Table 3: Number of Semiconductor Companies

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
IC Design	266	250	260	250	245	245	240	240	238	238	238	235
IC Manufacturing	14	16	15	15	16	16	16	15	15	15	13	13
IC Packaging and Testing	37	37	37	37	37	37	37	37	37	37	37	37
TOTAL	**317**	**303**	**312**	**302**	**298**	**298**	**293**	**292**	**290**	**290**	**288**	**285**

Source: IEK Consulting, ITRI

Over the years, the semiconductor industry has grown in importance and there has been an increasing number of persons employed in Taiwan's semiconductor industry. The 285 firms in 2021 employed more than 290,000 employees as of the end of that year, in a population of 23.4 million. That is up from 217,465 in 2010 and 225,000 just two years earlier in 2019, according to the Industrial Technology Research Institute (ITRI). The expansion of the number of persons employed in the semiconductor industry looks set to continue apace (see Table 4).[57]

Table 4: Number of Employees in Taiwan's Semiconductor Industry

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
IC Design	38,100	37,000	37,800	39,500	42,000	42,500	42,000	41,000	41,500	41,800	45,010	49,533
IC Manufacturing	85,393	80,614	83,526	83,854	85,674	87,559	88,960	83,392	83,475	83,559	96,628	109,176
IC Packaging and Testing	93,972	91,520	92,000	93,700	94,000	95,100	97,200	98,800	99,200	99,800	114,888	132,893
TOTAL	**217,465**	**209,134**	**213,326**	**217,054**	**221,674**	**225,159**	**228,160**	**223,192**	**224,175**	**225,159**	**256,526**	**291,602**

Source: IEK Consulting, ITRI

Upstream Segment

In 2022, the total production value of Taiwan's IC design industry reached US$ 41.6 billion. Leading Taiwanese chip design firms including MediaTek, Realtek Semiconductor and Novatek

[57] IEK Consulting, Industrial Technology Research Institute, April 2023.

Microelectronics were among the global top ten IC design companies by revenue in 2022, and were respectively ranked 5th, 7th and 8thworldwide. MediaTek is known for its mobile phone application processor (AP), and along with the USA's Qualcomm, is one of the world's largest mobile phone AP suppliers. Realtek is an innovator in wireless network cards while Novatek's strength lies in its display driver chips. Together, the three companies held 12% of the global market share (see Table 5).[58]

Today's IC designs have dramatically increased in function and capability, and the use of pre-verified IP components can make the process of completing chip design more efficient, quality assured and cost-effective. Moreover, with clusters, Taiwanese semiconductor companies can flexibly and quickly develop and produce products in close cooperation with global customers.

Table 5: Global Top 10 IC Design Companies by Revenue, 2021 & 2022

Unit: US$ Billion

2022 Ranking		2021 Revenue	2021 Market Share	2022 Revenue (Est.)	2022 YoY	2022 Market Share
1	Qualcomm (US)	29.3	15%	36.8	26%	17%
2	Broadcom (US)	21.3	11%	26.9	26%	13%
3	Nvidia (US)	25.8	14%	26.5	3%	12%
4	AMD (US)	16.4	9%	23.5	43%	11%
5	MediaTek (TW)	17.6	9%	18.2	3%	8%
6	Marvell (US)	4.5	2%	5.9	32%	3%
7	Realtek (TW)	3.8	2%	3.8	0%	2%
8	Novatek (TW)	4.8	2%	3.5	-27%	2%
9	Willsemi (CN)	3.2	2%	2.6	-19%	1%
10	Cirrus Logic (US)	1.6	1%	2.0	24%	1%
	Total	**128.3**	**68%**	**149.7**	**17%**	**69%**
	Taiwan's Total*	**26.2**	**13%**	**25.5**	**-2.7%**	**12%**

*Excluding TW companies outside the top 10 list

Source: DIGITIMES Research, February 2023

58 DIGITIMES, April 30, 2023.

Midstream Segment

The output value of Taiwan's IC manufacturing in 2022 hit US$ 90.2 billion, accounting for 63.8% of the global wafer foundry industry market. Four listed Taiwanese companies providing foundry services, namely, TSMC, UMC (United Microelectronics Corporation), PSMC (Powerchip Semiconductor Manufacturing Corporation) and Vanguard International Semiconductor Corporation (VIS) were ranked first, third, seventh and eighth respectively among the world's top ten foundry companies by revenue in 2022. Together, the four companies command 65% of the global market share (see Table 6).

