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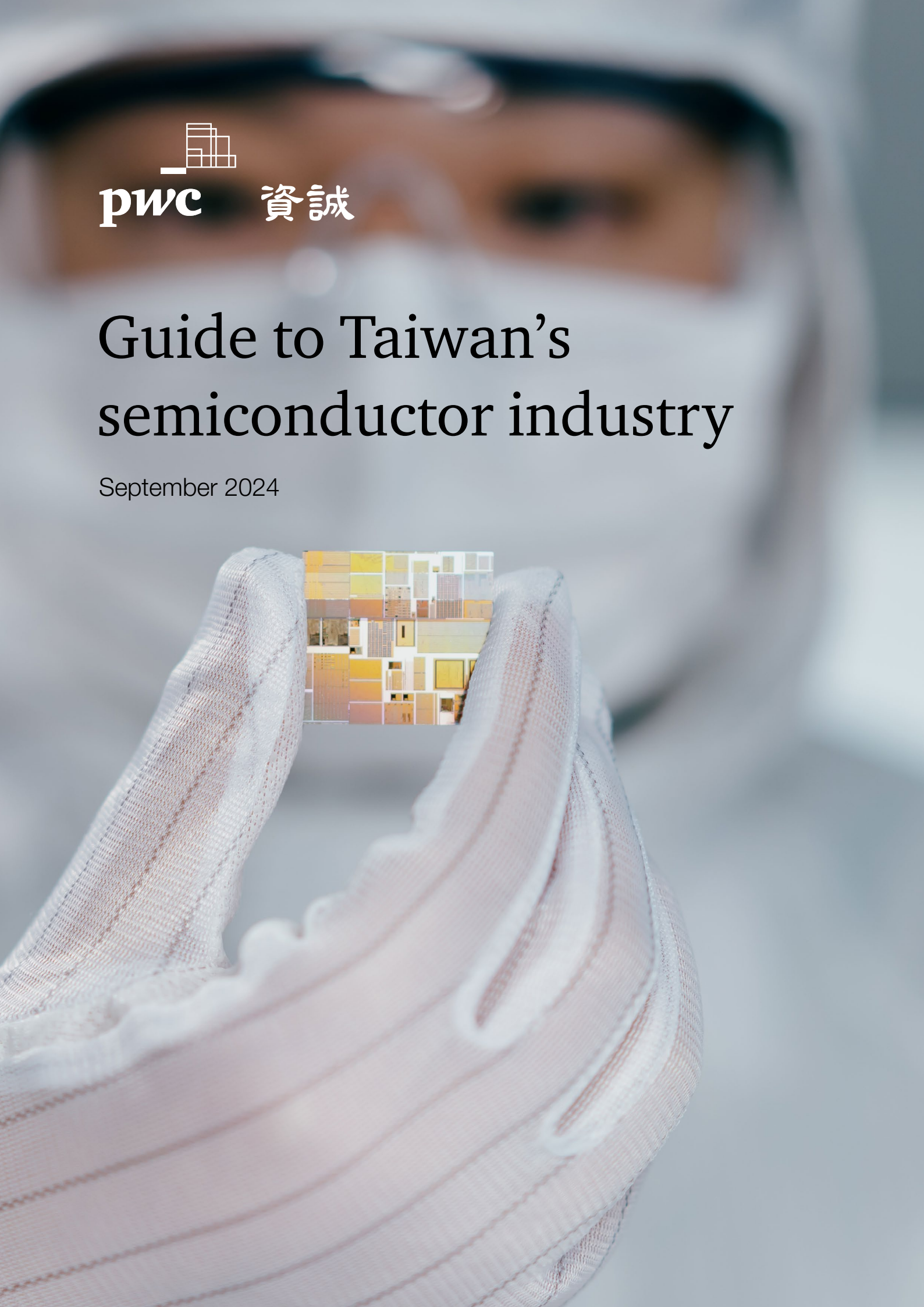
Guide to Taiwan's semiconductor industry

September 2024



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This publication was compiled by Damian Gilhawley, an industry specialist at PwC Taiwan. The content is drawn from publicly available information and is as of 31 August 2024, unless otherwise stated.

Foreword

Even though Taiwan has long been a key supplier to the global electronics ecosystem, it took the recent disruptions to semiconductor supply chains — impacted by the Covid-19 pandemic and heightened geopolitical tensions — to bring the island's unique position as a semiconductor leader into the international spotlight.

Taiwan plays a pivotal role in the world semiconductor industry, particularly in the supply of higher specification chips used to power next-generation technologies like 5G, generative AI and high-performance computing. It ranks first by global market share in both chip manufacturing and packaging and testing, and second in design.

Taiwan has spent the past 50 years building up a world-class semiconductor sector, underpinned by supportive government policies and initiatives. A clustering effect has led to the island developing substantial technological capacity and capability, where suppliers and manufacturers have forged a complete semiconductor ecosystem.

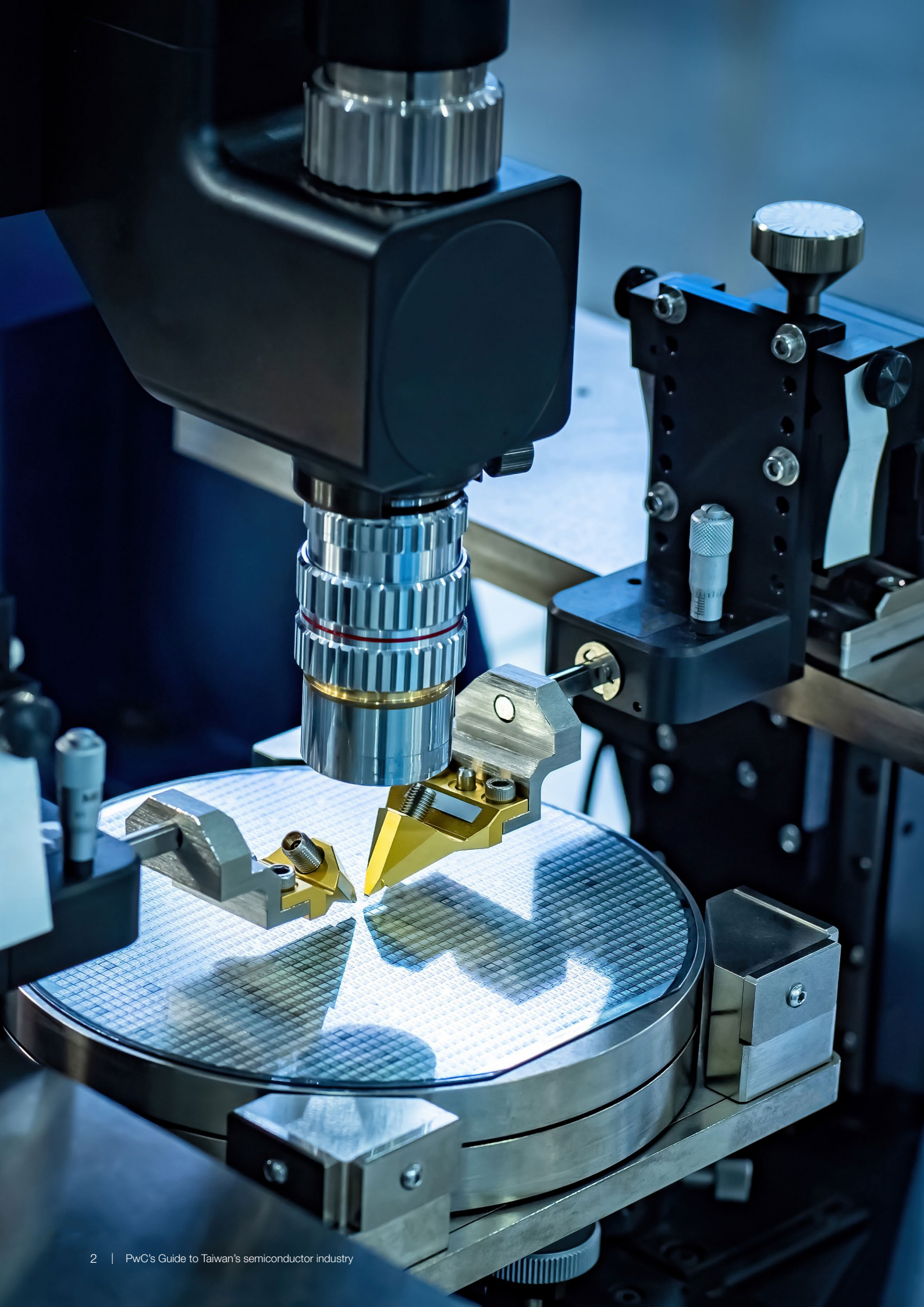
Consequently, Taiwan has a high concentration of semiconductor facilities and know-how that make it a crucial partner for technology companies across the globe. As an uncertain degree of US-China 'de-risking' and new global supply chain security efforts unfold, Taiwan's semiconductor prowess will continue to be a focal point.

For that reason, PwC has compiled this concise guide to Taiwan's semiconductor industry to assist international high-tech companies to understand the sector and the opportunities available to them. Indeed, the Taiwan government is keen to attract foreign investment in R&D and innovation to help further strengthen the industry.

