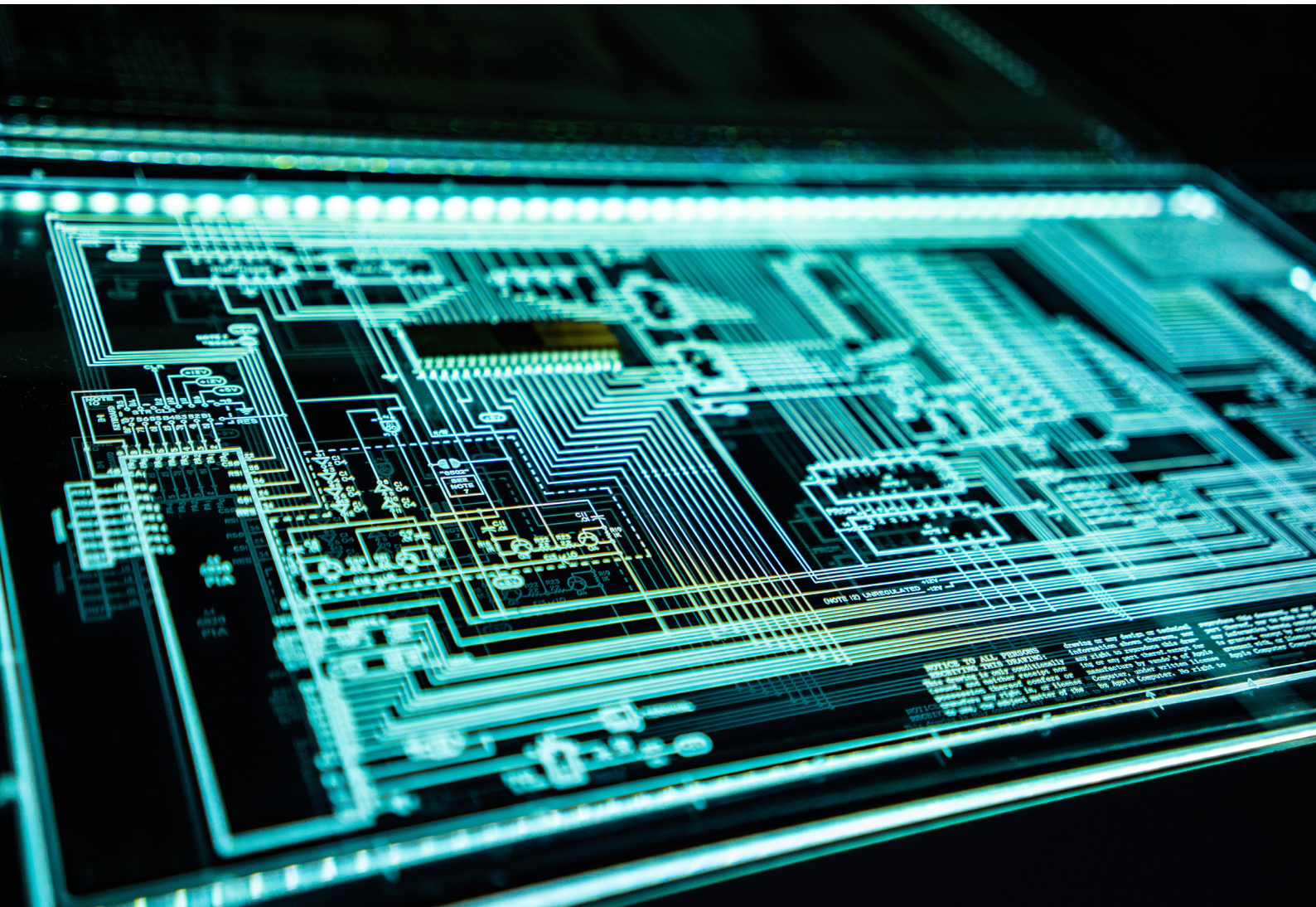
Netherlands Enterprise Agency

Research on the Next Generation Semiconductor Industry in Taiwan

Commissioned by the Netherlands Innovation Network at the Netherlands Office Taipei

June 2022



Preface

Dear reader,

With increasing demands for AI, 5G, IoT, high performance computing (HPC) and consumer electronics, the semiconductor industry is experiencing an unprecedented growth worldwide. The global semiconductor industry sales reached US$52.5 billion in the month of February 2022, with an increase of 26.2% Year-to-Year. Just behind the US, Taiwan ranks second in the global semiconductor industry market share showing outstanding economic performances and a GDP growth of 6.28% in 2021.

