Backgrounder
February 10, 2025

Taiwan's Semiconductor Manufacturing Industry and Its Role in the International Supply Chain

Introduction

Semiconductor products have emerged as the cornerstone of modern technology. The world's critical dependence on semiconductors was highlighted during the shortage following the COVID-19 pandemic. Semiconductors are the materials and substances that are the foundation of microchips, also known as integrated circuits (ICs). Without ICs, industries could not supply the demand for the technology that modern society is dependent on, such as phones, cars, household appliances, defense technology, and medical devices.[1] ICs are of varying sizes, measured in nanometers (nm), which equip devices with different capacities. For instance, 40nm chips can be applied to central processing units (CPUs), graphic processors, and hard disk drives while 3nm chips have been utilized in MacBooks, iPhone 15 Pro, and iPad Pro models.[2] These individual ICs are derived from a wafer. A wafer is a disc thinly sliced from a silicon rod mainly made of silicon extracted from sand.[3]

This backgrounder aims to provide an overview of Taiwan's semiconductor industry, including its development and current role in the international semiconductor supply chain.

A Brief History of Taiwan's Semiconductor Manufacturing Industry

1960-1974: Foreign-Invested Enterprises

Taiwan's semiconductor industry can be traced back to the establishment of its export processing zones (EPZs), which focused on light industries such as textiles, electronic appliances, or plastic products. During this period, Taiwan utilized its cheap labor force to attract foreign investment. Additionally, the capital needed to start a semiconductor assembly business was relatively low, which offered Taiwan an opportunity to have a role in the semiconductor supply chain. In this context, there were U.S. companies that relocated their transistor production lines and low-end IC assembly processes to Taiwan. The end products were, in turn, mainly exported to the U.S. at the time.[4]

In 1964, Taiwan's first semiconductor laboratory was established at National Chiao Tung University (NCTU) in Hsinchu. The semiconductor laboratory eventually led to the establishment of the Semiconductor Research Center (SRC), which is dedicated to conducting prospective research and cultivating talents for the semiconductor industry.[5] In addition, Hsinchu is also the home of the Industrial Technology Research Institute (ITRI), the National Tsing Hua University (NTHU), and Taiwan's first science park (which was established in 1980). NCTU and NTHU are prestigious research and education hubs for semiconductor-related fields such as electrical engineering, electronic engineering, materials science and engineering, and chemical engineering. ITRI was founded in 1973 and is dedicated to developing Taiwan's capabilities in industrial technology to enhance industrial competitiveness.[6]

1974-1979: Government-led Initiatives

In 1974, Wen-Yuan Pan (潘文淵), the laboratory director at Radio Corporation of America (RCA), established the Technical Advisory Committee (TAC, 電子技術顧問委員會) in the US.[7] TAC was composed of Taiwanese expats who were researchers and senior executives in technology or industrial companies. The members of TAC not only provided expertise but also professional networks.[8] In the same year, ITRI founded an electronics industry research center, which is now known as the Electronics Research and Service Organization (ERSO). With TAC's networks, ITRI and RCA signed a 10-year IC technology transfer and licensing contract in 1976 to officially introduce semiconductor technology in Taiwan. The technology transfer included IC design, photomasking, wafer fabrication, packaging and testing, and application and production management. After signing the contract, Taiwan sent out its first training group to RCA.[9] In 1977, Taiwan's first IC demo factory and production line were built.[10]

During this period, the semiconductor industry in Taiwan focused on developing its capacities in IC manufacturing. The policy was led by the government, while the low-end production lines were still mainly invested in by foreign companies such as Philips and Texas Instruments.[1112]

1980-1989: Government-led Industry and the Cultivation of Local Enterprises

During this period, Taiwan's semiconductor manufacturing companies started emerging as

