters of 2023	Market Value	PB Ratio	PE Ratio	Dividend Yield	Company Website
	6257	SIGURD	矽格	2003/08/25	0.15	0.63	0.37	0.93	1.77	16.97	6.58%	www.sigurd.com.tw
	2329	OSE	華泰	1994/04/20	0.26	0.52	0.39	1.05	4.09	28.93	1.43%	www.ose.com.tw
	8131	FATC	福懋科	2007/11/29	0.14	0.35	0.18	0.55	1.48	21.99	8.43%	www.fatc.com.tw
	8110	WALTON	華東	2007/10/31	0.17	0.32	0.17	0.25	0.76	-	0.98%	www.walton.com.tw
Wafer plant construction and system integration	2404	UIS	漢唐	2000/03/14	0.06	1.61	1.64	1.49	4	9.81	6.13%	www.uisco.com.tw
	6139	L & K	亞翔	2003/08/25	0.07	1.20	1.06	1.05	3.33	15.82	2.40%	www.lkeng.com.tw
Wafer manufacturing equipment	6196	MIC	帆宣	2004/05/24	0.06	1.69	1.33	0.86	2.5	11.26	4.19%	www.micb2b.com
	3413	Fiti	京鼎	2015/07/28	0.03	0.50	0.31	0.61	1.73	10.09	6.98%	www.foxsemicon.com.tw
Wafers	3532	FST	台勝科	2007/12/10	0.12	0.55	0.36	2.04	2.56	16.67	4.45%	www.fstech.com.tw
Photomasks	2338	TMC	光罩	1995/04/17	0.08	0.26	0.17	0.63	3.38	18.14	3.25%	www.tmcnet.com.tw
Chemicals, photoresist	1717	ETERNAL	長興	1994/03/31	0.38	1.64	1.02	1.12	1.39	24.07	4.05%	www.eternal-group.com
	5434	TOPCO	崇越	2003/08/25	0.06	1.77	1.20	1.10	2.4	12.48	5.46%	www.topco-global.com
	3010	WAH LEE	華立	2002/07/22	0.08	2.46	1.60	0.76	1.31	11.78	6.07%	www.wahlee.com
Packaging and testing equipment	2360	CHROMA	致茂	1996/12/21	0.14	0.74	0.44	2.93	4.24	22.54	3.72%	www.chromaate.com
	3583	Scientech	辛耘	2013/03/12	0.03	0.19	0.16	0.57	4.61	29.04	1.63%	www.scientech.com.tw
Substrates	3037	UNIMICRON	欣興	2002/08/26	0.49	4.71	2.53	8.64	3.03	16.42	4.51%	www.unimicron.com
	8046	N.P.C	南電	2006/04/07	0.21	2.17	1.06	5.13	3.38	15.83	7.26%	www.nanyapcb.com.tw
	3189	KINSUS	景碩	2004/11/01	0.15	1.39	0.62	1.44	1.43	51.24	6.55%	www.kinsus.com.tw
Lead frames	8070	CHANGWAH	長華*	2007/12/31	0.02	0.73	0.40	0.76	1.64	14.5	7.33%	www.cwei.com.tw

Industry Chain	Stock Code	Short Name of the Company in English	Short Name of the Company in Chinese	Listing Date	Capital	2022 Revenue	Revenue in the First Three Quarters of 2023	Market Value	PB Ratio	PE Ratio	Dividend Yield	Company Website
	2351	SDI	順德	1996/04/25	0.06	0.39	0.27	0.69	3.2	27.38	2.71%	www.sdi.com.tw
	5285	JihLin	界霖	2014/02/25	0.03	0.21	0.12	0.25	2.67	42.23	4.63%	www.jihlin.com.tw
IC distributors	3702	WPG	大聯大	2005/11/09	0.60	25.97	15.79	4.17	1.72	24.25	4.96%	www.WPGholdings.com
	3036	WT	文曄	2002/08/26	0.33	19.14	13.08	3.88	1.98	29.4	3.63%	www.wtmec.com
	8112	Supreme	至上	2007/12/31	0.17	5.83	3.33	0.89	1.78	18.95	7.87%	www.supreme.com.tw
	3048	EDOM	益登	2002/10/01	0.09	3.98	2.43	0.21	1.26	174.64	8.18%	www.edomtech.com

Note 1: The market value, PB ratio, PE ratio, and dividend yield are based on the closing prices of the companies on November 30, 2023, and the financial reports for Q3 2023.