Table 6: Global Top 10 Foundry Companies by Revenue, 2021 & 2022

Unit: US$ Billion

2022 Ranking		2021 Revenue	2021 Market Share	2022 Revenue (Est.)	2022 YoY	2022 Market Share
1	TSMC (TW)	56.8	52%	75.9	34%	55%
2	Samsung Electronics (KR)	19.0	17%	22.1	16%	16%
3	UMC (TW)	7.6	7%	9.2	21%	7%
4	GlobalFoundries (US)	6.6	6%	8.1	23%	6%
5	SMIC (CN)	5.4	5%	7.3	34%	5%
6	Hua Hong (CN)	3.0	3%	3.7	25%	3%
7	PSMC (TW)	2.3	2%	2.6	11%	2%
8	VIS (TW)	0.9	1%	1.7	23%	1%
9	Tower Semiconductor (IL)	1.5	1%	1.7	13%	1%
10	DB HiTek (KR)	1.1	1%	1.3	27%	1%
	Total	**104.3**	**96%**	**133.0**	**28%**	**97%**
	Taiwan's Total*	**67.6**	**62%**	**89.4**	**32.2%**	**65%**

* Excluding TW companies outside the top 10 list

Source: DIGITIMES Research, February 2023

TSMC, the world's largest foundry and the most prominent of Taiwan's midstream chipmakers, commands the number one share of the global foundry market and has highly advanced semiconductor processes. It started mass production of chips using its 3-nanometer process technology in the second half of 2022, and continues to research and develop processes below 2 nm.

Meanwhile, UMC, Taiwan's first semiconductor company, is focused on its 22/28 nm process technology and has made great leaps in communication and automotive chips. Recently, it signed a long-term automotive microcontroller control units (MCU) supply contract with Infineon, a major Integrated Device Manufacturer (IDM) manufacturer.[59]

Downstream Segment

In the downstream packaging and testing segment, Taiwan has a host of home-grown packaging and testing firms. Six Taiwanese firm, namely, Advanced Semiconductor Engineering (ASE), Powertech Technology, KYEC, Chipmos, Chipbond and Sigurd are among the world's top ten outsourced semiconductor assembly and test (OSAT) companies by revenue. They were ranked first, seventh, eighth, nineth and tenth in the world. Together, the six companies command about 45% of the world's market share in packaging and testing in 2022 (see Table 7).

ASE ranks first in the global packaging and testing industry. It is also known for system-in-package (SiP), and has actively invested in the construction of heterogeneous integrated packaging platforms in recent years.

In addition, there is also a number of firms that supply the materials needed for packaging and support the development of Taiwan's packaging and testing industry, including Chang Wah Electromaterials (gold wire and leadframes), Unimicron and Kinsus (IC carrier boards), Eternal Materials (molding and filling materials), and Yeh-Chiang Technology and Shenmao Technology (tin lead solder paste).[60]

[59] Infineon press release, "Infineon and UMC extend automotive partnership with long-term agreement for 40nm eNVM microcontroller production", March 7, 2023

[60] Ministry of Economic Affairs, R.O.C. (Taiwan), Key Innovative Industries in Taiwan- Semiconductors, 2022

Table 7: Global Top 10 OSAT Companies by Revenue, 2022

Unit: US$ Billion

2022 Ranking		2021 Revenue	2021 Market Share	2022 Revenue (E)	2022 YoY	2022 Market Share
1	ASE (TW)	11.5	29%	12.2	6%	29%
2	Amkor (US)	6.1	16%	7.0	15%	17%
3	JCET (CN)	4.7	12%	5.0	7%	12%
4	TFME (CN)	2.4	6%	3.1	25%	7%
5	Powertech (TW)	3.0	8%	3.0	1%	7%
6	Huatian (CN)	1.9	5%	1.8	-2%	4%
7	KYEC (TW)	1.2	3%	1.2	2%	3%
8	Chipmos (TW)	1.0	2%	1.0	1%	2%
9	Chipbond (TW)	1.0	2%	0.9	-7%	2%
10	Sigurd (TW)	0.6	2%	0.6	6%	2%
	Total	**33.4**	**85%**	**35.8**	**54%**	**85%**
	Taiwan's Total*	**18.3**	**46%**	**18.9**	**3.3%**	**45%**