At PwC Taiwan, we understand the complexities, nuances and uniqueness of the semiconductor market and their implications for your organisation. We provide solutions across assurance, tax, legal and advisory to help you tackle today's pressing business challenges and to identify new ways to develop and grow your business.

We hope you will find this guide to be a useful resource. If you would like more information or have questions about Taiwan's semiconductor industry and how PwC can be of help, please do not hesitate to contact us.

Tina Cheng
Semiconductor Leader
PwC Taiwan



1. What are semiconductors?

In today's digitally-powered society there are few components more crucial than semiconductors, also sometimes referred to as integrated circuits (ICs) or computer chips. A semiconductor is a substance with certain properties that enable it to serve as a core part of almost all electronic equipment that we use in our daily lives.

Semiconductors are typically made from a solid chemical element (either silicon or germanium) or a compound (such as gallium arsenide) — which have intermediate electrical conductivity between conductor and insulator materials — and designed to control the flow of current in circuits and follow specific computational instructions.

Electronic components using semiconductors are called semiconductor devices. These are tiny chips (generally smaller in size than a fingernail) and composed of billions of transistors (i.e., miniature semiconductors) that store, move and process data, speaking the binary language of 1s and 0s that underpins computing processing.

Many types of semiconductor devices have been developed in line with the expansion of application fields and the progress of electronic equipment. The main ones are discrete semiconductors (single devices with a single function, such as diodes and transistors) and ICs (devices with multiple functional parts mounted on one chip).

Figure 1: Types of semiconductor devices

Discrete devices

- Diodes
  - General-purpose rectifiers
  - High-speed rectifiers
  - Switching diodes
  - Zener diodes
  - TVS diodes
  - Variable-capacitance diodes
- Transistors
  - MOSFETs
  - Junction FETs
  - Bipolar transistors
  - IGBTs
- Thyristors
- Modules

Optical devices

- Light-emitting devices
  - LEDs
  - Laser diodes
- Photodetectors
  - Photodiodes
  - Phototransistors
  - Photothyristors
  - Phototriacs
  - Image sensors
- Composite optical devices
  - Photocouplers
  - Photorelays
  - Photointerrupters
- Optical communication devices

Microwave devices

- Discrete
  - High-frequency diodes
  - High-frequency transistors
- ICs
  - GaAs ICs
  - MMICs
- Modules

Sensors

- Sensor
  - Thermal sensors
  - Pressure sensors
  - Acceleration sensors
  - Magnetic sensors
  - Illuminance sensors
  - Accessing sensors

ICs

- Memories
  - Volatile memories
  - Non-volatile memories
- MPUs
- Logic ICs
  - General-purpose logic ICs
  - Bus switches
  - CMOS logic ICs
- Analogue ICs
  - General-purpose linear ICs
  - Power supply ICs
  - Op-amps
  - Driver ICs
  - Mixed-signal ICs

Hybrid ICs

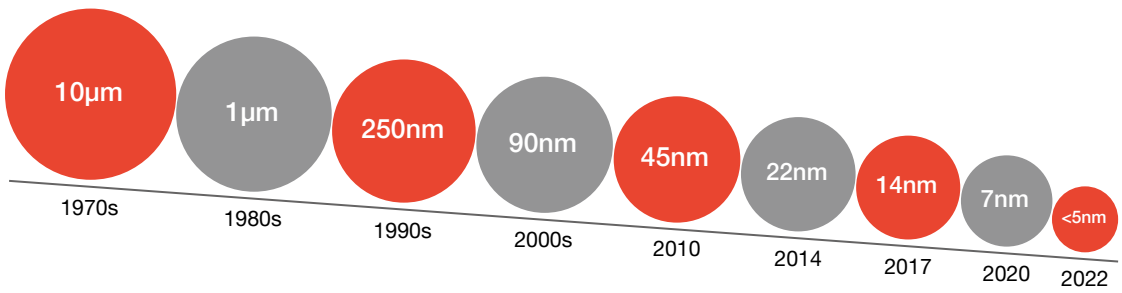
- Thin membrane
- Thick membrane

Source: Toshiba Electronic Devices & Storage Corporation.

Most semiconductors today are ICs, which come in different levels of technology advancement. Mature nodes are based on older semiconductor technology with lower complexity and less advanced production processes, while advanced nodes use state-of-the-art technology. (Node refers to the size of the transistors on a chip).

Rapid technological developments since the 1970s have made semiconductor devices smaller, cheaper, faster and more reliable. Generally, the smaller the technology or process node (measured in nanometres) means the smaller the feature size, producing smaller transistors which are both faster and also more power-efficient.

Figure 2: Ever-decreasing size of semiconductors



Note: µm is a micrometre (one millionth of a metre); nm is a nanometre (one billionth of a metre).
Source: PwC Taiwan.

1.1 How are semiconductors produced?

The key stages of the semiconductor production process are R&D, product design, front-end manufacturing (wafer fabrication) and back-end manufacturing (assembly, packaging and testing). A specialised ecosystem of raw materials, equipment, software design tools and core IP suppliers supports the whole production process.

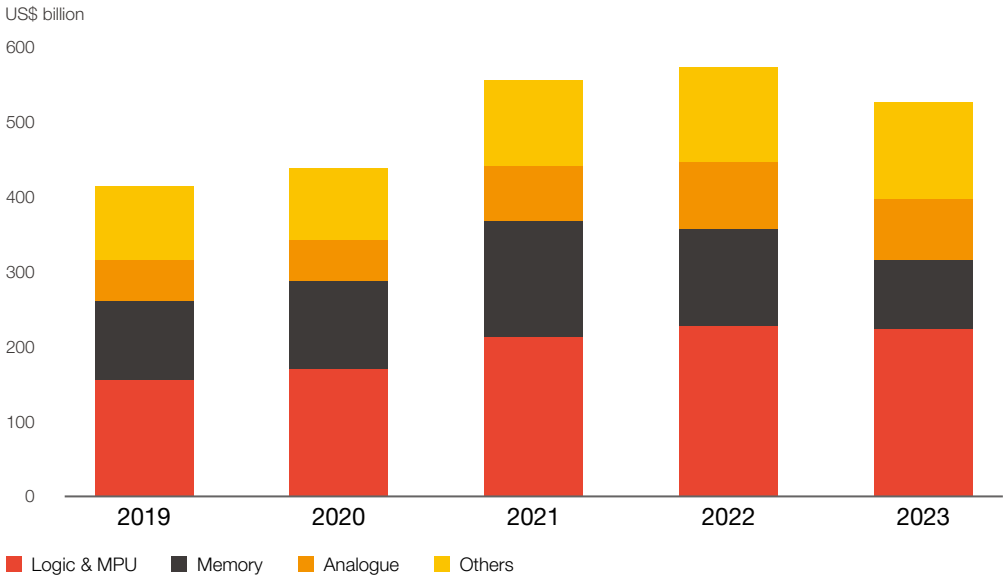
Semiconductor firms generally organise their activities around design and manufacturing. Companies that focus only on design are referred to as fabless firms, while those that focus solely on manufacturing are referred to as fabs or foundries. Semiconductor firms that do both are called integrated device manufacturers, or IDMs.

Figure 3: Major stages of the semiconductor value chain

Source: PwC Taiwan.

Semiconductor products can be classified into four main groups, based on their functionality: logic devices and microprocessors; memory; analogue; and optoelectronics, sensors and discretes. Some of these have broad functionality; others are designed for specific uses. The first two groups make up about 60% of global chip sales.

Figure 4: Global semiconductor sales by product segment, 2019-2023



Source: Semiconductor Industry Association.

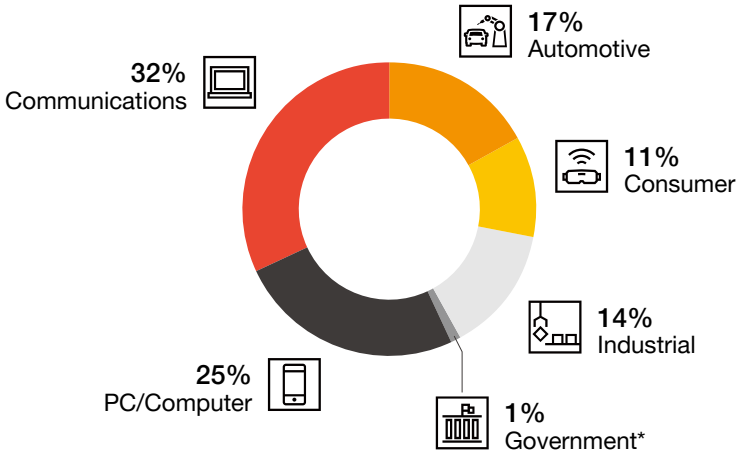
Semiconductors are highly complex products and very costly to make. No other industry has the same high level of investment in both R&D and capital expenditure, which is needed for design, new process technologies and production facilities. For example, building and equipping a state-of-the-art fab costs around US$10-20bn.