In the world's top 10 foundries, half of them are Taiwanese companies. Leading by the world's largest chip manufacturer, Taiwan Semiconductor Manufacturing Co. (TSMC), the total output value of Taiwan semiconductor manufacturing sector reached US$69.3 billion in 2021, accounting for 79.7% global market share (world's no. 1). Moreover, TSMC holds 92% global manufacturing capacity for the most advanced technology (under 10nm technology). Taiwan became one of the most competitive players in the industry for both advanced and mature process technologies. Despite the well-known global leader role in chip manufacturing, Taiwan also shows its ambition towards upstream IC design and downstream packaging and testing. In 2021, four Taiwanese IC design companies entered the world's top 10 list, naming MediaTek (ranks 4th), Novatek (ranks 6th), Realtek (ranks 8th) and Himax (ranks 10th). The total Taiwanese IC design output value reached US$43,2 billion, ranking 2nd in the world and accounting for 22% global market share. The packaging and testing output value reached US$22.8 billion with a market share of 59%, ranking first globally. From upstream to downstream of the supply chain, a thriving vertical-integrated semiconductor ecosystem is well developed in Taiwan and this increases Taiwan's visibility and impact in the global economy.

Following its crucial role in the global semiconductor industry, what are the focus areas of Taiwan for Next Generation Semiconductor development? And what are the opportunities between the Netherlands and Taiwan for the Next Generation Semiconductor revolution? This report dives into this giant industry and provides an overview of the current ecosystem and market in Taiwan. Moreover, Next Generation Semiconductor is analyzed by looking into research and development areas of Taiwan's semiconductor industry for the upcoming five to ten years.

There are four areas identified, for which the status and potential collaboration strategies are addressed in this report:

- Chip design: ARM-based high performance computing.
- Packaging: Advanced packaging with heterogeneous integration and chiplet technologies.
- Equipment: The localization of manufacturing equipment production.
- Emerging Technology: Photonics Integrated Circuits (PICs) development and manufacturing.

By providing an outlook into the future of Taiwan, the goal of this report is to explore more innovation and business opportunities between the Netherlands and Taiwan as well as to secure a solid position for Dutch partners in this cutting-edge "new oil" industry of the 21st century.

We wish to thank the Industrial Technology Research Institute (ITRI) for their dedication to write this report. We hope the report will offer all readers valuable insights to bring the bilateral cooperation between the Netherlands and Taiwan further. Your thoughts and comments on this report are therefore very much welcome.

We wish you a great read!

Anouk van der Steen – Director for Innovation, Technology & Science in Taiwan
Cathy Soong – Sr. Officer for Innovation, Technology & Science in Taiwan

Research on the Next Generation Semiconductor Industry in Taiwan

FINAL REPORT

Industrial Technology Research Institute (ITRI)
Industry, Science and Technology International Strategy Center (ISTI)

May 2022

CONTENT

FIGURES

TABLES

Executive Summary

Taiwan has cultivated the semiconductor industry for many years, and its chip-related industry chain has become the most critical economic lifeline for the nation. Taiwan's leading global foundry and advanced packaging & testing technologies have enabled it to gain high market shares, provide high-yield and stable professional IC chip services, and become a key player in the semiconductor supply chain.

In order to maintain its leading position, Taiwan is developing next generation semiconductor technology in the fields of Arm Architecture High-end Computing Chips and System-level Heterogenous Integrated Packaging and Advanced Packaging.

A weaker link in Taiwan's industrial chain is the semiconductor equipment sector. Taiwan's ambition is to encourage domestic production, and stimulate 100% own-made equipment. Following the strength of the Netherlands on equipment, there is a good opportunity to further establish Taiwan-Dutch partnerships in this field.

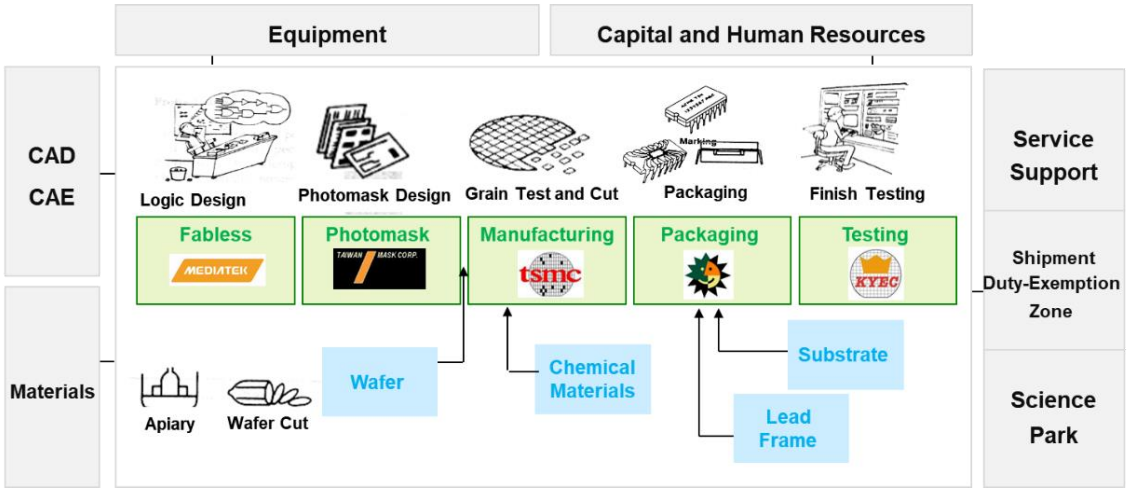
Another synergy effect between the Netherlands and Taiwan may evolve following Taiwan's strong capabilities in manufacturing, and the focus of Dutch companies and academic institutions to actively conduct semiconductor-related research (e.g. photonics chips) with the ambition to gradually achieving mass production.