*Excluding TW companies not on the top 10 list

Source: DIGITIMES Research, February 2023

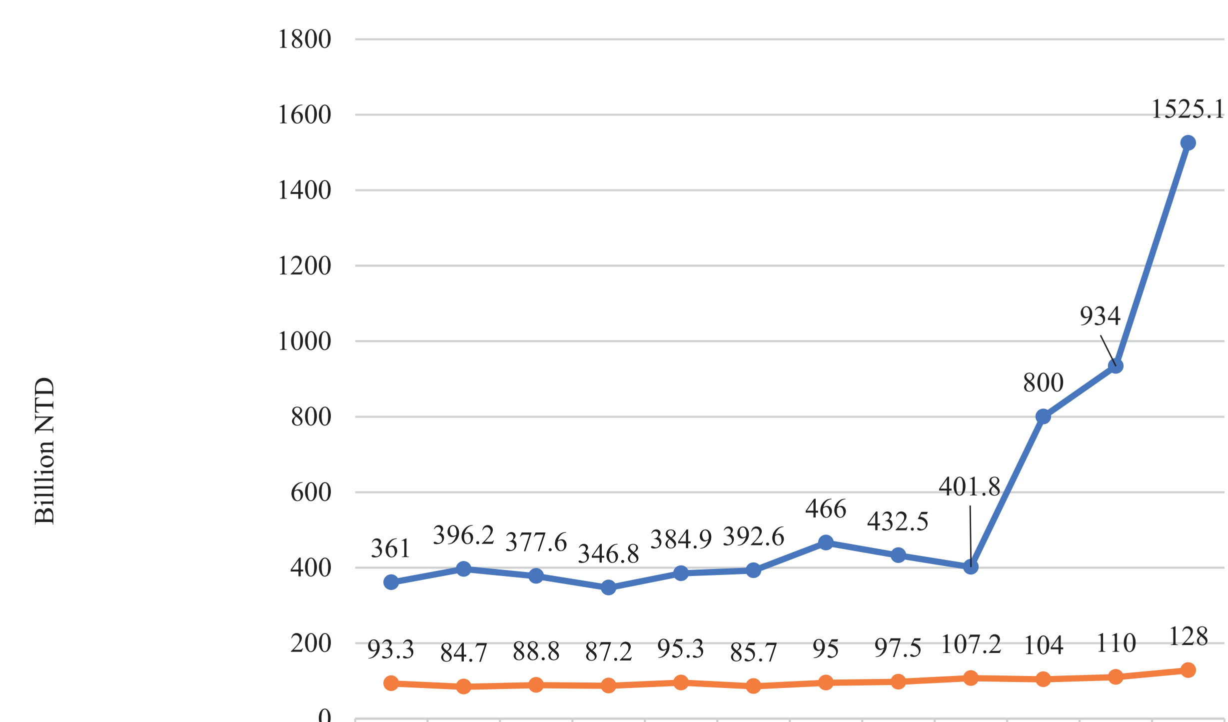
Each segment of Taiwan's semiconductor industry contributes its own irreplaceable value and supports the very high degree of integration among the upstream, midstream and downstream segments of the industry.

C. Capital Expenditure

Capital expense by Taiwan's IC manufacturing companies and IC packaging and testing companies has increased over the years, from NT$ 454.3 billion (US$ 14.67 billion) in 2010 to NT$ 1,653.1 billion (US$ 53.4 billion) in 2021. The increase is particularly significant in the case of IC manufacturing companies. IC manufacturing registered an almost threefold jump in capital expense from NT$ 401.8 billion (US$ 12.98) in 2018 to a whooping NT$ 1,525.1 billion (US$

49.26 billion) in 2021 (see Figure 6). This increase can be attributed to a surge in investment towards advanced process technology.[61]

Figure 6: Capital Expenditure of Taiwan's Semiconductor Industry



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
IC Manufacturing	361	396.2	377.6	346.8	384.9	392.6	466	432.5	401.8	800	934	1525.1
IC Packaging and Testing	93.3	84.7	88.8	87.2	95.3	85.7	95	97.5	107.2	104	110	128