1.2 What are semiconductors used for?

Continuous innovation in semiconductors has underpinned technological progress. Better chip performance and cost improvements made possible the evolution from mainframes to PCs in the 1990s, the expansion of the Web and online services in the 2000s, the smartphone revolution in the 2010s and now the current AI boom.

Semiconductors are integral components in nearly all industrial activity, enabling advances in communications, computing, healthcare, military systems, transportation, clean energy and countless other applications. They are also fundamental to the latest new technologies such as 5G, AI, cloud computing and the Internet of Things.

Figure 5: Global semiconductor demand share by end-use, 2023



*Military end-use is included in the Government category.

Source: Semiconductor Industry Association.

Modern automobiles illustrate the ubiquitous role and use of semiconductors. According to estimates, today's average car has between 1,400 and 1,500 semiconductor devices, and some hybrid electric vehicles have as many as 3,000. These chips are used to control everything from emissions systems to driver assist systems.

As the world becomes ever-more digital, the demand for semiconductors will continue to grow apace. McKinsey predicts the global semiconductor industry will become a trillion-dollar industry by the end of this decade, with 70% of growth to be driven by just three industries: automotive, computation and data storage, and wireless.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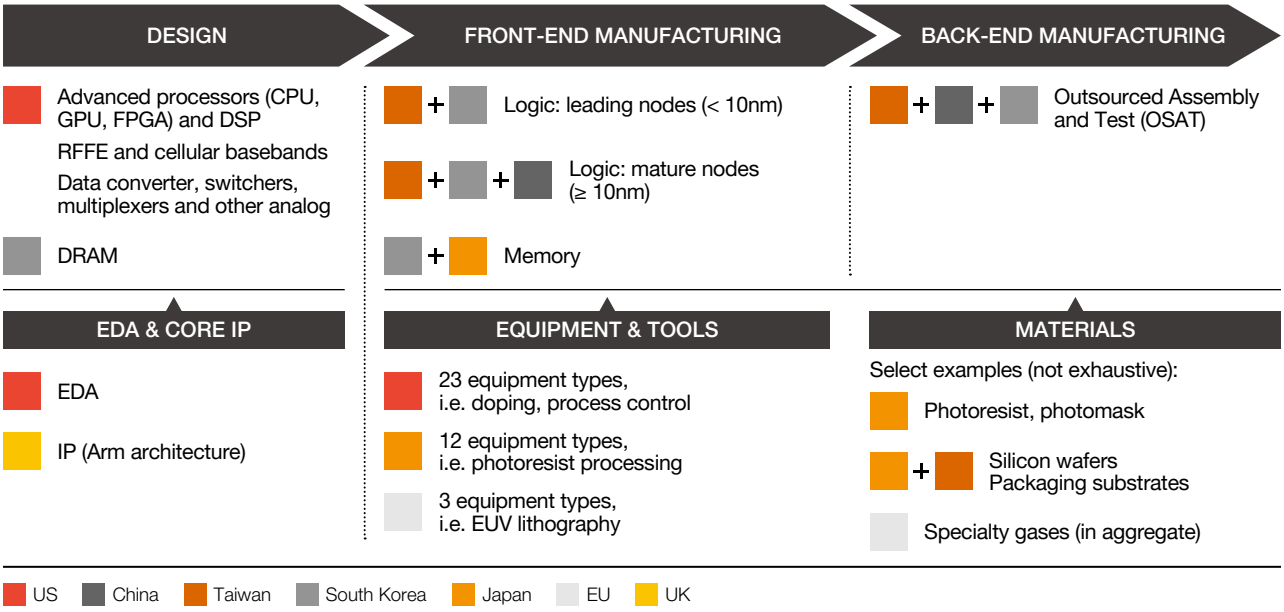
2. Shifting semiconductor landscape

The semiconductor industry's need for deep technical know-how and scale has resulted in a highly specialised supply chain, in which regions perform different roles according to their comparative advantages. There are over 50 points across the value chain where one region holds more than 65% of the global market share, as below.

Figure 6: Global semiconductor supply chain specialisation



Source: SIA/BCG report, Strengthening the Global Semiconductor Supply Chain in an Uncertain Era, April 2021.

The potential risks for disruption in semiconductor supply chains are significant. That is true whether the source of the disruption is a natural disaster like an earthquake or typhoon, a global shock to the economic system like the Covid crisis, caused by political considerations such as trade disputes or conflicts, or by other factors.

2.1 Supply chain vulnerabilities emerge

The recent global supply shortage of semiconductors across multiple industries (particularly in the auto sector), which emerged in 2020 and persisted into 2022, highlighted how indispensable these specialised components are in today's world economy. But it also exposed the vulnerability of the semiconductor supply chain network.

The Covid-19 pandemic caused major disruptions to production, supply chains and logistics which, coupled with a jump in global demand for digital goods and services owing to the shift to a stay-at-home economy, impacted the availability of key semiconductors necessary for the manufacture of a broad swathe of electronics.

Figure 7: The global semiconductor shortage

Source: PwC Taiwan.

Covid was not the only reason for the global chip shortage, as semiconductor supply chains already had many vulnerabilities and weak points that were merely exasperated by the pandemic. Other contributory factors included the impact of geopolitical tensions, particularly between the US and China and the war in Ukraine.

Shortages in the semiconductor industry are not new; they are cyclical in nature. Historically, these cyclical periods have typically been short lived (six months to one year), but the unpredictable events of the last few years have disrupted the industry's operating rhythm, with shortages still persisting for specific types of chips.

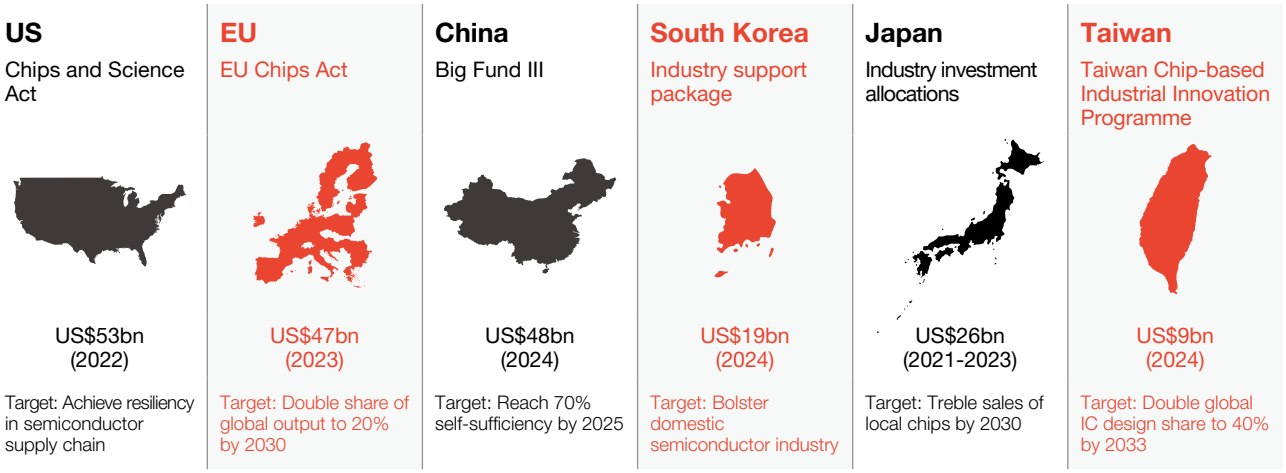
2.2 Added impact of geopolitical tensions

Geopolitical tensions have the potential to spark more severe chip shortages in the future. For instance, much of the semiconductor supply capabilities are concentrated in East Asia, particularly in Taiwan and South Korea which have disputes with China and North Korea respectively, so a conflict there could have major repercussions.

The rising trade tensions and intensifying technology rivalry between the US and China, which started in 2018 under former President Donald Trump's administration and is continuing under President Joe Biden, is another pressing issue that has serious consequences for semiconductor supply chains and the overall industry globally.

Supply-chain concerns have prompted the US, the EU, Japan and others to strengthen their own domestic semiconductor resilience by incentivising the reshoring of production. At the same time, they have sought to increase cooperation with like-minded global partners, particularly Taiwan, to strengthen semiconductor ties.

Figure 8: Key semiconductor funding initiatives



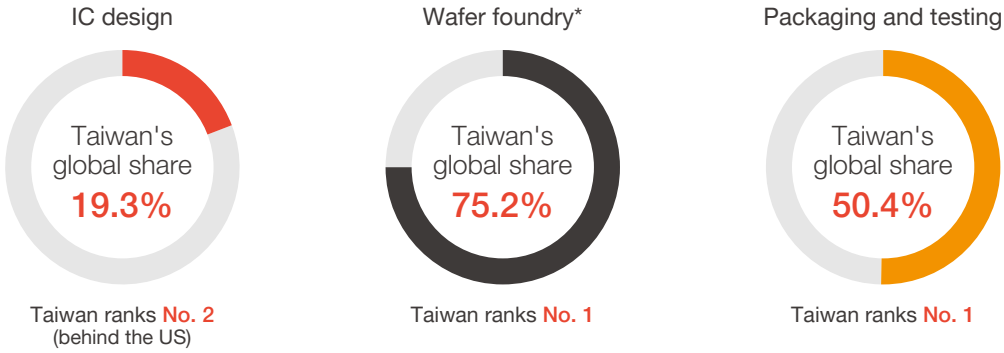
Source: PwC analysis based on public information.