This report highlights the interest of Taiwan towards various Next Generation Semiconductor technologies, and identifies collaboration strategies with the Netherlands. Below table provides a quick overview of the technologies analyzed in this report.

Technologies	Status on TW side	Status on NL side	Collaboration Strategy
ARM-based High Performance Computing	To reach high performance computing chip market based on the experience of developing ARM-based chip.	The growing high-performance computing chip market drives demand of semiconductor equipment.	Collaboration opportunity on the next-gen equipment for advanced technology process and on the energy efficiency optimization of equipment.
Advanced Packaging / Chiplet Packaging	To develop advanced packaging technology. TSMC keeps expanding its 3DFabric production capacity to provide chiplet with front-end and back-end chip integration services.	Dutch advanced packaging companies have strong R&D and technology capabilities, e.g. in die-to-wafer chiplet packaging.	TW foundries and NL equipment companies could strengthen collaboration on chiplet packaging, and share the benefits from this significantly growing market.
Semiconductor Equipment	To promote localization of equipment manufacturing.	Main supplier of semiconductor equipment.	TW's equipment manufacturers can collaborate with NL companies and research institutes to establish local equipment supply chains.
Photonics IC	Focus on Silicon Photonics technology with the Si PIC research program subsidized by MOST.	Focus on PIC on III-V materials and leading R&D results in the photonics field.	NL's PIC companies can collaborate with TW suppliers (LandMark, WIN, etc.) to improve production yields and to reduce manufacturing costs. Furthermore, there's potential to collaboration on III-V on Si Photonics integration.

I. Taiwan Semiconductor Industry Overview

Based on its production value chain, Taiwan's semiconductor ecosystem can be roughly divided into IC design, manufacturing, packaging, testing, and equipment and materials industries needed for operations. Figure 1-1 shows the semiconductor industry chain and the leading companies in Taiwan. The Taiwan Semiconductor Manufacturing Company (TSMC) had started with foundry operations in 1987 and gradually developed into the current vertical upstream and downstream division of labor industrial structure. The order from upstream to downstream is IC design, IC manufacturing, IC packaging, and IC testing. Among them, IC manufacturing is mainly based on foundry and dynamic random access memory (DRAM) manufacturing. The pure-play foundry business model is also an important factor behind the success. Taiwan's vertical division and industrial cluster provide flexibility, speed, and low-cost competitive advantages to Taiwan's IC industry.



Source: ISTI of ITRI (2022/03)

Figure 1-1. Semiconductor Industry Chain and Iconic companies in Taiwan

1. Output Value of Taiwan's IC industry

The total output value of Taiwan's IC industry reached US$145.7 billion in 2021*[1]. Taiwan's IC design output value reached US$43.2 billion in 2021, which accounted for 22.0% of the total worldwide and ranked second globally, just behind the United States. Taiwan has held the top global market share position for a long time in terms

[1] Exchange rate from Bank of Taiwan – 1 USD = 28 TWD (2021) , 1 USD = 29.6 TWD (2020).

of foundry service as well as IC packaging and testing. Taiwan's foundry output value reached US$69.3 billion in 2021 with a global market share of 79.7%, and its IC packaging and testing output value reached US$22.8 billion with a market share of 59.0%.

Table 1-1. Annual output value and growth rate of various sectors in Taiwan's IC industry

Unit: NT$100 million

	2016 (YoY)	2017 (YoY)	2018 (YoY)	2019 (YoY)	2020 (YoY)	2021 (YoY)
Taiwan's IC Industry Gross Output Value	**24,493 (8.2%)**	**24,623 (0.5%)**	**26,199 (6.4%)**	**26,656 (1.7%)**	**32,222 (20.9%)**	**40,820 (26.7%)**
IC Design Industry Output Value	6,531 (10.2%)	6,171 (-5.5%)	6,413 (3.9%)	6,928 (8.0%)	8,529 (23.1%)	12,147 (42.4%)
IC Manufacturing Output Value	13,324 (8.3%)	13,682 (2.7%)	14,856 (8.6%)	14,721 (-0.9%)	18,203 (23.7%)	22,289 (22.4%)
- Foundry	11,487 (13.8%)	12,061 (5.0%)	12,851 (6.6%)	13,125 (2.1%)	16,297 (24.2%)	19,410 (19.1%)
- Memory Manufacturing	1,837 (-16.8%)	1,621 (-11.8%)	2,005 (23.7%)	1,596 (-20.4%)	1,906 (19.4%)	2,879 (51.0%)
IC Packaging & Testing Industry Output Value	4,638 (5.1%)	4,770 (2.8%)	4,930 (3.4%)	5,007 (1.6%)	5,490 (9.6%)	6,384 (16.3%)

Source: ISTI of ITRI (2022/03)

Table 1-1 summarizes Taiwan's IC industry output values and growth rates in the past six years. The data shows that the semiconductor industry in Taiwan is growing at a high velocity and analysts from ITRI Industrial Economics and Knowledge Center are forecasting a continuous growth at a compound annual growth rate (CAGR) of 10.3% over the forecast period 2021-2025.