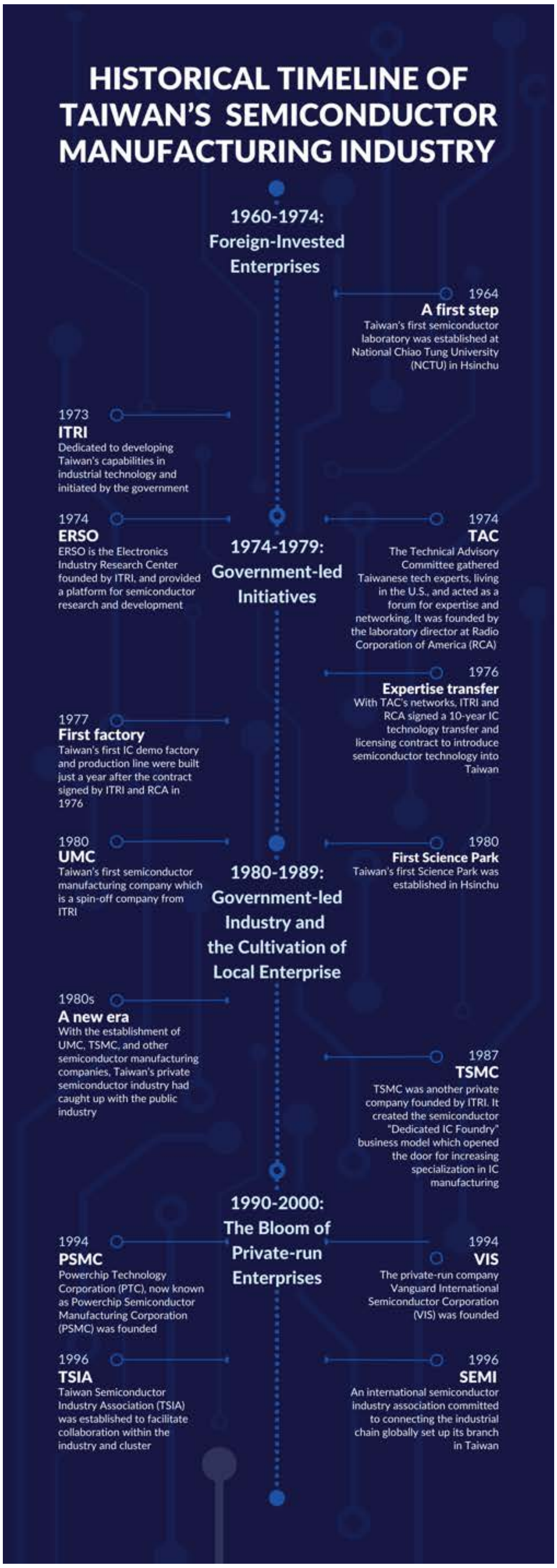

Figure 1. Historical Timeline of Taiwan's Semiconductor Manufacturing Industry

spin-off companies from ITRI. Moreover, in 1980, the first Science Park was established in Hsinchu.

In the same year, with the support of ITRI, United Microelectronics Corporation (UMC) was founded. UMC is Taiwan's first semiconductor manufacturing company and a spin-off company from ITRI. The establishment of UMC was the result of a government-led research agency that had been conducting technology transfer to the private-run company.[13] The purpose of creating this spin-off company was to assist the private industry in catching up with the government-led policy. During this period, government-led policy and technological capabilities did not match manufacturing capacities in private-run companies. To facilitate and advance the production capabilities of IC products, ITRI set up another spin-off company, Taiwan Semiconductor Manufacturing Company (TSMC), in 1987. TSMC created the semiconductor "Dedicated IC Foundry" business model (專業晶圓代工模式) which opened the door for increasing specialization in IC manufacturing.[14]With the establishment of UMC, TSMC, local IC design companies, and other semiconductor manufacturing companies, Taiwan's semiconductor industry entered a new era. Private-run companies had become capable of maintaining a local semiconductor supply chain that included IC design, wafer fabrication, IC assembly and testing.

1990-2000: The Bloom of Private-run Enterprises

After decades of government-led initiatives and development in Taiwan's semiconductor industry, private-run semiconductor companies started emerging following the establishment of ITRI spin-off companies. Taiwan's semiconductor industry entered an era in which the role of the government shifted from leading the industry to supporting it, working with private-run companies.[15] The private-run companies founded during this period include Powerchip Technology Corporation (PTC), known as Powerchip Semiconductor Manufacturing Corporation (PSMC) today and Vanguard International Semiconductor Corporation (VIS) both of which were founded in 1994.[16]

In 1996, the Taiwan Semiconductor Industry Association (TSIA) was established to facilitate collaboration within industry and cluster. It has since been dedicated to creating a bridge between Taiwan's semiconductor industry and international collaboration as well as providing policy recommendations to the government.[17] SEMI, an international semiconductor industry association committed to connecting the industrial chain globally, set up its branch in Taiwan in the same year.[18]