2.3 Taiwan's pivotal role in the spotlight

Even though Taiwan has long been a key supplier to the world electronics ecosystem, it took the recent global shortage of semiconductor chips and the escalation of tensions between US and China over technology, and specifically a heightened focus on semiconductors, to bring the island's unique position into the spotlight.

Taiwan plays a pivotal role in the global semiconductor industry, particularly in the supply of higher specification chips used to power next-generation technologies like 5G, generative AI and high-performance computing. It ranks first by global market share in both chip manufacturing and packaging and testing, and second in design.

Figure 9: Taiwan's share of the global semiconductor market, 2023



*Wafer foundry refers to manufacturing-only (pure-play) foundries and does not include IDMs.
Source: IEK Consulting (ITRI) and Taiwan Semiconductor Association.

Taiwan has a high concentration of semiconductor facilities and know-how that make it a crucial partner for technology companies across the globe. As an uncertain degree of US-China 'de-risking' and new global supply chain security efforts unfold, Taiwan's strategic role in semiconductors will continue to be a focal point.

3. Taiwan's semiconductor industry

Taiwan's semiconductor industry has recorded strong growth over recent decades to become the world's top manufacturer of IC chips. It also plays critical roles in other parts of the global semiconductor value chain, including chip design; semiconductor materials (such as silicon wafers); and assembly, packaging and testing.

Taiwan produces over 60% of the world's semiconductors and more than 90% of the most advanced ones (below 7 nm) used to power cutting-edge technology applications. Moreover, it accounts for 19% of the global IC design market and 50% of the global packaging and testing sector — ranking second and first, respectively.

The semiconductor industry is also a key pillar of Taiwan's economy in terms of its output value and share of exports. In 2023, total industry revenue was NT$4.3tn (US$139bn), equal to 18.4% of the island's GDP, while semiconductor exports amounted to US$167bn, accounting for 38.5% of all Taiwan's exports or 22.1% of GDP.

Figure 10: Major indicators of Taiwan's semiconductor industry, 2020-2024

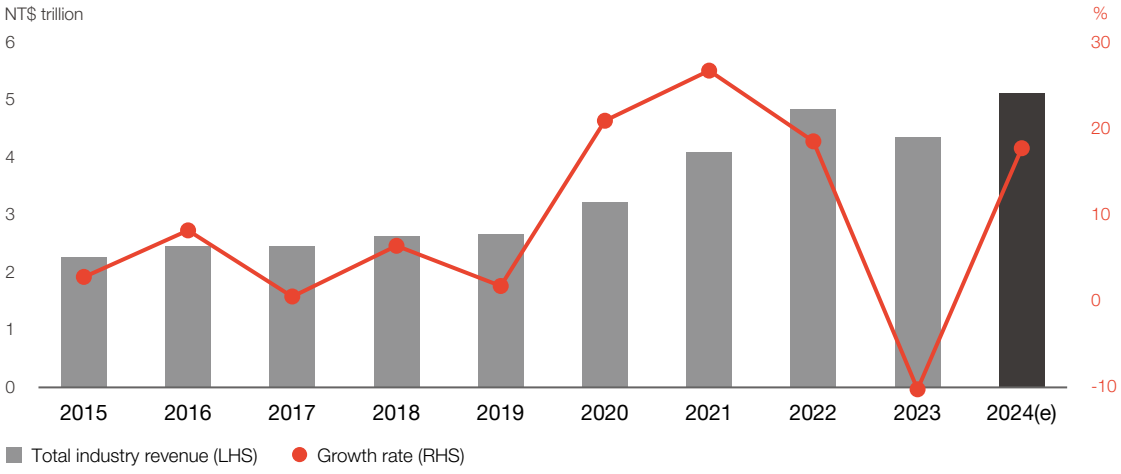
	2020	2021	2022	2023	2024(e)
Number of companies	288	300	314	307	321
Total industry revenue (NT$bn)	3,222.2	4,082.0	4,837.0	4,342.8	5,113.4
Annual growth (%)	20.9	26.7	18.5	(10.2)	17.7
Value-added (NT$bn)	1,818.9	2,384.0	2,990.8	2,611.7	3,111.3
Value-added rate (%)	56.4	58.4	61.8	60.1	60.8
R&D employees	47,107	54,720	60,221	59,392	62,920
R&D expenditure (NT$bn)	317.0	408.5	459.1	488.5	5,461.0
R&D expenditure / revenue (%)	9.8	10.0	9.5	11.2	10.7
Number of employees	256,526	294,254	320,298	316,905	339,314
Average revenue per employee (NT$m)	12.6	13.9	15.1	13.7	15.1

Source: IEK Consulting (ITRI), 2024 Semiconductor Industry Yearbook, July 2024.

Taiwan's semiconductor industry experienced strong revenue growth in the 2020-2022 period on the back of pandemic-related demand, but recorded a 10.2% decline in 2023. That mirrored the 8.2% drop seen in global semiconductor industry sales for the year, largely due to inventory adjustments on global demand weakness.

For 2024, ITRI's Industrial Economics and Knowledge Centre (IEK) forecasts that local semiconductor industry revenue will rebound by 17.7% to hit a new high of NT$5.1tn (US$158bn), boosted by the recovery of end-markets and global demand for more and higher-end chips to power AI applications and 5G mobile services.

Figure 11: Taiwan's semiconductor industry revenue, 2015-2024



Source: IEK Consulting (ITRI) and Taiwan Semiconductor Industry Association.

Thanks to its continuous development of high-end processes, Taiwan's semiconductor industry is expected to maintain its leading position in IC manufacturing in the coming years. This advantage will allow Taiwan to retain significant market share in advanced semiconductors for emerging application technologies like 5G, AI and IoT.

3.1 Historical background

Taiwan first entered the global semiconductor supply chain in the 1960s, when foreign firms such as General Instrument, Philips and Texas Instruments established IC assembly and packaging plants on the island. Yet, the domestic accumulation of chip engineering and manufacturing know-how proceeded slowly until the 1970s.

That's when the government began to focus on semiconductors as a key industry to move Taiwan's economy up the value chain. The first major milestone was the setting up in 1973 of the government-sponsored Industrial Technology Research Institute (ITRI), which has been critical to technology development and diffusion in Taiwan.

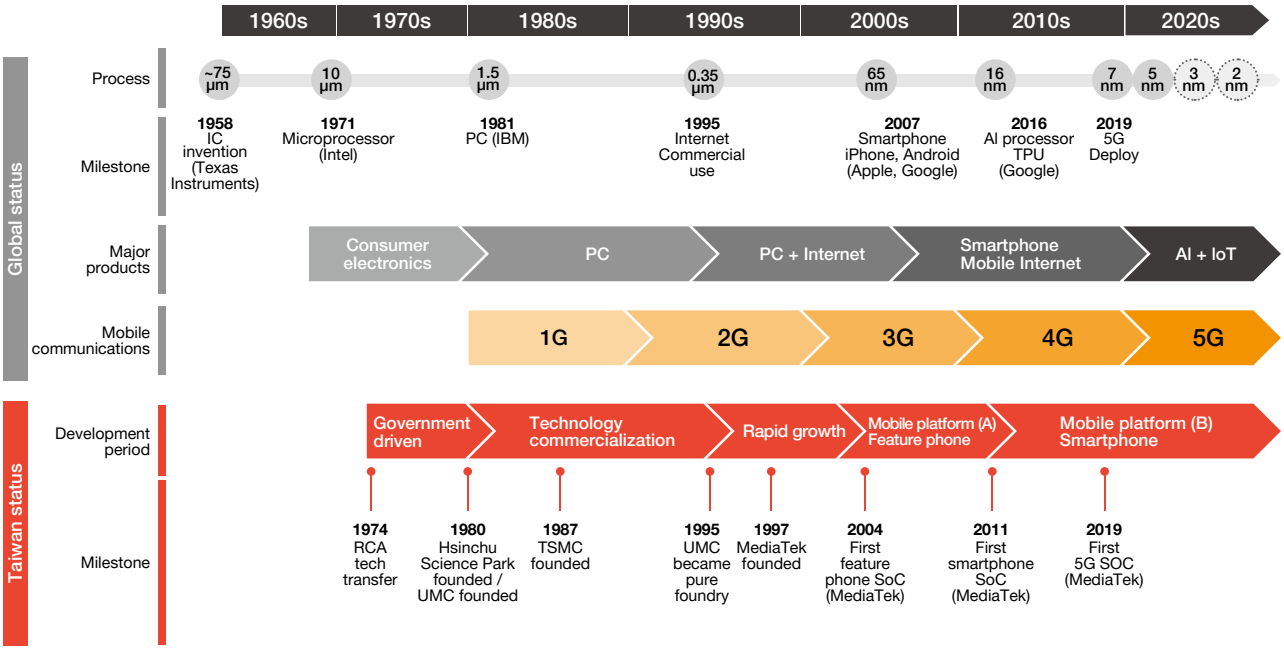
The local industry got a kickstart in 1976 when ITRI signed an IC technology transfer and licensing contract with American electronics company RCA to introduce semiconductor technology into Taiwan. In the next few years, an IC pilot plant (including design, manufacturing and testing capabilities) was completed with the help of RCA.