2. Import & Export Ratio for Taiwan's IC Related Products

In addition to enjoying a very high market share and playing a key role in the global IC industry, Taiwan's IC industry contributes extensively to its economy. It is the most critical import and export commodity in the nation. Statistics from the past six years show that the total value of Taiwan's IC product exports accounts for 28% to 35% of Taiwan's total exports.

Table 1-2. The ratio accounted for by Taiwan's IC product (HS code: 8542) import and export value to total import and export value and the historical trends

Unit: NT$100 million

IC products Total Import/Export Values (ratios to Taiwan's total imports/exports)	2016	2017	2018	2019	2020	2021 (Preliminary Values)
Total imports value (including re-imports)	116,950 (15.83%)	132,624 (16.93%)	153,300 (17.85%)	166,088 (18.80%)	184,093 (21.76%)	227,960 (21.36%)
Total exports value (including re-exports)	251,662 (27.97%)	280,943 (29.25%)	289,249 (28.73%)	310,282 (30.47%)	361,582 (35.45%)	435,459 (34.83%)

Source: ISTI of ITRI (2022/03)

3. Taiwan IC Industry Employment and R&D Statistics

The IC industry supports Taiwan's economic development and brings vast job opportunities. The IC-related industries employed over 250,000 people in 2020 and nearly 300,000 people in 2021. There is an increased shortage of talent in the IC-industry, and the competition on the employment market is expected to continue and even grow. Companies such as TSMC announced they look for 8.000 new employees in 2022. Also the Dutch company ASML aims to attract 1.000 new engineers in Taiwan in 2022, amongst others.

Table 1-3. Historical employment trend for Taiwan's IC industry

Unit: person

Total No. of people employed by the IC industry (Ratio for No. of R&D personnel)	2017	2018	2019	2020	2021 (Preliminary Values)
IC Design	41,000 (72.1%)	41,500 (72.3%)	41,800 (72.5%)	45,010 (72.0%)	49,533 (72.7%)
IC Manufacturing	83,392 (10.0%)	83,475 (10.1%)	83,559 (10.2%)	96,628 (8.9%)	109,176 (10.1%)
IC Packaging & Testing	98,800 (4.3%)	99,200 (4.3%)	99,800 (4.3%)	114,888 (4.4%)	132,893 (4.3%)
Total	**223,192 (18.9%)**	**224,175 (19.0%)**	**225,159 (19.1%)**	**256,526 (18.4%)**	**291,602 (18.1%)**

Source: ISTI of ITRI (2022/03)

The upstream in the vertical division of labor in IC industry accounts for the largest ratio of R&D personnel. In particular, the value of the IC design industry mostly derives from R&D personnel and expertise, and over 70% of the employees within

the enterprises are R&D personnel. Taiwan's IC design industry has developed steadily and is moving towards a model of continuous R&D and added value re-creation from existing products. Therefore, the growth of employment has slowed down. In recent years, wafer manufacturers and packaging and testing vendors have actively expanded production capacities, improved process technologies, and continued to invest in the R&D of advanced technologies.

4. Major IC companies in Taiwan

Table 1-4 summarizes the top ten IC companies in Taiwan based on revenue. The top-ranked Taiwan Semiconductor Manufacturing Company (TSMC) accounts for 50% of the total value among the top ten companies and is a critical semiconductor manufacturer in Taiwan. According to a report published by IC Insights at the end of 2021, TSMC ranks No. 3 among the semiconductor manufacturers worldwide, just behind Samsung in South Korea and Intel in the United States.

Taiwan's second-largest semiconductor company MediaTek ranks No. 9 among the top 10 semiconductor companies worldwide in 2021. It is also the fourth largest fabless pure IC design company globally, behind the three U.S. semiconductor giants Qualcomm, Nvidia, and Broadcom.

The third-largest semiconductor manufacturer in Taiwan is the packaging and testing giant ASE Group, which owns two leading packaging and testing manufacturers, ASE and SPIL, with a combined global market share of over 30%. They are the largest wafer packaging and testing companies worldwide, and their market shares are approximately twice that of Amkor, the second-largest U.S.-based packaging and testing company.

Taiwan's top three semiconductor companies are coincidently divided into three major areas: IC design, manufacturing, and packaging and testing. The overall IC industry is generally in a state of balanced development, with larger enterprises growing even stronger. The revenues of the top 10 IC companies in Taiwan account for nearly 80% of the IC industry in Taiwan. This study will introduce the innovative R&D technologies investigated by these leading companies in accordance to future trends of semiconductor development.