Note 2: TWD to US$ exchange rate: 2022 revenue: 29.849; revenue in the first three quarters of 2023: 30.955; capital, market value: 31.255

Source: Financial reports of companies on the Market Observation Post System(https://mops.twse.com.tw/mops/web/index) compiled by the Taiwan Stock Exchange Corporation, December 2023

B. Talent Cultivation

In terms of human resources, more than 10,000 people graduate from IT-related programs in Taiwan and join the workforce every year.[142] As countries pledge billions for domestic chip production and companies scramble to build new plants, the need for semiconductor talents to design, manufacture and test chips has intensified globally.

The semiconductor workforce, which is estimated at more than two million direct semiconductor employees worldwide in 2021, will need to grow by more than one million additional skilled workers by 2030, according to Deloitte's 2023 semiconductor industry outlook. That means adding about more than 100,000 workers annually, the report said.[143]

Addressing the chip talent shortage is a top priority for Taiwan. To this end, Taiwan passed the National Key Fields Industry-University Cooperation and Skilled Personnel Training Act in May 2021 to allow companies and national universities to jointly develop talent in key sectors. As of June 2023, six semiconductor research institutes have been set up across the island: the Graduate School of Advanced Technology at National Taiwan University, the Innovation Frontier Institute of Research for Science and Technology at National Taipei University of Technology, the College of Semiconductor Research at National Tsing Hua University, the Industry Academia Innovation School at National Yang Ming Chiao Tung University, the Academy of Innovative Semiconductor and Sustainable Manufacturing at National Cheng Kung University, and the College of Semiconductor and Advanced Technology Research at National Sun-yat Sen University. Together, in 2022, they admitted 483 master's students and 80 doctoral students, helping the semiconductor industry to resolve the high-level talent shortage.[144]

Since 2023, the Taipei Representative Office in Singapore (TRO) has been working with the following eight universities in Taiwan which offer degree programs to broaden the pool of talented candidates for positions in the global semiconductor industry:

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142 Ministry of Economic Affairs, R.O.C. (Taiwan) – Key innovative Industries in Taiwan: Semiconductors, November 2022. https://investtaiwan.nat.gov.tw/getFile?file=a78f26d2-dbe0-4fb3-9ece-093f18f60ee3.pdf&Fun=ArticleAction&lang=eng. Accessed April 1, 2024.

143 Parichart Jiravachara, 2023 Semiconductor Industry Outlook, Deloitte, September 22, 2022.

144 Ministry of Education, Republic of China (Taiwan), Press Release: "The Private and Public Sectors Work Together to Fill Talent Gaps Six Major Semiconductor Research Colleges," June 26, 2023.

1. National Cheng Kung University
2. National Sun Yat-sen University
3. National Taipei University of Technology
4. National Taiwan University
5. National Tsing Hua University
6. National Yang Ming Chiao Tung University
7. Lunghwa University of Science and Technology
8. Minghsin University of Science and Technology

[A copy of the brochure is available at: https://www.roc-taiwan.org/uploads/sites/86/2023/08/Study-Semiconductor-in-Taiwan0829_compressed.pdf]

Talent development is critical for a world run by semiconductors and for developing an indigenous semiconductor industry. Just as it takes years to build semiconductor fabrication facilities, it takes time to develop talent for the industry. Besides racing to set up specialized "chip schools" that run year-round to train its next generation of semiconductor engineers, Taiwan is also introducing chip courses into high school curricula to spur the interest of high school students in choosing STEM (science, technology, engineering and mathematics) programs at the university level.