After the 1990s, the domestic semiconductor supply chain was well-developed. Taiwan's semiconductor industry then entered a period in which private enterprises managed to compete with other semiconductor design and manufacturing countries, such as the U.S. and Japan. Since 2000, Taiwan has been leading in semiconductor manufacturing technology while also dominating the market.[19]

Semiconductor Cluster in Taiwan Today

The formation of a semiconductor cluster enables IC design houses and manufacturing companies to increase their production capacity, reduce costs, and facilitate healthy competition within the industry. In Taiwan, the geographic proximity between different semiconductor companies in Science Parks and the completeness of the domestic semiconductor supply chain are significant advantages. These factors contribute to Taiwan's ability to maintain a flexible and cost-effective environment for advancing IC design and manufacturing capacity. The geographic proximity between different companies creates efficient flows of knowledge and exchanges of experience, which is beneficial to the innovation of related technology. In addition, proximity shortens the time needed to place orders, deliver products and discover potential product issues. In turn, this increases flexibility in the response to optimizing products. The shorter time and distance between different companies during the manufacturing process also makes the whole process more cost-effective. In other words, the semiconductor cluster allows Taiwan to produce ICs in a flexible, efficient, and cost-effective manner. Apart from the industry itself, the vicinity between universities cultivating talents in semiconductor-related professions and Science Parks are also crucial to the advancement and sustainability of semiconductor clusters. For instance, NCTU and NTHU not only work in close collaboration with the Hsinchu Science Park, but are also located nearby.

The semiconductor cluster in Taiwan mainly focuses on IC design and manufacturing with a vertical disintegration style instead of operating as integrated device manufacturers (IDM) like Samsung that handles both IC designs and manufacturing by itself. The manufacturing part includes both front end and back end. Front-end manufacturing refers to wafer fabrication and back-end manufacturing includes packaging and testing.[20]

The formation of the semiconductor cluster is related to what the semiconductor supply chain looks like. The semiconductor supply chain can be broadly divided into three sections: (1) pre-competitive research, (2) design, and (3) manufacturing.[21] Potential customer needs and market demand are explored and identified in the pre-competitive research stage. In the design stage, the company designs the chip according to the result of research on customer needs and market demand. After the design stage, semiconductor manufacturing companies fabricate wafers based on the chip design and then conduct IC packaging and testing.[22] In Taiwan, the process of IC design, fabricating wafers, and packaging and testing are divided between several different companies specializing in respective stages.

The three major types of companies are fabless IC design houses (IC design houses that have no capacity to fabricate wafers), fabrication companies, and packaging and testing houses. IC design houses design chips, which are produced by fabrication companies. The semiconductor fabrication company is usually called a “foundry”, which provides wafer fabrication services. Packing and testing houses are companies that are in charge of the assembly and testing process at the end of manufacturing ICs.

Taiwan’s semiconductor cluster includes all these types of companies, from IC design to IC assembly