Source: IEK Consulting, ITRI

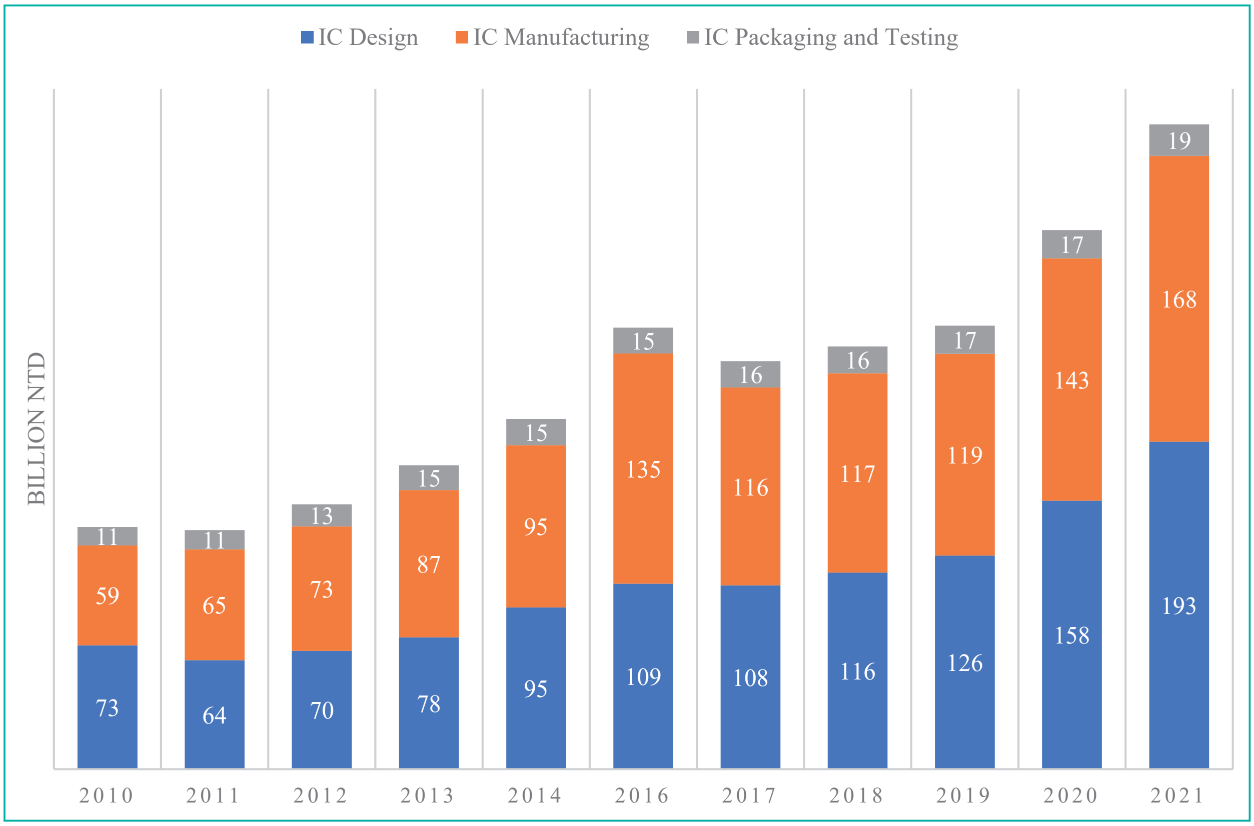
D. R&D Expenditure and Researchers

Businesses in Taiwan are responsible for a large majority of research and development spending. Spending on research and development in the semiconductor industry in Taiwan hit a record high in 2021. From a total spending of NT$ 143 billion (US$ 4.6 billion) in 2010, it increased 122% to NT$ 318 billion (US$ 10.2 billion) in 2020. This spending grew another 19% from 2020 to 2021 to NT$ 380 billion (US$ 12.2 billion). Taiwan IC manufacturing companies invested NT$ 168 billion (US$ 5.4 billion) in R&D in 2021 while its IC packaging and testing

61 Taiwan Semiconductor Industry Association, Overview on Taiwan Semiconductor Industry (2022 Edition)

and IC design invested NT$ 19 billion (US$ 612 m) and NT$ 193 billion (US$ 6.2 billion) respectively (see Figure 7).[62]

Figure 7: R&D Expenditure of Taiwan's Semiconductor Industry



	2010	2011	2012	2013	2014	2016	2017	2018	2019	2020	2021
IC Design	73	64	70	78	95	109	108	116	126	158	193
IC Manufacturing	59	65	73	87	95	135	116	117	119	143	168
IC Packaging and Testing	11	11	13	15	15	15	16	16	17	17	19
TOTAL	143	140	156	180	205	259	240	249	262	318	380

Source: IEK Consulting, ITRI

Commensurate with the increase in R&D spending, the number of researchers involved in the various segments of the semiconductor industry value chain in Taiwan also reached new

62 Taiwan Semiconductor Industry Association, Overview on Taiwan Semiconductor Industry (2022 Edition)

highs in 2021. In 2010, there were a total of 40,821 semiconductor researchers, with 8,790 in IC design, 8,265 in IC manufacturing and 3,796 in IC packaging and testing. From 2010 to 2021, the total number of researchers increased by 29% to 52,740, with 36,010 in IC design, 10,980 in IC manufacturing and 5,750 in IC packaging and testing (see Table 8).