In 2023, the Ministry of Economic Affairs conducted a series of recruitment missions in ASEAN countries and India to recruit outstanding local college students for direct employment and the "Study in Taiwan" program.[145] Taiwan's Ministry of Education also led a 17-member delegation comprising vice presidents or deans from eleven universities in Taiwan to India in November 2023 to promote bilateral educational collaboration.[146] To attract more international talent to study, work and add vitality to its semiconductor sector, Taiwan has simplified key rules for hiring foreign university graduates, including removing the need for two years of work experience to qualify for work visas in Taiwan since April 2023.[147]

[145] Taiwan Immigrants' Global News Network, "The Ministry of Economic Affairs went to ASEAN countries to recruit outstanding local college students for "direct employment," May 28, 2023.

[146] Ministry of Education, Republic of China (Taiwan), Press Release: "Ministry of Education Delegation Visit to India Advances Semiconductor Personnel Training Collaboration," February 29, 2024.

[147] Yojana Sharma, "Taiwan ups drive to attract foreign students, researchers," University World News, December 31, 2023.

C. Resilience of the Global Supply Chain and Peace across the Taiwan Strait

Semiconductors produced in Taiwan are essential components of the world economy. As semiconductor technologies expand into every aspect of industry and daily life, or as enablers for new services, the semiconductor industry is the foundation for not just Taiwan's but the world's future. A semiconductor supply chain disruption involving Taiwan will be devastating to not only Taiwan but the rest of the world as well.

The potential economic impact of a conflict over Taiwan is indeed staggering. According to Bloomberg, the cost could be around US$ 10 trillion, which is equivalent to about 10% of global GDP.[148] This figure is significant and would dwarf the economic impacts of other major global events such as the war in Ukraine, the COVID-19 pandemic, and the Global Financial Crisis. The economic impact of such an event can be far-reaching, affecting not just the countries directly involved, but also global trade, investment, and financial markets. Moreover, beyond the economic costs, such a conflict will also cause enormous human suffering and has substantial social impacts. Therefore, efforts towards maintaining peace and stability are of utmost importance.

To conclude, countries committed to economic growth and technological innovation have an enormous stake in the resilience of the global semiconductor supply chain as well as in the stability and peace across the Taiwan Strait.

Antony J. Blinken, US Secretary of State (July 14, 2023)

The United States also seeks to maintain peace and stability in the Taiwan Strait, which is in the interest of all nations. Fifty percent of global commerce goes through that strait every single day. Some 70 percent of the semiconductors made for the world are made in Taiwan. We continue to oppose unilateral changes to the status quo by either side.[149]

[148] Jennifer Welch, Jenny Leonard, Maeva Cousin, Gerard DiPippo, and Tom Orlik, "Xi, Biden and the $10 Trillion Cost of War Over Taiwan," Bloomberg, January 9, 2024.

[149] US Department of State, Press Release: "Secretary Antony J. Blinken at a Press Availability", July 14, 2023.

UK’s foreign secretary, David Cameron (March 21, 2024)

Former British prime minister David Cameron has warned the world is currently a "more dangerous" place than it has been for many years, citing conflicts around the globe and China's expansive plans, especially in relation to Taiwan.

"The lights on the global dashboard are flashing red, so it is a much more dangerous, difficult, uncertain world."