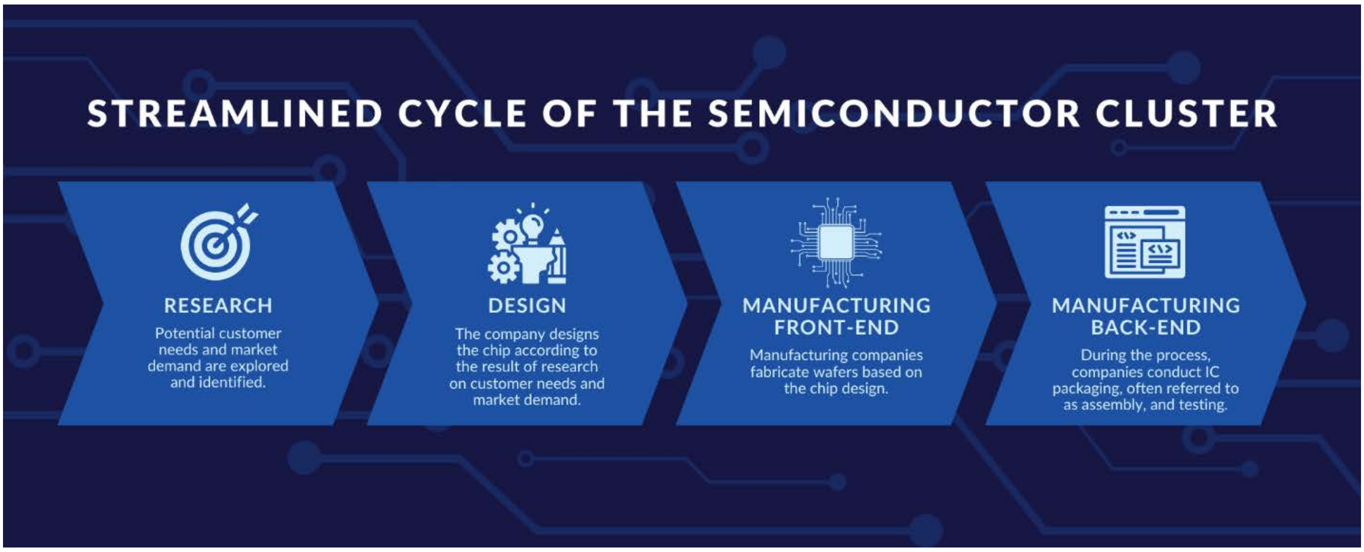

Figure 2. Streamlined Cycle of the Semiconductor Cluster

and testing. According to TSIA, by the end of 2023, Taiwan had 256 fabless design houses, 15 fabrication companies, and 36 packaging and testing companies.[23] According to the statistics in 2023, Taiwan's foundries, packaging and testing companies are leading in the global semiconductor industry. Its foundries accounted for 75.2 percent of the global market share while packaging and testing companies' revenue accounted for 50.4 percent of global total revenue. [24] In IC design, Taiwan is ranked No. 2 with 19.3 percent of the global IC design market, trailing behind the U.S.

An example of upstream design houses working closely with midstream and downstream manufacturers within Taiwan's semiconductor cluster is the collaboration between MediaTek (MTK), TSMC, and Advanced Semiconductor Engineering Inc. (ASE). MTK is the largest IC design company in Taiwan, which is also often ranked as one of the top five fabless semiconductor companies in the world.[25] TSMC is a semiconductor foundry, ranked first as the largest semiconductor supplier in the world by sales revenue in 2023.[26] As for the ASE, it holds the largest global outsourced semiconductor assembly and test (OSAT) market share in 2022 and 2023.[27] An example of this process is MTK's Dimensity 9400 flagship 5G smartphone chip. MTK designed the flagship chip, which is fabricated by TSMC and the assembly and testing process are mainly handled by ASE.[28] From design to IC testing, MTK, TSMC, and ASE all benefit from the geographic proximity within Taiwan's semiconductor cluster.

Taiwan's Role in the International Semiconductor Supply Chain

The international semiconductor supply chain is mainly divided into upstream, midstream, and downstream suppliers and manufacturers. Taiwan plays a key role in midstream IC wafer fabrication and downstream IC assembly and testing. One of the keys to Taiwan's semiconductor manufacturers is the leading players in midstream and downstream production. These companies have developed