Table 1-4. Top 10 IC industry enterprises in Taiwan for 2020 & 2021

Unit: NT$100 million

2021 ranking	Enterprise name	Enterprise type	2020 revenue	2021 revenue	Growth rate (%)
1	TSMC	Foundry	13,393	15,874	18.5%
2	MediaTek	IC Design	3,221	4,934	53.2%
3	ASE Group	IC Packaging & Testing	2,700	3,225	19.4%
4	United Microelectronics Corporation	Foundry	1,768	2,130	20.5%
5	Novatek Microelectronics	IC Design	800	1,354	69.3%
6	Realtek Semiconductor Corp.	IC Design	778	1,055	35.6%
7	Winbond Electronics Corp.	Memory Manufacturing	607	996	64.1%
8	Nanya Technology	Memory Manufacturing	610	856	40.3%
9	Powertech Technology Inc.	IC Packaging & Testing	762	838	10.0%
10	Powerchip Technology Corp.	Foundry	457	656	43.5%
-	**Grand Total**		**25,096**	**31,918**	**27.2%**

Source: ISTI of ITRI (2022/03)

II. Emerging Technologies / Next Generation Semiconductor Targeted by Taiwanese Semiconductor Manufacturers in the next 5-10 Years

This research selects two emerging technologies (arm computing and advanced packaging) based on the R&D fields of Taiwan's leading providers in IC design, manufacturing and packaging industries. With the trend towards artificial intelligence and new automotive needs, the market for high-performance computing chips has increased. ARM architecture's computing power and low energy consumption meets the necessary conditions for entering these emerging consumer markets. IC design companies worldwide started to launch related products.

With high demand of transistor numbers and device performance, traditional Moore's law for IC physical scaling down seems to reach its limit. That's when advanced packaging comes in and plays an important role for the new era of Moore's law. IC manufacturing and packaging companies are investing in related technology to further develop it's R&D. This chapter demonstrates the characteristics and trends of these technologies, as well as the R&D directions of Taiwanese semiconductor providers.

1. Arm Architecture High-end Computing Chips

Arm-based chip processors use Reduced Instruction Set Computer (RISC) instruction sets. They are widely used in embedded systems, mobile IoT devices, AIoT related chips, and other applications. In recent years, they have also become supercomputer processors due to their energy-saving features and continuously improved computing performances. It's reported by Arm that its silicon partners shipped a record 6.7 billion Arm-based chips in the third quarter of 2020. The ecosystem of ARM architecture is growing and it's expected to see increased adoption of Arm IP.

Various Taiwanese IC design companies are using ARM-licensed IP, mostly standardized core licenses. Table 2-1 summarizes" Taiwanese IC design companies and their products authorized by the ARM architecture.

Table 2-1. Taiwanese IC designer using ARM-licensed IP

Taiwan's IC design companies	Products using ARM-licensed IP
MediaTek	Smartphone Application Processor (AP) and IoT products (ARM Cortex-A and Cortex-M series)
Novatek Microelectronics	Digital TV SoC chips (ARM Cortex-A series)
Realtek Semiconductor Corp.	IoT modules, Bluetooth headsets (ARM Cortex-A and Cortex-M series)
Phison	SSD Controller (ARM Cortex-R Series)
Silicon Motion	SSD Controller (ARM Cortex-R Series)
Sunplus	Multimedia IC and Consumer IC (ARM Cortex-A Series)
Nuvoton	General purpose MCU (ARM Cortex-M series)
Holtek	General purpose MCU (ARM Cortex-M series)
Sonix	General purpose MCU (ARM Cortex-M series)
Kneron	General purpose MCU (ARM Cortex-M series)
Global Unichip, Faraday, socle, Alchip	All are IC design service companies and provide Silicon Intellectual Property (SIP). In addition to their own important IP products, they also cooperate with ARM to authorize product development.
eMemory	As a SIP supplier, it cooperates with ARM to launch advanced IoT chip security application solutions.

Source: ISTI of ITRI (2022/03)

After a 10 year interval, ARM released a new comprehensive computing solution for Armv9 architecture in March 2021. It includes the next-generation Cortex CPUs and Mali series GPUs with enhanced Scalable Vector Extension (SVE). ARMv9 is expected to improve processor performance by over 30% and meet the clients' security, AI, and various special computing needs. It is actively entering the high-end computing market such as data centers and autonomous cars. These features are also the key trends of electric vehicles which the Netherlands focus on.

As mentioned above, many IC design providers in Taiwan have developed chips based on ARM technology. The improvement of ARM's computing power is expected to help Taiwan IC design companies access more markets with familiar technologies.

For example, MediaTek has deeply cultivated the smartphone processor chip market and is a leading company in this field. They launched Dimensity 9000 at the end of

2021 and use TSMC's 4nm process. It is the first chip to announce the use of ARMv9 Cortex-X2 comprehensive computing solutions. MediaTek also developed its latest technology based on the new ARM architecture showcasing the best mobile application platform.

As Apple has launched ARM-based CPUs in its computers for two consecutive years, including the high-performance M1 Pro and M1 Max chips released in 2021, it proves that the ARM architecture can also be used for professional computing. This has boosted the confidence of Qualcomm and MediaTek, which are ARM architecture mobile phone chip design specialists, and inspired them to enter the notebook processor market. In fact, MediaTek has launched Chromebook laptop processors as early as 2015. But MediaTek's laptop processors wasn't gained notice by the market until the impacts of COVID-19 in 2020 that set off a large demand for educational notebooks.