Table 8: Number of Researchers in Taiwan's Semiconductor Industry

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
IC Design	28,760	27,380	27,518	27,813	29,573	30,277	29,887	29,555	30,005	30,000	32,400	36,010
IC Manufacturing	8,265	8,382	8,473	8,563	8,784	8,907	9,131	8,339	8,414	8,497	9,707	10,980
IC Packaging and Testing	3,796	3,755	3,870	4,000	4,060	4,250	4,200	4,220	4,230	4,250	5,000	5,750
TOTAL	**40,821**	**39,517**	**39,861**	**40,376**	**42,417**	**43,434**	**43,218**	**42,114**	**42,649**	**42,747**	**47,107**	**52,740**

Source: IEK Consulting, ITRI

E. Expansion of Taiwan's Foundries

A number of Taiwan's foundries, including TSMC, Powerchip, UMC and Vanguard International Semiconductor Corporation (VIS) have announced plans to increase their production capability (see Table 9).

TSMC

Taiwan accounted for approximately 70% of the global production capacity of advanced chips below 7 nm in 2022.[63] All these advanced chips are manufactured by a single company, Taiwan Semiconductor Manufacturing Corporation (TSMC).

In 2022, TSMC began mass-producing 4 nm chips, and in December closely followed Samsung's lead to mass-produce 3 nm chips. TSMC is also working to produce cutting-edge 2 nm chips in its Hsinchu and Taichung sites in northern- and central Taiwan by 2025.[64]

[63] Industrial Development Bureau, Ministry of Economic Affairs, R.O.C. (Taiwan), March 2023.

[64] Bloomberg, "TSMC Starts Next-Gen Mass Production as World Fights Over Chips", December 28, 2022.

On April 1, 2023, TSMC opened an overseas operations office to supervise fabs under construction in the U.S. State of Arizona and Japan's Kumamoto Prefecture. The overseas office is in charge of supervising and managing TSMC Arizona Corp. and Japan Advanced Semiconductor Manufacturing Inc. (JASM).[65]

TSMC will offer 4 nm chips at its new plant in Arizona, USA, which is targeted to begin operations in 2025.[66] It also plans to offer 3 nm at a second US plant in 2026. Through JASM, TSMC is also building an US$ 8.6 billion wafer plant in Kikuyo, Kumamoto Prefecture, using the company's 12/16 nm high-level logic processes as well as 22/28 nm specialty processes, with commercial production expected to start in 2024. Sony Group Corp. and Denso Corp., a major Japanese auto parts vendor, are also investing in the factory while the Japanese government is providing financial aid.[67]

UMC

In February 2022, UMC announced that it would be building a new manufacturing facility next to its existing 12-inch fab (Fab12i) in Singapore. The first phase of this greenfield fab will have a monthly capacity of 30,000 wafers with production expected to commence in late 2024. The new fab (Fab12i P3) will be one of the most advanced semiconductor foundries in Singapore, providing UMC's 22/28 nm processes. The planned investment for this project will be US$ 5 billion. UMC has operated as a pure-play foundry supplier in Singapore for more than 20 years and the location is also the company's designated R&D center for advanced specialty process technologies.[68]

Powerchip and Vanguard

To keep up with demand for their chips, both Powerchip and Vanguard announced their plans to expand in Taiwan in 2021. According to the original announcements, Powerchip plans to offer 1x-50 nm chips in 2024, while Vanguard is expected to offer 90/110 nm+ chips in 2023. However, due to the inventory adjustment throughout the supply chain in 2022, the time frames of the introduction of new production capacity are delayed for both companies.

65 Overseas Community Affairs Council, R.O.C. (Taiwan), "TSMC opens overseas operations office to supervise fabs in U.S., Japan", April 3, 2023.