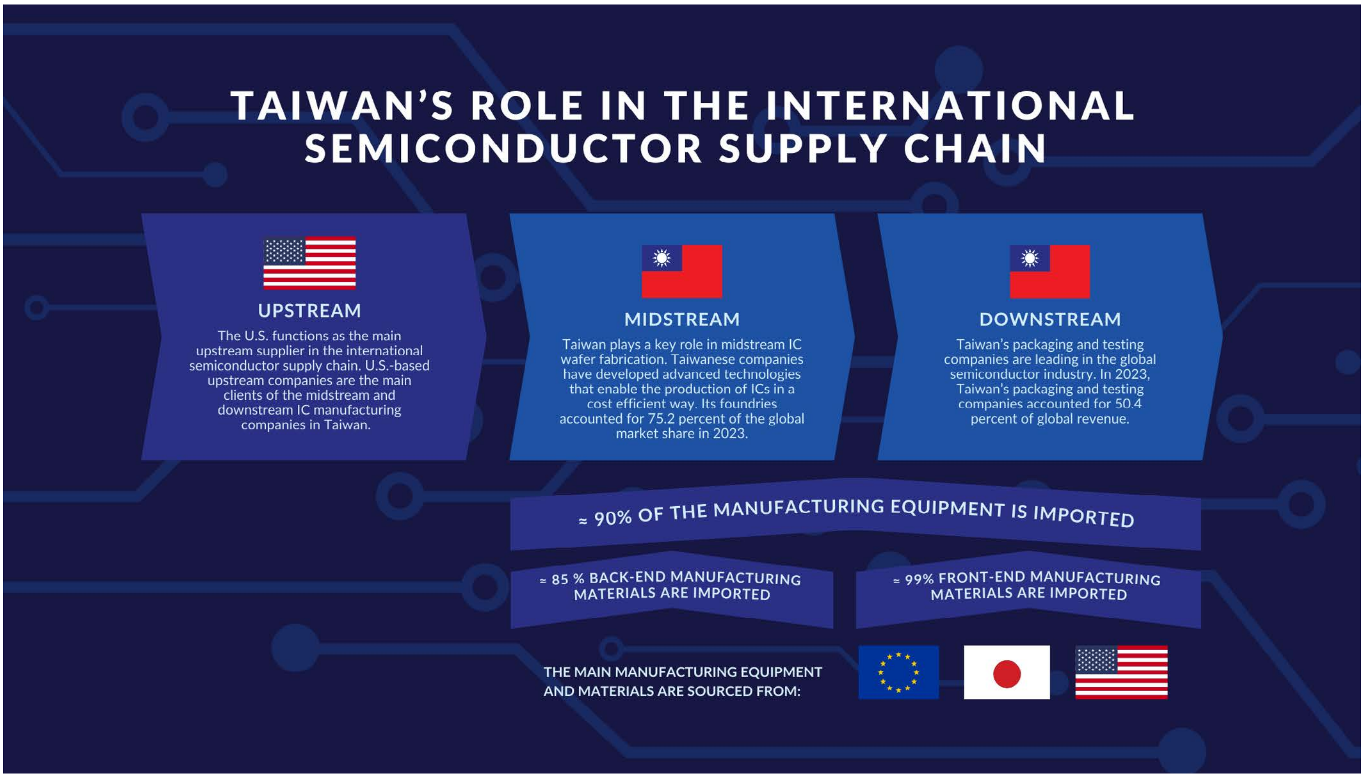

Figure 3. Taiwan's Role in the International Semiconductor Supply Chain

advanced technologies that enable the production of ICs from larger wafer sizes, whilst also reducing production costs, increasing yield, and improving the performance and power efficiency of the ICs.[29] Apart from midstream and downstream operations, the U.S. functions as the main upstream supplier in the international semiconductor supply chain. It focuses on IC design and accounted for around 71 percent of the global market share in 2023.[30] The U.S.'s IC design industry leads cutting-edge innovation in the global market. Except for MTK, other major IC design companies, such as Nvidia, Advanced Micro Devices (AMD), Qualcomm, Broadcom, and Intel, are all based in the U.S. As upstream companies, they are the main clients of the midstream and downstream IC manufacturing companies in Taiwan.

Except for IC design, IC manufacturing, and IC assembly and testing, sustaining a semiconductor supply chain requires the supply of raw materials and manufacturing equipment. Taiwan's manufacturers need to import raw materials, such as raw wafers, chemicals, photoresists, and gases, from foreign suppliers, such as the U.S. and Japan.[31] According to statistics in the second quarter of 2022, the self-sufficiency rate of semiconductor manufacturing materials in Taiwan is 1 percent in front-end manufacturing and 15 percent in back-end manufacturing.[32] Taiwan also imports a significant amount of manufacturing equipment from the U.S., the Netherlands and Japan.[33] The U.S., Europe, and Japan are the main semiconductor manufacturing equipment suppliers in the international semiconductor supply chain.[34] The equipment they export includes extreme ultraviolet lithography systems, physical vapor deposition and chemical vapor deposition systems, wafer cleaning systems, etc.[35] In 2022, Taiwan's domestically produced equipment only accounted for 10 percent of the equipment used in production.[36] Taiwan is dependent on importing raw materials and manufacturing equipment. It can, therefore, be concluded that even though Taiwan plays a key role in the global semiconductor supply chain and is considered the world leader in this technology, its industry is to a high extent integrated in the global supply chain, and dependent on other countries.

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