ITRI spun off this plant in 1980 to create Taiwan's first private semiconductor company, United Microelectronics Corporation (UMC), which initially followed an IDM model. Seven years later, the government established Taiwan Semiconductor Manufacturing Co. (TSMC) to provide foundry services to a burgeoning IC design sector.

TSMC was created as a joint venture between the Taiwan government, Dutch multinational electronics giant Philips and other private investors. TSMC's unique strategy of manufacturing chips for outside companies soon proved to be a major success, and it has since evolved to become the world's largest contract chip manufacturer.

ITRI also spun off several other incubated semiconductor companies during the 1980s and the 1990s, which helped foster a wave of private investment in the industry and the gradual development of a complete ecosystem. The cooperative interplay between the state and market players has been a key factor in the industry's success.

Figure 12: Evolution of Taiwan's semiconductor industry



Source: Bor-sung Liang, Entrepreneurship-driven growth in the integrated circuit design industry, April 2021.

3.2 Policy support initiatives

Taiwan's semiconductor industry continues to enjoy strong government support. It is a major component of the "Programme for Promoting Six Core Strategic Industries," launched in 2020, which seeks to capitalise on global supply chain changes and Taiwan's technological strengths to catalyse the island's industrial transformation.

Enhancing Taiwan's edge in semiconductors

The government initiative includes an objective to develop Taiwan as a world-leading centre for advanced semiconductor manufacturing through building a more comprehensive ecosystem. It originally set a target of raising the industry's annual output value to NT$5tn (US$163bn) by 2030 (which will be reached early in 2024).

To achieve this goal, the government has pursued a four-pronged approach: ensuring a sufficient supply of semiconductor talent; strengthening leading-edge semiconductor R&D efforts; promoting semiconductor clusters in southern Taiwan; and optimising the investment environment to attract more foreign businesses.

The current semiconductor policy is focused on development of AI chips and applications to establish critical technologies that industries need to build smart systems. The government has prioritised IC design and pioneering semiconductor technologies, with a goal of achieving sub-nanometre process technology by 2030.

Larger tax breaks for technology R&D investments

With the US, the EU and Japan offering hefty subsidies and significant tax incentives to build semiconductor capacity domestically, the Taiwan government has stepped up efforts to ensure the latest cutting-edge process technologies remain on the island by increasing the main tax breaks available for technology R&D investments.

The Statute of Industrial Innovation was amended in January 2023 to provide larger tax credits for companies that innovate technologies and have a critical role in global supply chains. Qualifying firms can receive tax credits equal to 25% of R&D expenditure and 5% of spending on advanced process equipment in a fiscal year.

The new tax breaks took effect in February 2024. The eligibility criteria for applicants include a minimum annual R&D expenditure of NT$6bn (US$193m) and a R&D intensity ratio (of R&D expenses to operating revenue) of at least 6%, plus a minimum spend of NT$10bn (US$321m) on equipment for advanced process manufacturing.

Ten-year national plan for semiconductor innovation

To accelerate the move toward advanced processes, in November 2023, the government launched the "Taiwan Chip-based Industrial Innovation Programme," which seeks to lay the groundwork today for the tech industry of tomorrow. A total of NT$300bn (US$9bn) was earmarked for its implementation between 2024 and 2033.

The programme targets four areas: integrating AI with chips to promote innovation; enhancing the domestic talent incubation environment and attracting global R&D talent; accelerating innovations in heterogeneous integration and advanced technologies; and attracting international start-ups and venture capitalists to Taiwan.

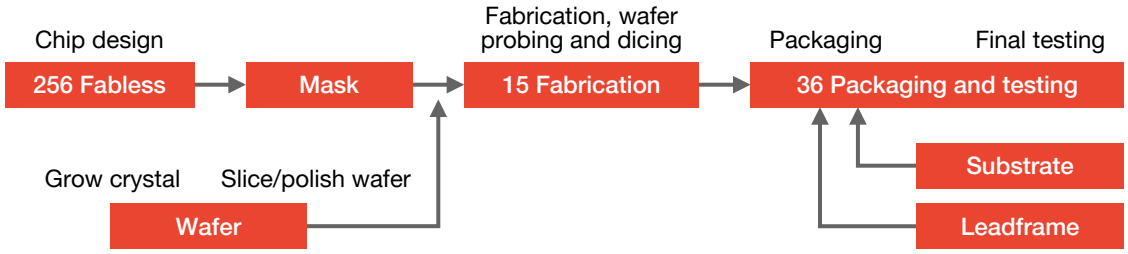
The first phase, to last five years, will focus on creating semiconductor centres, developing talent and establishing related infrastructure at the ITRI. The second five-year phase aims to increase Taiwan's global IC design market share from 20% at present to 40% by 2033, including an 80% global market share for advanced semiconductors.

3.3 Semiconductor value chain

Taiwan is home to the most complete semiconductor industry clusters and specialisations in the world and has leading companies in all segments of the semiconductor value chain. The industry's high degree of vertical integration and clustering gives it the advantages of flexibility, speed, service customisation and lower costs.

Taiwan's semiconductor industry currently comprises 256 fabless IC design companies, 15 semiconductor manufacturers and 36 packaging and testing houses, which together employ around 320,000 people. Other support businesses include substrate suppliers, wafer suppliers, mask makers and lead frame companies.

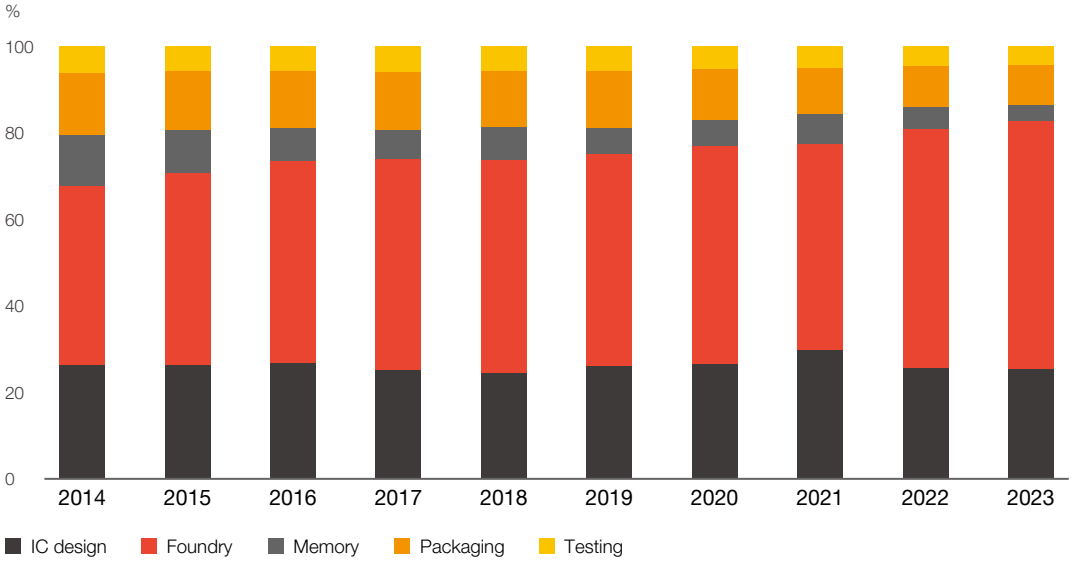
Figure 13: Structure of Taiwan's semiconductor industry



Source: Taiwan Semiconductor Industry Association.

Taiwan's semiconductor industry operates on a global scale across the three main stages of production. In 2023, IC design accounted for 25.2% of the industry's overall output value, while manufacturing took 61.3% (of which the foundry segment represented 57.4% and memory 3.9%), and packaging and testing together had 13.4%.

Figure 14: Taiwan's semiconductor output value by segment share, 2014-2023



Source: IEK Consulting (ITRI) and Taiwan Semiconductor Industry Association.

3.3.1 Design

In the upstream part of the semiconductor value chain, chip design houses conceive new products and specifications to meet customer needs and develop particular logic and IC designs for manufacturing. Taiwan's design firms mostly focus on peripheral IC development to pair with the main chips of US-based suppliers.

Taiwan's semiconductor design sector is the second largest in the world behind the United States, with its 2023 revenue of NT$1.1tn (US$35bn) accounting for around 19% of the global market. Local IC design houses greatly benefit from their proximity to and close cooperation with the island's foundry manufacturing companies.