66 Bloomberg, "TSMC Cuts 2023 Outlook Ahead of Delay to Marquee US Project", July 20, 2023.

67 Japan Times, "TSMC considering second chip plant in Kumamoto", June 6, 2023.

68 UMC Press Release: "UMC announces new 22nm wafer fab in Singapore", February 24, 2022.

Table 9: Expansion of Taiwanese Foundries

	Company	Announced Month	Major Expansion Plan and Location	Process Node	Yr. of Mass Production	Initial Capacity	8" equivalent wafer capacity
Foundry	TSMC	2020.6	New 12" fab in Arizona, U.S.	5 nm mass production	2024	20,000	45,000
	TSMC	2021.4	Expand 12" fab in Nanjing, China	28 nm mass production	2022	40,000	90,000
	TSMC	2021.10	New fab in Kumamoto, Japan	12-28 nm mass production	2024	55,000	123,750
	TSMC	2021.10	New fab in the former CNPC refinery site in Kaohsiung City	7nm mass production	2024	40,000	90,000
	Powerchip	2021.3	New 12" fab in Miaoli, Taiwan	1x-50 nm mass production	2024	25,000	56,250
	UMC	2021.4	New 12" fab in Tainan Science Park	22/28 nm mass production	2023	27,500	61,875
	UMC	2022.2	Expand 12" fab in Singapore	22/28 nm mass production	2024	30,000	67,500
	Vanguard (VIS)	2021.4	Expand 8" fab through acquisition of AUO's fab in Hsinchu, Taiwan	90/110nm+	2023	40,000	40,000

Source: MIC, Institute for Information Industry, October 2022

4. Opportunities and Prospects

A. Technology Trends

Taiwan's semiconductor industry is well positioned in core technologies and applications fueling innovations in fields essential to future economic growth such as personalized healthcare, robotics, and intelligent products. To meet the needs of the technologies of the future and to stay ahead in the face of global competition, Taiwan is heavily investing in R&D and promoting technological collaborations.

1.4 Nanometer Chip

On July 28, 2023, TSMC launched its global Research and Development Center at its manufacturing base in Taiwan's Hsinchu, where its state-of-the-art facilities are producing ever-smaller silicon wafers that have skyrocketed in demand, especially due to the recent boom in AI-related technology. TSMC will remain "rooted in Taiwan", its chief executive said in a bid to allay concerns that the world's largest contract chipmaker could abandon its island home as it expands abroad. At the launch of the R&D facility, TSMC chairman Mark Liu said the center would "develop world-leading technologies in the semiconductor industry more actively to explore two-nanometer and 1.4-nanometer technology, and even smaller". The company is racing to begin mass production of a 1.4-nanometer chip -- tinier than a fraction of a fingernail -- ahead of its rival Samsung, the world's second-largest producer.[69]

Breakthrough on Applications of 2D Materials

Teams from TSMC and National Yang Ming Chiao Tung University collaborated with the Taiwan Instrument Research Institute (TIRI)'s Atomic Layer Deposition (ALD) Joint Laboratory to develop a high coverage ALD process, successfully producing a device with a two-dimensional material with an effective 1 nm oxidation, in addition to developing a nanosheet gate-all-around (GAA) transistor made with a two-dimensional semiconductor material. Both achievements were jointly reported at the 2022 International Electron Devices Meeting (IEDM) and are critical pieces of research required to achieve "More than Moore" technology.

[69] Reuters, "TSMC says it is "rooted in Taiwan" even as it expands abroad", July 28, 2023

Vertically Stacked CFETs by a Low-temperature Bonding Technique

Complementary field-effect transistors (CFETs) can reduce transistors' footprint and are considered the next-generation semiconductor devices' structure. The low-temperature wafer bonding technology developed by the Taiwan Semiconductor Research Institute (TSRI) of the National Applied Research Laboratories (NARLabs) and National Institute of Advanced Industrial Science and Technology (AIST), Japan, can directly bond single crystalline semiconductor substrates with different wafer orientations or materials into one substrate, which can be applied directly to the production of CFET devices. In this technology's double-layer nanosheet stacked structures, the Ge/Si or (111) Ge/(100) Ge for upper pFET/ bottom nFET CFETs constitute a brand-new CFET structure. The results of this research have been published at the International Electron Devices Meeting (IEDM) and IEEE Symposium on VLSI Technology and Circuits (VLSI).

Developing Frontier Semiconductor Process Inspection Equipment

Taiwan Instrument Research Institute (TIRI) plans to develop a field monitoring and inspection module for cluster equipment, which can be applied to the inspection of advanced 2D semiconductor process materials. The technology can also assist domestic semiconductor wafer manufacturers in establishing standards for the use of extreme ultraviolet light components for domestic semiconductor inspection companies to develop the technology. The cluster semiconductor inspection technology and equipment developed will enable the most accurate surface information to be obtained without sample contact with the air.