With the success of the latest ARMv9 architecture mobile phone chips, MediaTek also indicated that it would use this technology to conduct further R&D in various fields such as laptops and IoT, and actively enter the high-performance computing market other than mobile phones. ARM-based chips are expected to have a 10% market share in the NB/PC market by 2025, aiming to challenge the x86 architecture that had almost exclusively dominated the computer processor market in the past.

On the Dutch side, it is chipmaker NXP that widely adopted ARM architecture in their automotive processors, IoT, consumer, or industrial multimedia display chips. In addition to well-known large chip makers, the small and medium-sized IC design companies and ASIC service providers in the Netherlands mainly focus on developing radio frequency (RF) and analog-related chips. Such chips do not require vast computing power, and the cooperation relationship with ARM is less intense.

In addition, the market for advanced processes will continue to grow due to the needs of high-performance computing. Therefore, the demand for EUV equipment exclusively supplied by Dutch company ASML will also increase, however, the energy efficiency of EUV machines is a potential issue.

Less than 2% of the light energy is left after multiple reflections. The improvement of power consumption will be one of the key factors to strengthen competitiveness of equipment manufacturers towards the foundries.

2. System-level Heterogeneous Integrated Packaging and Advanced Packaging

Following the lightweight, small and thin chip size requirements for wearable devices, the space for the motherboard is limited. Highly integrated chips are required for improved performance and reduced power consumption. Major providers of IC packaging such as ASE have developed various component packaging solutions to integrate heterogeneous chips such as logic computing, memory, and sensors chips to meet the system in package (SiP) demands.

For example, the Integrated Passive Devices (IPD) technology can miniaturize and integrate the original discrete passive devices during the back-end fab process into an IPD Chip. The Chip Scale Package (CSP) method is then adopted to reduce the area usage rate. The networking antenna can also be integrated using Antenna on Package (AoP), so it would not occupy any additional area in the X-Y direction. Another method is to embed passive or even active components into the embedded substrate to reduce the X-Y direction area usage.

System in Package is primarily divided into 3 major categories: Flip Chip hybrid bonding, Fan Out packaging, and Embedded Die packaging. Among them, embedded packaging has the highest compound annual growth rate (CAGR), which has been the key development area for packaging manufacturers in Taiwan in recent years.

Embedded substrate (chip or passive component) packaging can achieve advantages of area usage reduction, good heat dissipation, reduced noise, and can take better advantage of additional substrate functions. In addition to embedding the wafer into a substrate to save space, other passive components can also be embedded to achieve good spatial configuration. Embedded substrates also have better electrical performance due to shorter transmission paths between chips. ASE established a joint venture company in 2015 with Japanese business TDK to advance the

embedded SiP technology further. Their goal is to merge the SiP and embedded substrate technology to improve yield, and pave the way for a packaging method required by IoT terminal products in the future.

In addition to packaging manufacturers using system-level heterogeneous integrated packaging also fabs have begun to transcend the Moore's Law limitations by using advanced wafer manufacturing processes to improve chip computing performance.

Since the shrinking speed of the front-end wafer process is faster than that of the back-end, the technology node gap between advanced processing chips and back-end packaging has widened. Advanced packaging technologies such as fan-out and silicon interposer have become critical to fill this gap. Since the degree of difficulty for advanced packaging technology is higher, value-added chips can differentiate fabs from competitors, bringing opportunities for advanced high-precision packaging.

The ratio of advanced packaging is increasing annually, and it is expected to account for approximately 49.4% of the overall packaging and testing revenue in 2025. Advanced packaging includes Fan-In Wafer Level Packaging (FIWLP), Fan-Out Wafer Level Packaging (FOWLP), embedded packaging, and 3D packaging.

The 3DFabric released by TSMC in 2020 is a one-stop integrated technical service platform for 3D silicon stacking and advanced packaging technology. It includes a variety of advanced packaging technologies, such as the Integrated Fan-Out (InFO) packaging method based on fan-out packaging, which can reduce the thickness by 30% achieving outstanding results on Apple's iPhone processor. Starting from the A10 processor for iPhone 7 in 2016, each subsequent mobile phone processor chip has been produced by TSMC and adopted its InFO packaging technology.

TSMC has another advanced packaging technology called Chip on Wafer on Substrate (CoWoS), which uses the silicon interposer to directly package several chips with different functions into "one" IC with comprehensive functions. It is known as 2.5D packaging. The CoWoS technology has been widely used in Nvidia,

AMD's high-end processing chips, and even adopted by Fujitsu's supercomputer chips.

Advanced packaging has pushed the technology of related equipment forward. Examples include the etching and exposure processes needed to achieve product structure miniaturization, internal defect detection required for 3D stacking, zero-contact wafers transfer through suspension to achieve protection, deep cleaning using megasonic wave or supercritical fluid technology to prevent structural damage, and using atomic layer deposition (ALD) to ensure tighter thin-film structural coating.