Figure 15: Key indicators of Taiwan's semiconductor design sector, 2020-2024

	2020	2021	2022	2023	2024(e)
Number of companies	238	250	262	256	270
Total sector revenue (NT$bn)	852.9	1,214.7	1,232.0	1,096.5	1,261.7
Annual growth (%)	23.1	42.4	1.4	(11.0)	15.1
Global market share (%)	20.1	22.0	20.8	19.3	20.1
Global ranking	2	2	2	2	2
Value-added (NT$bn)	270.4	483.5	515.0	407.9	504.7
Value-added rate (%)	31.7	39.8	41.8	37.2	40.0
R&D employees	32,400	37,960	39,378	39,073	40,214
R&D expenditure (NT$bn)	157.8	220.5	232.0	225.8	239.7
R&D expenditure / revenue (%)	18.5	18.2	18.8	20.5	19.0
Number of employees	45,010	51,668	54,091	53,524	54,862
Average revenue per employee (NT$m)	18.9	23.5	22.8	20.5	23.0

Source: IEK Consulting (ITRI), 2024 Semiconductor Industry Yearbook, July 2024.

The leading Taiwanese IC design houses include MediaTek Inc., Novatek Microelectronics Corp. and Realtek Semiconductor Corp., which were among the world's top ten chip design companies by revenue in 4Q 2023, ranking the fifth, seventh and eighth largest, respectively, according to technology research firm Trendforce.

MediaTek is known for its mobile phone application processor (AP), and along with US-based Qualcomm, is one of the world's largest mobile phone AP suppliers. Novatek is strong in display driver chips, while Realtek is an innovator in wireless network cards. The three had a combined global market share of 12.0% in 4Q 2023.

3.3.2 Manufacturing

Next, semiconductor chips are manufactured, or fabricated, on circular sheets of silicon or other semiconducting materials, called wafers (typically about 8 or 12 inches in diameter). Electronic circuitry is then etched onto each wafer, with multiple chips being produced at the same time at a tiny scale with thousands of automated steps.

Taiwan's semiconductor manufacturing sector had total revenue of NT$2.7tn (US$85bn) in 2023, of which the foundry segment accounted for 94% and the memory segment 6%. Taiwanese manufacturers produce over 60% of the world's semiconductors, benefitting from high demand for 5G and high-performance computing chips.

Figure 16: Major indicators of Taiwan's semiconductor manufacturing sector, 2020-2024

	2020	2021	2022	2023	2024(e)
Number of companies	13	13	15	15	15
Total sector revenue (NT$bn)	1,820.3	2,228.9	2,920.3	2,662.6	3,201.4
Annual growth (%)	23.7	22.4	31.0	(8.8)	20.2
Global market share - Foundry (%)	77.3	79.7	77.6	75.2	76.8
Global ranking - Foundry	1	1	1	1	1
Value-added (NT$bn)	1,286.1	1,590.9	2,141.7	1,923.1	2,286.9
Value-added rate (%)	70.7	71.4	73.3	72.2	73.7
Capital expenditure (NT$bn)	934.0	1,644.0	2,112.5	1,137.1	1,094.5
Capital expenditure / revenue (%)	51.3	73.8	72.3	42.7	34.2
R&D employees	9,707	10,980	13,992	14,496	16,032
R&D expenditure (NT$bn)	142.5	168.1	205.1	244.0	283.0
R&D expenditure / revenue (%)	7.8	7.5	7.0	9.2	8.8
Number of employees	96,628	109,176	120,788	132,504	143,105
Average revenue per employee (NT$m)	18.8	20.4	24.2	20.1	22.4

Source: IEK Consulting (ITRI), 2024 Semiconductor Industry Yearbook, July 2024.

Taiwan has become the leading location for semiconductor foundry manufacturing. TSMC, the most prominent and advanced of the island's chip foundries, commands the largest overall share of the global foundry market, at 61.2% in 4Q 2023. Also, it controls a 90%-plus share of the global market for sub-10nm cutting-edge chips.

The other local foundry companies are UMC, Vanguard International Semiconductor Corp. and Powerchip Semiconductor Manufacturing Corp. They ranked the fourth, eighth and tenth largest, respectively, among the world's top ten foundry manufacturers by revenue in 4Q 2023, according to technology research firm TrendForce.

3.3.3 Packaging and testing

The back-end manufacturing process involves slicing the wafers made in the front-end stage into individual chips, which are assembled and packaged into protective frames (plastic or ceramic) and encased in a resin shell to become usable in electronic devices. Also, the chips are tested to determine their final quality and efficiency.

Taiwan's IC packaging and testing sector revenue amounted to NT$584bn (US$19bn) in 2023, accounting for around 50% of the global total and ranking first worldwide. Taiwan dominates advanced packaging and testing, and has relocated most of its more mature packaging and testing operations to China and Southeast Asia.

Figure 17: Major indicators of Taiwan's semiconductor packaging and testing sector, 2020-2024

	2020	2021	2022	2023	2024(e)
Number of companies	37	37	37	36	36
Total sector revenue (NT$bn)	549.0	638.4	684.7	583.7	650.3
Annual growth (%)	9.6	16.3	7.3	(14.8)	11.4
Global market share (%)	57.7	57.6	53.9	50.4	50.1
Global ranking	1	1	1	1	1
Value-added (NT$bn)	262.4	309.6	334.1	280.7	319.7
Value-added rate (%)	47.8	48.5	48.8	48.1	49.1
Capital expenditure (NT$bn)	110.0	129.0	139.5	104.6	141.2
Capital expenditure / revenue (%)	20.0	20.2	20.4	17.9	21.7
R&D employees	5,000	5,780	6,851	5,823	6,674
R&D expenditure (NT$bn)	16.7	19.9	22.0	18.7	23.4
R&D expenditure / revenue (%)	3.3	3.1	3.2	3.2	3.6
Number of employees	114,888	133,410	145,419	130,877	141,347
Average revenue per employee (NT$m)	4.8	4.8	4.7	4.5	4.6

Source: IEK Consulting (ITRI), 2024 Semiconductor Industry Yearbook, July 2024.

Taiwan accounted for five of the world's top ten largest IC packaging and testing service providers by revenue in 2023, according to industry research firm MIC. The three largest Taiwanese companies were Advanced Semiconductor Engineering, Inc. (1st), Powertech Technology Inc. (5th) and King Yuan Electronics Corp. (7th).

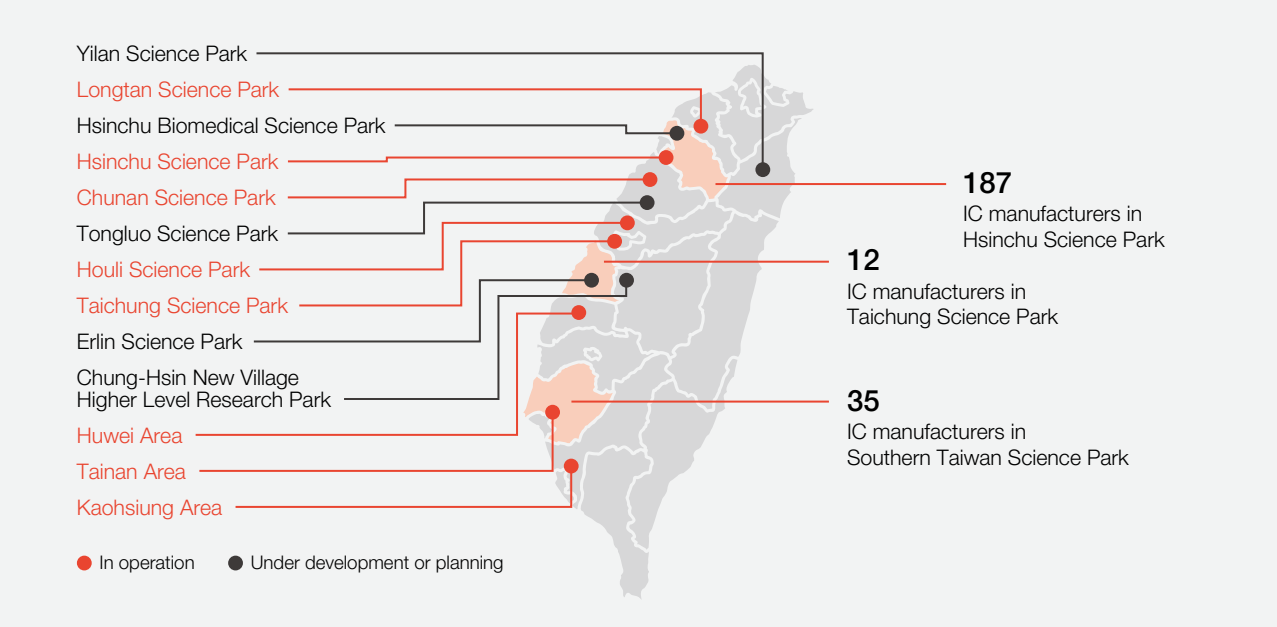
With the development of advanced foundry processes, local firms like these rely on their particular strengths to continually develop and improve the corresponding packaging and testing technologies. They are boosting capacity in Taiwan and overseas to meet semiconductor demand being driven by next-generation applications.

3.4 Semiconductor industry clusters

Over the past five decades, the Taiwan government has established a network of industrial and science parks around the island to provide a nurturing base of operations for high-tech industries, where companies and skilled local workforces combine to create mutually reinforcing ecosystems that support industry clustering.

The science park ecosystems offer high-quality, subsidised factory buildings, tax and import duty exemptions, grants and subsidised credit, and connections with local universities and research institutes. The government plans to build more science parks, and has upgraded export processing zones into technology industrial parks.