Custom System-on-Chip Design Platform

Using the Custom System-on-Chip Design Platform developed by the TSRI, research teams from National Taiwan University (NTU) and National Yang Ming Chiao Tung University are developing biomedical chips, self-driving cars, and smart robots. Professor Chia-Hsiang Yang from the NTU Department of Electrical Engineering, his research team, and TSRI have used the platform to design, test, and display three custom systems-on-chips: the "AI Computing Acceleration Chip," which can accelerate computation by four to six times; the "Seven-axis Autonomous Mobile Robot Motion Control Chip," which can increase maximum motion control frequency by 22 times and energy efficiency by 350 times more than recorded in past literature, and the "Next-generation Genetic Sequencing Data Analysis Chip," which is the first in the world to achieve gene variant computation and can reduce analysis time from several days to half an hour or less. All three systems-on-chips were selected for presentation at the International

Solid-State Circuits Conference (ISSCC).[70]

3DIC Technology for Next-generation HPC and Mobile Applications

As the development of silicon process slows down after 10 nm, 3DIC technology becomes a "new Moore's law" to continue driving performance boost of semiconductor systems. 3DIC technology integrates several chiplets or wafers using vertical stacking or bonding processes. This technology provides tremendous flexibility as designers could "mix and match" technology IP blocks with various memory and I/O elements in novel device form factors. For high-performance computing (HPC), 3DIC offers great advantages of power, performance, and area (PPA).

TSMC is one of the leaders in 3DIC technology with its own CoWoS (Chip on Wafer on Substrate), InFo (Integrated Fan-out), and SoIC (System-on-Integrated-Chips) technology. To help customers overcome the rising challenges of system-level design complexity with 3DIC technology, TSMC introduced the new 3DFabric Alliance in 2022, a significant addition to TSMC's Open Innovation Platform (OIP). Meanwhile, TSMC established a 3DIC R&D center in Japan to pursue research into the next generations of three-dimensional silicon stacking and advanced packaging technologies in materials science.

Advancement of Third-Generation Semiconductor Devices

Third-generation semiconductor devices usually refer to devices made with silicon carbide (SiC) or gallium nitride (GaN). Owing to its Wide Band Gap (WBG) nature, third-generation semiconductor is suitable for high temperature, high frequency, radiation resistant and high-power devices such as electric vehicles, data centers, and renewable energy production.

Based on a market analysis[71], the output value for third-generation power semiconductors is expected to grow at 48% CAGR (compound annual growth rate) from US$ 980 million in 2021 to US$ 4.71 billion in 2025. In Taiwan, there are several companies working on third-generation semiconductor including TSMC, Episil Technology, WIN Semiconductors, and Mosel Vitelic. It is expected that these companies will enjoy robust global demand for third-generation semiconductors for power grids, electric vehicles and telecom base stations in recent years.

[70] National Applied Research Laboratories (NARLabs), TSRI Develops Custom System-on-Chip Design Platform, May 2023.

[71] TrendForce, "8-inch Substrate Mass Production in 2H22, 3rd Gen Power Semiconductor CAGR to Reach 48% by 2025, Says TrendForce," March, 2022.

B. Application Trends

AI-Generation Trend (IoT, 5G, Smart City)

Today's artificial intelligence (AI) applications can not only process data but also learn from experience and apply that experience to improve how they function. With AI applications gaining traction in the industrial, retail, health care, military, research, and consumer sectors, demand for specialized sensors, integrated circuits, improved memory, and enhanced processors is increasing. This demand is changing the semiconductor supply chain by directly impacting design and manufacturing decisions.[72]

A McKinsey report[73] projects that, by 2030, internet of things (IoT) products and services will create between US$ 5.5 trillion and US$ 12.6 trillion in value. The growing penetration of internet usage across residential and commercial space as a result of a higher disposable income and improvements in the IT sector, the increasing demand for connected wearable devices, and the rising trend of industrial automation are creating growth opportunities for the IoT chip market.

Semiconductors are involved in every level of 5G from the network infrastructure (antennae, base stations, switches) to mobile phones and other connected devices. According to a report by the Global System for Mobile Communications Association (GSMA), global 5G adoption will reach 17% by 2023, and by 2030, it is expected to contribute a staggering US$ 1 trillion to the global economy.[74]

Both 5G and the internet of things have the potential to transform cities into smart cities, with artificial intelligence technologies used to reduce traffic congestion, improve public safety and protect the environment.[75] In addition, Taiwan will play a very important role in the development of beyond fifth-generation (B5G) networks and sixth generation (6G) wireless communication networks, particularly MediaTek and WIN Semiconductors Corp.