This development is interesting for various players in the Netherlands. F.e. ASMI is one of the leading ALD equipment manufacturers worldwide. They conduct R&D in the field of heterogeneous integration, such as hybrid bonding and laser cutting. Other companies are Besi, with advanced wafer grabbing equipment, and Trymax, who introduced plasma ashing and etching equipment for advanced packaging processes.

Heterogeneous integrated packaging in the Netherlands has also developed to the technology of combining the two fields of photonics and electronics into a single chip. This enables the chip to have both optical and electrical advantages, and can be widely used in automotive lidar, medical and data transmission. There is a strong interest from the Netherlands to develop the photonics integrated circuits further, and possible collaborate with partners in Taiwan to upgrade the manufacturing capabilities for PIC.

The Dutch's R&D efforts are stimulated further by the Chip Integration Technology Center (CITC) that provides in-depth research on integrated packaging technology. CITC collaborates with local semiconductor giants, such as NXP and Nexperia, to conduct technology R&D according to market trends and demands.

2.1. Trends and Developments in Chiplet

The development of advanced packaging technology has also inspired the key

chiplet technology, which enables high-performance computing chips continuous development. Multiple processors, memories, power management chips, RF components, sensing components, etc., can be integrated into one chip via homogeneous and heterogeneous integration.

Using Chiplet approach to design and manufacture wafers is a global trend. At present, major high-performance processor chip manufacturers such as Intel, Samsung, AMD, and Nvidia have launched high-end chiplet technology-based products. The biggest challenge in designing and producing wafers using the Chiplet design is the compatibility and integration amongst wafers. Foundries like TSMC will need to play a key role. They can participate customer's designing from the beginning, integrate and develop the compatible technologies of manufacturing and packaging. TSMC has continued to expand its 3DFabric production capacity and invest in advanced packaging plants to provide chiplet with front-end and back-end chip integration services. There is a direct possibility to cooperate with Dutch companies such as Besi and ASM as they also continuously invest in die-to-wafer chiplet packaging.

In order to solve the compatibility issue amongst wafers. Major manufacturers have strived to develop unified interface standards. Intel announced in March 2022 to establish the Universal Chiplet Interconnect Express (UCIe) alliance with ASE, AMD, Arm, Google, Meta, Microsoft, Qualcomm, Samsung, and TSMC. The goal is to establish die-to-die interconnect standards and promote an open Chiplet ecosystem. After the Chiplet interconnection standard is established, IC design companies will only need to develop the type of chips that they have competitive strengths in. The rest can be produced and assembled by different system vendors according to the needs from the market.

III. Taiwan-Dutch International Cooperation Analysis

- *Taiwan Semiconductor Policies*

Due to the impact of Covid-19 and the trade barrier policies of the US and China, the cost of international trade but also the uncertainty in the supply chains increased. In order to minimize risks and prevent key resources from being stuck, major trading economies have proposed relevant policies in response to dramatic changes in global economy and the supply chain restructuring. Taiwan's Executive Yuan promulgate "Six Core Strategic Industries" to promote plans for six major industries: information and digital technology, cybersecurity, medical technology and precision health, green and renewable energy, national defense and strategic industries, and strategic stockpile industries. These include next-generation semiconductor technologies and their applications such as AIoT, 5G ORAN, etc. The endeavor is aimed at taking early advantage of global supply chain transformations in the post-pandemic era to position Taiwan as a key power in the world economy.

Taiwan also actively attracts international manufacturers to develop emerging technologies in Taiwan. For example, the Department of Industrial Technology, MOEA (Ministry of Economic Affairs) announce a program, “Pioneers for Innovation Leadership on Technology Program (PILOT)”, focusing on emerging semiconductor technologies such as next-generation memory, high-frequency and high-power semiconductors. This program aims to encourage domestic and foreign international manufacturers to develop leading technologies in Taiwan, to boost R&D collaboration with Taiwan’s industrial chain, and to create value together.

Taiwan’s semiconductor equipment field does not occupy an important global position compared to design, manufacturing, packaging, and testing. The key semiconductor equipment primarily relies on imports. The total import value of semiconductor equipment was 15 times that of related exports. Taiwan plans to promote and become an "advanced semiconductor process center", that involves establishing a comprehensive semiconductor ecosystem and actively supporting Taiwan's semiconductor materials and equipment industry. The goal is to introduce

foreign investments, establish local supply chains, and provide talent funding subsidies to encourage international semiconductor equipment manufacturers and suppliers to drive the momentum for domestic parts and materials suppliers, precision machines, and automation-related enterprises to enter the global semiconductor industry supply chain. The "Semiconductor Equipment Cross-industry Alliance Cooperation Memorandum" signed in December 2020 is to promote the localization of foreign equipment and advanced packaging equipment manufacturing.