Figure 18: Semiconductor industry clusters in Taiwan



Source: Ministry of Economic Affairs.

These efforts have bestowed Taiwan's semiconductor clusters with unique advantages that are unmatched anywhere else. The Hsinchu Science Park in northern Taiwan, known as Taiwan's Silicon Valley, is the most influential of these. It was established in 1980 and has become the main hub for the local semiconductor industry.

The Hsinchu complex contains a complete industry chain — including IC design firms, cutting-edge fabrication plants and packaging and testing operations, as well as key materials, equipment and services suppliers. These entities are frequently within walking distance of each other, enhancing efficiency and shortening cycle times.

Development of southern semiconductor corridor

In order to disperse risks associated with earthquakes and other natural disasters, a larger share of more recently added semiconductor production capacity in Taiwan has been built in science parks in the island's central and southern regions, while packaging and testing firms are mainly concentrated in the Kaohsiung area.

Taiwan continues to expand its semiconductor clustering scale by developing more dedicated science parks. Construction started in 2022 on the Nanzih Technology Industrial Park in Kaohsiung, which is intended to become the core zone of a semiconductor corridor in southern Taiwan for high-end technology development.

3.5 Foreign investment and collaboration

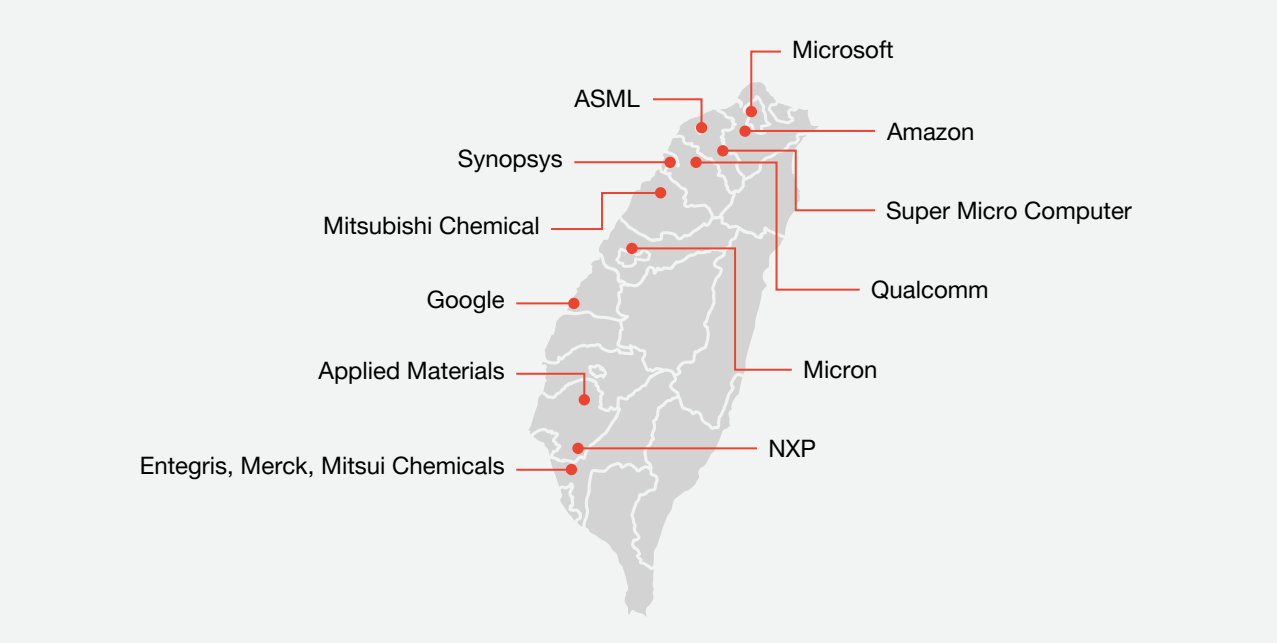
As Taiwan's semiconductor industry has grown steadily in importance, especially in the field of advanced chip manufacturing, it has attracted strong international investment interest. Its R&D capability and cluster strengths offer potential synergies for foreign businesses that establish research centres or production sites on the island.

The Taiwan government actively encourages and facilitates foreign investment and collaboration in the domestic semiconductor industry to sustain its progress. It provides policy support and tax incentives to encourage foreign direct investments, support technological innovation and promote industry-academia collaboration.

The Ministry of Economic Affairs has outlined three focus areas of partnership with international semiconductor suppliers: joining Taiwan's semiconductor cluster; exploring the growing market for semiconductor equipment and materials; and establishing R&D centres and local operations to tap into the fast-growing Asia market.

Taiwan has already attracted many top international semiconductor companies and suppliers to invest on the island. Currently, about 30 multinational firms have set up R&D centres in Taiwan, investing a total of about NT$60bn (US$1.9bn) and generating an estimated annual production value of nearly NT$340bn (US$11bn).

Figure 19: Multinational innovative R&D centres in Taiwan



Source: Ministry of Economic Affairs.

Increasing FDI in Taiwan's semiconductor industry

Recent notable investments include major local expansions. In May 2023, Entegris, a leading American supplier of advanced semiconductor materials, opened its largest global production site in Kaohsiung as part of an US$500m plan to expand its manufacturing presence in Taiwan and better support customers across Asia.

Also, ASML a Dutch company that makes advanced lithography machines used to produce cutting-edge chips, received approval in August 2023 to invest US$330m to set up its sixth factory in Taiwan (located in New Taipei City) for the development and manufacturing of 2-nanometer wafer optical measurement equipment.

Furthermore, in November 2023, American chipmaker Micron Technology, which is one of the largest foreign investors in Taiwan, opened a new facility in Taichung to produce its most advanced dynamic random access memory (DRAM) chips, ahead of any its other production sites worldwide, to meet demand from AI applications.

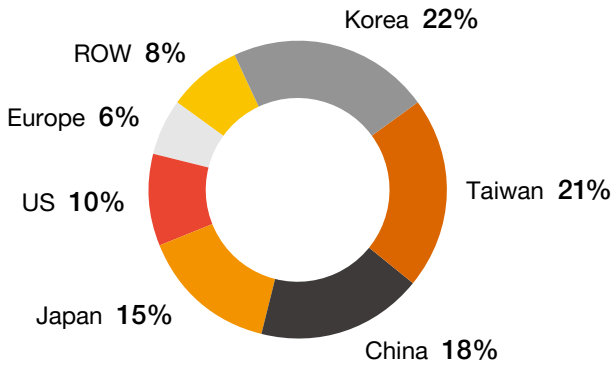
With Taiwan's semiconductor industry expected to invest US$210 billion over the next five years to cement its lead in the global market, according to the National Development Council, there will be high demand for advanced semiconductor materials and equipment. This will attract more foreign vendors to expand in Taiwan.

4. Strengthening supply chain resilience

The semiconductor industry has a very geographically dispersed value chain, making it highly complex. The production process is carried out by different firms and countries with comparative advantages in specific parts of the semiconductor supply chain, such that no nation has complete end-to-end control of chip manufacturing.

Broadly speaking, the US leads in the most R&D-intensive areas of the value chain, such as electronic design automation, core IP, chip design and advanced manufacturing equipment. Front- and back-end manufacturing processes are largely concentrated in East Asia, which accounts for 75% of global chip production capacity.

Figure 20: Global share of semiconductor production capacity, 2022



Source: IEK Consulting (ITRI).

4.1 Policy push for semiconductor reshoring

The global disruptions to semiconductor supply chains in 2020-2022 exposed the risks associated with the high concentration of chip manufacturing capacity in East Asia (Taiwan and Korea in particular), prompting many governments around the globe to introduce policies designed to reduce this reliance and promote self-sufficiency.

The US and European Union (EU) have both enacted new legislation that aims to boost their domestic and regional semiconductor production capacity. Other key countries in the semiconductor industry, such as Japan and South Korea, have also made efforts to bolster their positions within global semiconductor supply chains.

United States

In 2022, the US enacted the the CHIPS and Science Act to boost US-based semiconductor manufacturing and innovation. It provides U$52.7bn in subsidies and tax incentives for semiconductor R&D, manufacturing and workforce development, which aim to help lower the cost gap between investing in the US and investing abroad.

European Union

In 2023, the EU passed the European Chips Act in an effort to bolster Europe's competitiveness and resilience in semiconductor technologies and applications. It allocated €43bn (US$46.7bn) of funding to encourage chip manufacturing in the region, with a goal of doubling the EU's share of global industry output to 20% by 2030.

Japan

Japan is also ramping up support for its domestic semiconductor industry. From fiscal 2021 to 2023, the Japanese government allocated ¥3.9 trillion (US$26bn) in supplementary budgets to support the sector, including subsidies for chip-making companies, with a goal of tripling sales of chips made in Japan by 2030.

At the same time, aligning semiconductor policies to secure critical technologies and semiconductor supply chains has become more important. Hence, the top semiconductor countries also seek to expand international collaboration with like-minded partners, most notably Taiwan, to achieve a well-balanced supply chain network.