72 Institute of Electrical and Electronics Engineers, International Roadmap for Devices and Systems (2020 Edition).

73 McKinsey, "IoT value set to accelerate through 2030: Where and how to capture it", November 2021.

74 Global System for Mobile Communications Association, "The Mobile Economy 2023", March 2023.

75 Schroders Wealth Management, "Semiconductors - key to smart, green cities of the future", June 2020.

Automotive Applications (EVs, Smart Cars)

With increasing demand for advanced driver assistance systems, growing electrification of vehicles, and advancements in autonomous technologies, automotive semiconductors will become indispensable components. The automotive semiconductor market is expected to grow by more than 9% annually through 2030.[76] New semiconductor technologies will be driven by the demand for comfort, safety, and convenience features.

Automobiles have about 1,200 chips in a standard internal combustion engine and 3,000 chips in a fully electric vehicle. Experts estimate that 8% of annual chip production goes to automobiles. According to Hsiao-Lu Lee, a partner leading McKinsey and Company's semiconductor practice in Asia, 66% of consumers are willing to change car brands based on their autonomous driving function. She believes that there will be more semiconductor complexity, and purpose-built chips will be more prevalent.[77]

A Digitimes Asia report highlighted that TSMC dominates the global chip foundry market, and high-performance computing chips for self-driving capability must be made using advanced processes. TSMC is in pole position in 28 nm and below processes needed to make automotive chips. The automotive segment accounted for about 5% of TSMC's overall company sales in 2022. In the first quarter of 2023, the percentage rose to 7%. The automotive segment could generate as much as NT$ 140 billion (US$ 4.56 billion) in sales in 2023 for TSMC on an estimated overall company sales of NT$ 2 trillion (US$ 32.1 billion) for the year.[78]

C. Stock Market

The semiconductor industry is also considered the core of Taiwan's stock market. In end-2022, the market value of the semiconductor industry was about NT$15.77 trillion (US$ 514.68 billion), accounting for more than 30% of the value of the Taiwan stock market.[79]

Compared with other securities markets in the world, Taiwan's price-to-earnings (P/E) ratio of about 10.39 times in 2022 is slightly higher than Singapore's and comparable to Hong Kong's,

[76] Boston Consulting Group, "Automotive Industry Semiconductor Outlook", October 2022.

[77] AmCham Taiwan, "EV Industry Drives Chip Growth, Green Future", November 30, 2022.

[78] Digitimes Asia, TSMC growing presence in EV sector, May 5, 2023.

[79] Taiwan Stock Exchange, April 2023.

but is lower than that of other securities markets. The P/E ratio of Taiwan's semiconductor industry at the end of 2022 is about 10.99, low when compared to other securities markets, indicating that Taiwan stocks have a price advantage. In terms of yield rate, Taiwan's overall market yield reached 4.88% while that of the semiconductor industry is 3.93 (see Table 10).

The profit on Taiwan's 2021 cash stocks reached a record high of NT$ 2.19 trillion (US$ 70.31 billion), an increase of more than 50% compared with 2020. Dividends are significantly better than major markets such as the United Kingdom, Hong Kong, China, Japan, South Korea, and the United States. In addition, in 2022, the turnover rate of Taiwan's transaction value was 115.44%, and the turnover rate of semiconductor transaction value was 114.71%. Overall, Taiwan's turnover rate was better than Singapore and Hong Kong, and comparable to the United States.

Table 10: Comparison of 2022 Global Stock Exchange PE Ratio and Yield Rate

Stock Exchange	End of 2022		
	P/E Ratio	Yield (%)	Turnover Ratio (%)
Taiwan	**10.39**	**4.88**	**115.44**
- Semiconductor	**10.99**	**3.93**	**114.71**
Singapore	9.22	4.09	35.38
United Kingdom	17.00	3.76	35.76
Hong Kong	10.31	3.37	61.64
Shanghai	12.78	2.77	204.79
Japan	14.40	2.27	107.12
United States	19.18	2.07	121.74
South Korea	10.76	1.97	165.24
Shenzhen	23.44	1.23	383.24

Sources: Taiwan Stock Exchange, Bloomberg, and indicators of the securities and futures market.

Note:

1. The turnover ratio of semiconductor is based on statistics from the official website of the stock exchange and calculated by dividing the transaction value by the market value.
2. Data date: December 30, 2022

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.

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