Table 3-1. "Localization of Semiconductor equipment" Promotion Strategies

Promote Taiwan as Asia's High-end Manufacturing Center and Advanced Semiconductor Process Center		
Introduce foreign investment	Establish local supply	Talent funding subsidy
• Inventory equipment procurement requirements • Introduce foreign investments in Taiwan (Investment Office, Investment Promotion Center)	• Cultivate local manufacturers • International technology matchmaking (Industrial Development Bureau)	• Global R&D Innovation Partnership Plan • Foreign professional employment solicitation (Technical Office, Ministry of Labor)

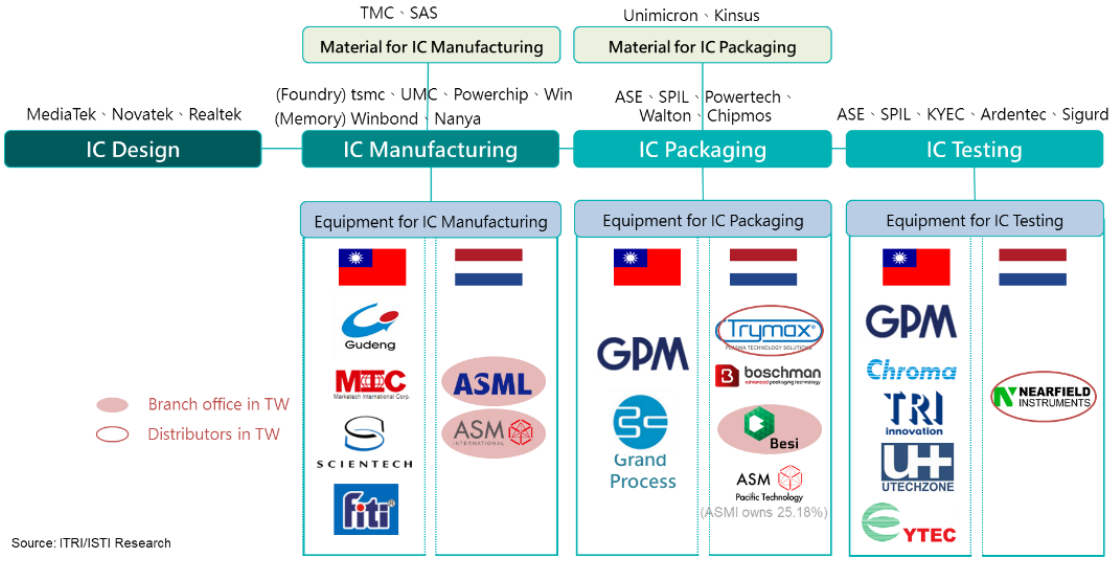
Source: ISTI of ITRI (2022/03)

- *Potential Collaborations between Taiwan and the Netherlands*

The Netherlands plays an important role in semiconductor equipment industry, f.e. with the renowned lithography equipment manufacturer ASML. Its extreme ultraviolet (EUV) exposure machine holds the key to advanced process technology breakthroughs. Furthermore, there are many other equipment manufacturers in the Netherlands with leading technology and rich market experience. This creates various opportunities for further collaboration towards localization of the equipment industry ambitioned by Taiwan.

Figure 3-1 provides an overview of Taiwanese manufacturers and the relevant Dutch equipment manufacturers at the various phases of Taiwan's semiconductor supply chain.

Figure 3-1. Taiwan's semiconductor industry chain and the semiconductor equipment suppliers in Taiwan and Netherlands



Source: ISTI of ITRI (2022/03)

Taiwan's local equipment manufacturers are primarily machine components or equipment module OEMs. One example is Marketech International Corp.'s long-term partnership with ASML to provide OEM for its EUV laser voltage regulator modules.

In the IC packaging and testing field, Taiwan has several local IC testing manufacturers that can provide automatic optical inspection (AOI) and various electrical testing equipment. However, Taiwan's packaging equipment capacities are relatively weak. Most of them are equipment manufacturers such as Hong Plastic Technology Co., Ltd. and Gallant Precision Machining Co., Ltd. that specialize in wet processes such as etching. The Netherlands has a much more comprehensive packaging equipment supply chain from film-assisted molding (FAM), reel-to-reel, and plasma etching to wafer clamping with professional equipment manufacturers for each process. They can perfectly complement Taiwan's industry chain. Taiwan's equipment manufacturers have market and customer advantages as well as a comprehensive field. This partnership can better meet the clients' demands while providing more valuable equipment solutions.

Furthermore, the Netherlands' advantages and experience in optical instruments and equipment have allowed it to continue to achieve leading R&D results in the photonics field. Optical components are fabricated into photonic integrated circuits (PICs) using III-V materials such as InP and GaAs optical components. Using photons to transmit and process signals can reach higher-speed fiber optic transmission capabilities, reduce the size of communication modules, improve reliability, and reach excellent power consumption performance. They can also achieve optical communication application advantages such as data center information transmission and medical equipment.

The Netherlands has extensive PIC development experience and established a comprehensive supply chain from design, manufacturing, and packaging to systems and products. Taiwan should incorporate Netherlands' strengths into Taiwan's well-established IC mass production capacity and form partnerships with Taiwan's III-V compound semiconductor manufacturers. For example, collaborations with Taiwan's epitaxy wafer suppliers such as LandMark Optoelectronics Corp. and Visual Photonics Epitaxy Co., Ltd. or wafer foundries such as WIN Semiconductors and GCS Holdings, Inc. can further improve production yields, reduce manufacturing costs, and gain more market shares.