4.2 Global expansion by Taiwanese chipmakers

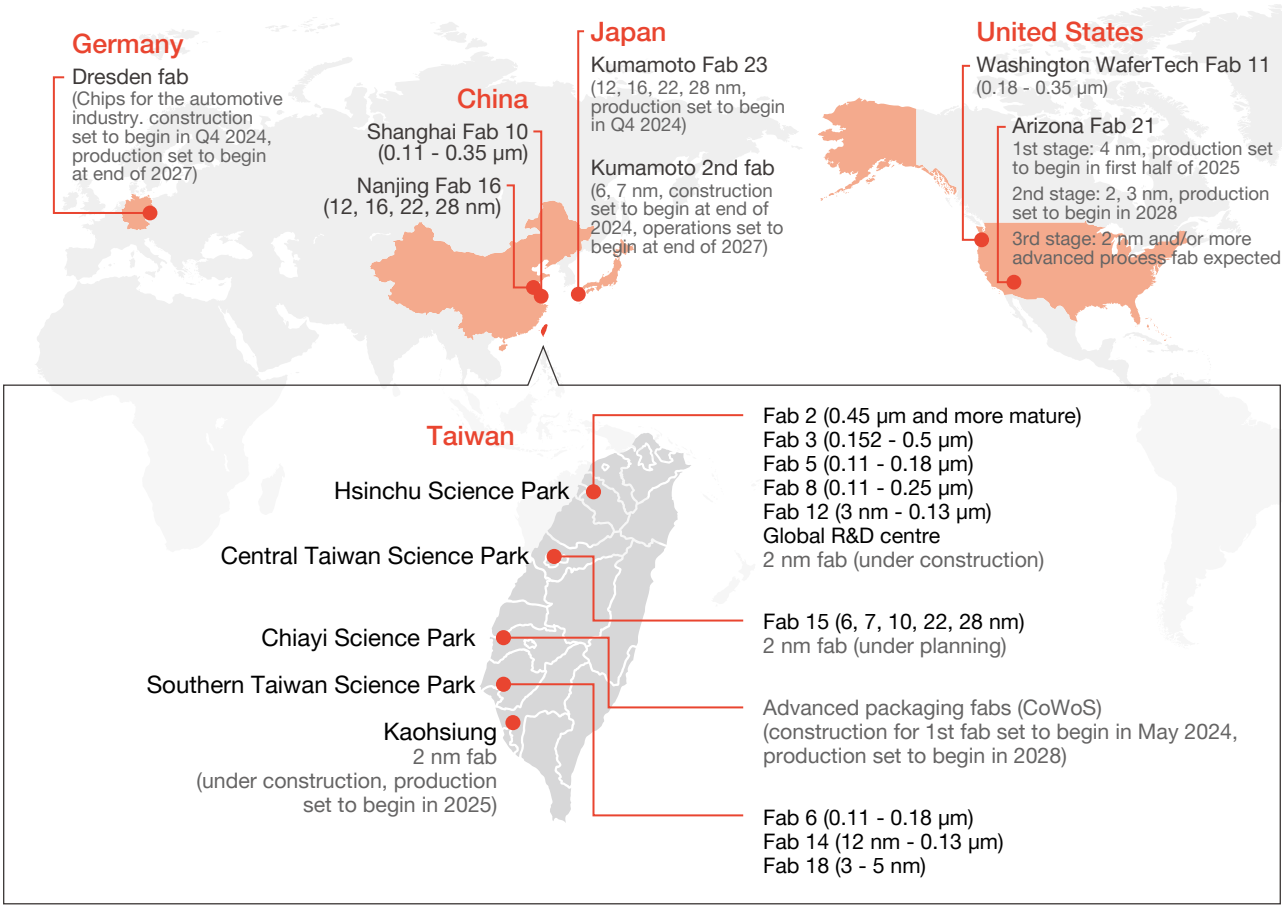
In response to the changing geographic dynamics in the semiconductor industry, Taiwanese chipmakers are expanding their overseas manufacturing sites to assuage major customers' concerns about supply chain resilience amid geopolitical tensions. At the same time, they are also committed to further expanding in Taiwan.

Taiwan's foremost semiconductor manufacturer, TSMC, has emerged as a global strategic asset, which the US, Japan and the EU have all courted for local fabrication plants to reduce supply chain risks. Each have offered big subsidies and incentives to the company to establish manufacturing operations within their borders.

TSMC has committed to building three advanced fabs in the US state of Arizona at a cost of US$65bn to serve American customers. It is also spending around US$20bn to build two plants in Kumamoto, Japan through a joint venture, and has agreed to invest in a US$11bn joint venture semiconductor fab in Dresden, Germany.

While TSMC's overseas investments have sparked worries the company might halt its development in Taiwan, it has said that is not the case. Demonstrating its long-term commitment to investing in Taiwan, in July 2023, TSMC launched a new global R&D centre in Hsinchu to further its development of next generation technologies.

Figure 21: TSMC's global expansion



Source: Adapted from CNA graphic, April 2024.

Fellow Taiwanese chipmakers have also started to expand globally. For example, UMC is building a US$5bn facility in Singapore, while Powerchip plans to build a US$5bn foundry in Japan and a US$11bn joint-venture fab in India. These investments have prompted several local suppliers to follow their major clients overseas.

While more and more Taiwanese semiconductor companies are going abroad, the majority of production will remain in Taiwan. Local chipmakers have committed US$120bn to constructing at least 20 new fabs around the island, and TSMC has committed to maintaining at least a one generational lead for its Taiwan-based fabs.

5. Industry links and resources

Key government bodies

- Ministry of Economic Affairs: www.moea.gov.tw
  - Department of Industrial Technology: www.moea.gov.tw/MNS/doit
  - Industrial Development Administration: www.ida.gov.tw
  - InvesTaiwan Portal: https://investtaiwan.nat.gov.tw
  - Smart Electronics Industry Project Promotion Office: www.sipo.org.tw
- National Science and Technology Council: www.nstc.gov.tw
  - National Applied Research Laboratories (NARLabs): www.narlabs.org.tw
  - Science Park Administration:
    - Hsinchu Science Park: www.sipa.gov.tw
    - Central Taiwan Science Park: www.ctsp.gov.tw
    - Southern Taiwan Science Park: www.stsp.gov.tw

Research institutes

- Industrial Technology Research Institute: www.itri.org.tw
  - Industry, Science and Technology International Strategy Center: https://ieknet.iek.org.tw/
- Taiwan Semiconductor Research Institute, NARLabs: www.tsri.org.tw

Industry associations

- Taipei Computer Association: www.tca.org.tw
- Taiwan Automation Intelligence and Robotics Association: www.tairoa.org.tw/
- Taiwan Electrical and Electronic Manufacturers' Association: www.teema.org.tw
- Taiwan IOT Technology and Industry Association: www.twiota.org
- Taiwan Optoelectronic Semiconductor Industry Association: www.tosia.org.tw
- Taiwan Semiconductor Industry Association: www.tsia.org.tw

Trade shows

- Computex: www.computextaipei.com.tw
- Semicon Taiwan: www.semicontaiwan.org

Other links

- DigiTimes: www.digitimes.com.tw
- Institute for Information Industry (III): www.iii.org.tw
  - Market Intelligence & Consulting Institute (MIC): https://mic.iii.org.tw

6. How PwC can help

At PwC, our purpose is to build trust in society and solve important problems.

It's this focus which informs the professional services we provide and the decisions we make. It shows our commitment to working towards the highest quality outcomes for our clients, people and society.

About PwC Taiwan

We're a member of the PwC global network of firms in 151 countries with over 364,000 people who are committed to delivering quality in assurance, advisory and tax services.

PwC Taiwan was established in 1970 under the original name of Chen & Chu, and our firm has since grown steadily in size and strength to become one of the leading professional service providers in Taiwan.

We have over 3,700 people in six offices — in Taipei, Taoyuan, Hsinchu, Taichung, Tainan and Kaohsiung — who provide industry-focused services to private and public entities of all sizes and backgrounds.

Our semiconductor industry services

With long experience of working with clients across the semiconductor value chain, we understand the complexities, nuances and uniqueness of the industry and their implications for your organisation.

Our multi-disciplinary semiconductor practice provides integrated services for a wide range of business needs. In view of the risks and challenges facing the semiconductor industry, we particularly focus on:

- **Business risk — Management and governance**
  Risk management is important in corporate governance because it protects against potential losses. We provide a range of services to help you identify, mitigate and manage key risks across your business.
- **Sustainable development — Net Zero and supply chain management**
  The global push to reduce carbon emissions is having a transformative impact on semiconductor supply chains. We can assist you with applying good practice across your operations to meet net zero targets.
- **Growth strategy — R&D and M&A strategy**
  With R&D budgets challenged by new products, semiconductor companies are increasingly turning to M&A to acquire new technologies and business scale. We offer services across all stages of the deals process.

Also, our supporting High-Tech Industry Research Centre provides insights and analysis on Taiwan's high-technology industries and emerging sectors, including the latest semiconductor trends and developments.

Key contacts

Contact us to learn more about our services and how we can help you.

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