"We don't want to see any unilateral action to change the situation between China and Taiwan. There's no doubt that were there to be something like a blockade it would have an absolutely calamitous effect, not just on Taiwan, but on the global economy. We've had recent evidence of a calamitous event with COVID. I think if that were to happen with Taiwan, it would be more significant."[150]

U.S. Director of National Intelligence Avril Haines (May 5, 2023)

Director Haines presented what she called a "general estimate" during testimony before the [US] Senate Armed Services Committee:

She noted that the advanced semiconductor chips produced by Taiwan Semiconductor Manufacturing Company Ltd (TSMC) are used in 90 percent of "almost every category of electronic device around the world." If a Chinese invasion stopped TSMC from producing those chips, " it will have an enormous global financial impact that I think runs somewhere between [US]$ 600 billion to [US]$ 1 trillion on an annual basis for the first few years," she said.[151]

[150] 7.30, ABC News, “Former British prime minister David Cameron warns China conflict with Taiwan would be 'calamitous' as world enters 'dangerous' era, March 21, 2024.

[151] Reuters, “Taiwan chip production would be 'enormous' global economic blow”, May 5, 2023.

D. Forging A Semiconductor Partnership with Taiwan

Currently, Taiwan's semiconductor manufacturing companies mainly manufacture products in Taiwan and sell them across the globe. More than 90% of the main production sites as well as high-end technologies, advanced processes, and forward-looking research and development remain in Taiwan.

ASML, Applied Materials, Lam Research, and Tokyo Electron Laboratories, Inc (TEL), the four semiconductor equipment giants, have made investments in Taiwan since the Investing in Taiwan program took off, with ASML starting its R&D of the next-generation wafer metrology system in Taiwan, Applied Materials launching its first combined display manufacturing and R&D center at Tainan's Southern Taiwan Science Park in 2019, Lam Research developing advanced etching equipment in Taiwan, and TEL setting up its operations center in Tainan.[152]

Together with TSMC's advanced manufacturing technology, the entry of the international leading materials and equipment companies provide Taiwan's local manufacturers and suppliers with more opportunities of joining the global supply chain. This, in turn, will strengthen the resiliency and synergy within the semiconductor industry.

Leading international information and communication technology (ICT) and IC companies such as Apple, Broadcom, and Qualcomm have selected Taiwanese companies to provide contract wafer manufacturing and IC packaging and testing services. These collaborations highlight the significance of Taiwan's expertise in semiconductor manufacturing and its impact on cutting-edge technologies as well as its role as a reliable and secure partner in the semiconductor supply chain.

Although the United States, Japan, and Europe have invited TSMC, the top Taiwanese semiconductor company, to set up operations in their countries, the new plants in these countries will not change Taiwan's position

[152] Liu Chien-ling, Tseng Chi-yi, and Alison Hsiao, "Taiwan investment program inflows forecast to reach NT$230 billion in 2024," Focus Taiwan, February 6, 2024.

in the global semiconductor industry. TSMC continues to advance its most cutting-edge processes and advanced packaging technologies in Taiwan.[153] It is also difficult for other countries to take over Taiwan's production capacity or its pivotal role in the global semiconductor industry in the near and foreseeable future.

The semiconductor industry is a cornerstone of global economic development in the digital age. Every effort will be made by the Taiwan government to support foreign investment and collaboration with Taiwan in the semiconductor industry. Its Ministry of Economic Affairs has outlined three areas of partnership with Taiwan, namely, 1) joining Taiwan's core cluster, 2) exploring the growing global market for semiconductor equipment and materials, and 3) establishing operations and research centers to tap into the fast-growing Asia market.[154]

- **Joining Taiwan's Core Cluster of the Global Semiconductor Industry**

The complete semiconductor industry chain, production clusters, and R&D capability in Taiwan generates potential synergies for foreign businesses that set up R&D centers or production sites in Taiwan.

In terms of human resources, more than 10,000 people graduate from IT-related programs in Taiwan and join the workforce every year. OECD data shows that Taiwanese students are ranked 4th in the world in science education. The Taiwan AI Academy was also established in 2017 to cultivate talent for the AI industry. Taiwan has a big competitive advantage in edge computing and AI chips, and Taiwan has succeeded in building up a very complete supply chain ecosystem.

In addition, Taiwan also passed the National Key Fields Industry-University Cooperation and Skilled Personnel Training Act in May 2021 to allow companies and national universities to jointly develop talent in key sectors, in addition to efforts by private universities. Thirteen universities have set up semiconductor colleges or engineering departments and begun recruitment to strengthen basic research and the partnerships necessary for semiconductor development.

[153] John Liu and Paul Mozur, "Why TSMC Will Keep Its Roots in Taiwan, Even as It Goes Global," The New York Times, August 4, 2023.
[154] Ministry of Economic Affairs, "Key Innovative Industries in Taiwan-Semiconductors," 2022. https://investtaiwan.nat.gov.tw/showIndInfo?guid=1&lang=eng&menuNum=3

The AI on Chip Taiwan Alliance (AITA) formed in July 2019 is composed of local and foreign semiconductor and ICT vendors, local universities, and national research institutions such as ITRI. Four "key technology committees" in AITA focus on AI system applications, heterogeneous integration, emerging architectures, and AI system software. AITA will be building on Taiwan's existing advantages by moving from horizontal division of labor to vertical integration. It will also help the industry reduce its R&D costs for AI chips by 90% and shorten their development time by over 6 months.

In addition, information security has become critical as the globe embraces smart manufacturing and digitalization. SEMI, an international semiconductor industry association, published the first information security standards for semiconductor wafer equipment in Taiwan in December 2021 and organized the inauguration of the Semiconductor Supply Chain Information Security Alliance. The event was attended by representatives of major semiconductor plants in Taiwan and foreign countries such as TSMC, ASE, and Applied Materials. Information security standards were jointly decided by semiconductor companies in Taiwan, which demonstrates Taiwan's key position in the global semiconductor industry.

Going forward, Taiwan looks forward to foreign companies forming technical partnerships with Taiwanese businesses to invest in the development, growth and resilience of the semiconductor industry.

- **Exploring the Growing Global Market for Semiconductor Equipment and Materials**

IoT, AI, 5G, industrial and service robotics, smart city initiatives, smart lifestyle products, automotive electronics, and high-speed computing applications all require the support of the semiconductor industry. The future growth potential is considerable, and further growth in demand for semiconductor products is expected.

According to global semiconductor trade association SEMI, semiconductor material spending worldwide hit a new high of US$ 72.7 billion in 2022. Due to the large number of foundries and packaging plants, Taiwan has been the largest consumer of semiconductor materials in the world for 13 consecutive years. Taiwan spent US$ 20.1 billion on semiconductor materials in 2022, putting it ahead of South Korea and China.[155]

[155] Focus Taiwan, “Taiwan ranked No. 1 semiconductor material buyer in 2022,” June 14, 2023.

Currently in the field of semiconductor materials, high-performance photoresists, metal target materials, coating agents, and specialty reactive gases used in IC production processes, as well as wire bonding, molding, and filling materials used in IC packaging, are all imported. IC companies are hoping international vendors can produce those materials in Taiwan. In addition, the 5 nm and 7 nm IC production process recently began mass production in Taiwan as R&D for 2 nm technology continues. According to media reports, TSMC looks set to start mass producing 2 nm chips in 2025, and both Apple and Intel are at the front of the line for them. [156]

Taiwan has a high demand for high-level IC production and packaging materials and hopes to enhance cooperation with foreign vendors. Among front-end wafer process materials, items in strong demand include metal sputtering deposition materials (target materials, parts/accessories), EUV photoresists, cleaning chemicals, and CMP slurry. As for back-end packaging and testing process materials, there is demand for high-end solid-state/liquid-state molding compounds, IC substrate materials with a low thermal expansion rate and a high heat dissipation rate, high-definition/low-stress buildup materials, die attach materials, flip chip underfill, and solder resist ink.

In terms of semiconductor equipment, the industry has benefited from growth in the demand of semiconductor front-end-of-line processes including wafer manufacturing, wafer plants facilities, and mask equipment, as well as rear-end-of-the-line assembly, packaging, and testing equipment

Taiwanese vendors are capable of supplying equipment for conventional packaging processes and components for wafer production equipment and also has many leading global chip manufacturers. This makes Taiwan a great experimental site for the latest equipment, and Taiwan can update equipment suppliers on the latest changes in the semiconductor industry. The aim is to cooperate with international upstream equipment vendors on advanced packaging equipment and equipment for 12-inch wafer processes. Foreign vendors in the following areas are therefore invited to invest in Taiwan:

1. Front-end wafer production equipment

Deposition technology, dry etching technology, DUV and EUC exposure technology, photoresistor coating and developing technology, chemical mechanical polishing technology.

[156] Jason England, "Forget M3 — Apple and Intel are moving to 2nm chips next year," Tom's Guide, February 1, 2024.

2. *Advanced packaging process equipment*

Exposure technology, copper-plating technology, deposition technology, and dry etching technology.

- **Establishing Operations and Research Centers**

Taiwan is home to the most complete semiconductor industry clusters and specializations in the world. As an active, innovative economy, Taiwan is an attractive destination for foreign-funded R&D centers. Coupling this with the growth of the Asian semiconductor industry, Taiwan has attracted top global semiconductor companies such as Intel, Nvidia, Qualcomm, NXP, Synapsys, Cadence, ASML, Lam Research and ULVAC to set up operations, R&D, logistics, testing and/or training centers on its shores. As recent as May 2023, American Applied Materials (AMAT) announced the establishment of a semiconductor process technology and manufacturing equipment cooperative research and development center in Taiwan to accelerate the development and commercialization of basic technologies that are essential to the global semiconductor and computing industries.

The global semiconductor industry is moving in the direction of regionally defined development, with specific foundries in different regions churning out specific types of wafers. At the same time, this trend is generating demand from manufacturers for after-sales service. China, Taiwan and South Korea remain the top three countries for equipment expenditures in 2022. Beyond that, the production in the semiconductor industry is expected to take on a role of greater importance in Japan. Countries of Southeast Asia will continue to develop stronger packaging and testing capabilities.

In light of the trends described above, foreign firms with increasing numbers of customers and devices in Taiwan and neighboring Asian countries can look at using Taiwan as a services hub. Foreign firms can set up equipment repair and refurbishment facilities, training facilities, or experimental sites in Taiwan. In addition, given that Taiwan is one of the largest semiconductor equipment and material markets in the world and also a major exporter of semiconductor components, international semiconductor manufacturers can also look at setting up global logistics centers in Taiwan.

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2024/02/28
Taiwan Talks

Can the U.S. Regain Its Position in Chip Manufacturing?

The U.S. has declared plans to boost investment in its semiconductor industry, aiming to improve its chip design capabilities with the CHIPS and Science Act of 2022. In this episode of Taiwan Talks, we explore how this reshapes the global semiconductor landscape and what implications it might have on the tech rivalry between the U.S. and China.

2024 /03/08
Taiwan Connected

Startups Innovating in Semiconductor Industry by Leveraging Taiwan | Connected with Divya Gopalan

Smartphones, computers, cars, tablets, gaming consoles and home appliances are all around us. What do they all have in common? Semiconductors! Taiwan has long held a place at the forefront of chip technology, so how are startups in the industry leveraging its advantages? We #CONNECTED with Mavis Ho, general manager of IMEC for Greater China and SE Asia, and Niraj Mathur, co-founder of Blumind, to understand how startups are contributing to current advances and innovations in the field of semiconductors and microchips.

2024/03/26
Taiwan Talks

Can the U.S. Regain Its Position in Chip Manufacturing ?

Japan's economy has fallen to number four in the world, having been overtaken by Germany. In this episode of Taiwan Talks, we explore the collaboration between Taiwan and Japan in the semiconductor sector and whether this partnership could mark a turning point for Japan's economic fortunes.

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