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DEVELOPMENTS IN THE COMPETITION FOR SUPREMACY IN THE FIELD OF ADVANCED SEMICONDUCTORS

— WHO WILL CONTROL "THE NEW OIL" IN THE 21ST CENTURY? —

Rieko Tsuji
Consumer Innovation Dept., Technology & Innovation Studies Div.
Mitsui & Co. Global Strategic Studies Institute

SUMMARY

- The conflict between the US and China is intensifying over advanced semiconductors, which are key strategic materials that support AI and digital technologies. The US is strengthening domestic manufacturing by offering subsidies and is trying to restrain China with regulations. Meanwhile, China is promoting domestic production with massive investments.

- A Chinese company surprised the world by successfully manufacturing semiconductors through a 7-nm process[1], but it faces challenges in moving toward mass production. The manufacture of advanced semiconductors requires leading-edge technological capabilities, and it is unlikely that Chinese technology will catch up with that of the US in the space of a few years.

- In semiconductor production, while Taiwanese and South Korean companies are expected to continue to dominate, the US and Japan are also making strides, and market shares are likely to gradually become less concentrated in certain countries. As China's presence in legacy areas[2] makes full decoupling difficult, competition is forecast to persist under mutual interdependencies.

1. ADVANCED SEMICONDUCTORS AND THEIR POSITIONING

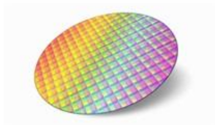
1-1. Semiconductor supply chain

Semiconductors are strategic materials used in a broad variety of applications, from consumer products like smartphones and personal computers to defense equipment such as fighter jets. Advanced semiconductors are semiconductors micro-fabricated using the most advanced processes, generally 16-nm or smaller processes, and are used in chips for smartphones, CPUs for PCs, and GPUs for AI processing, and play a vital role in supporting the foundations of the digital society. Countries are competing over the development and production of advanced semiconductors, and industrial policies and export controls are being formulated with the aim of taking the lead on both the economic and security fronts. To date, the supply chain for semiconductors, including advanced semiconductors, has been based on an international division of labor.

[1] Process refers to the sequence of steps in which electronic circuits such as transistors and wiring are formed using silicon wafers as substrates to ultimately manufacture chips and is used as an indicator of how finely the circuits are arranged. It is often used in the sense of "XXnm process". In the past, the numerical part of XXnm corresponded to the width of electronic circuit lines (circuit line width), but in recent years, it no longer always represents the actual circuit line width because of the introduction of three-dimensional structures for miniaturization and other factors.

[2] Legacy areas are fields for which semiconductors are manufactured with relatively old technology and often refers to semiconductors manufactured using processes with circuit line widths of 28 nm or greater.

Figure 1: Semiconductor manufacturing process and the supply chain

Process stage and business type	Logic design by Fabless	Manufacturing by Foundries	Assembly, packaging and testing by OSAT
Process description	Based on the desired functionality, the circuit layout is designed and refined through repeated simulations. The optimized pattern is transferred onto a transparent glass substrate to produce a master.	Electronic components such as transistors are fabricated on the surface of a silicon wafer, which is cut from a monocrystalline silicon ingot.	The wafer is diced, and each chip is separated and fixed in a designated position on a frame. It is then electrically connected to other components and encapsulated. Finally, inspections are conducted for performance and appearance
Image			
Countries/Regions with strength (Major players)	US (Intel, Qualcomm, AMD, NVIDIA)	Taiwan (TSMC), South Korea (Samsung)	Asia (leading OSAT companies in Taiwan, China, and Southeast Asia), US (Amkor)

○ EDA tools vendors for semiconductor design: The US has competitive edge in this field; the top three EDA vendors are US-based companies
○ Semiconductor IP vendors: the US maintains a strong position in this area

○ Semiconductor equipment manufacturers: Japan, the US, and the Netherlands are strong in this area
○ Semiconductor materials: Japan has strength in this area, with a high market share

Source: Compiled by MGSSI

The semiconductor production flow can be divided into three main stages (Figure 1): Design; Manufacturing; and Assembly, Packaging, and Testing. US fabless companies[3] occupy a prominent position in the Design stage, while Taiwanese and South Korean companies lead in Manufacturing as major foundries[4]. In the Assembly, Packaging, and Testing stage, many leading OSATs[5] have established bases in Taiwan, China, and Southeast Asia, taking advantage of lower labor costs and efficient mass production systems. In addition, a broader range of countries contributes technologies, equipment, and materials essential to each stage. The US is strong in EDA[6] and IP[7] vendors required for design, while Japan, the US, and the Netherlands are competitive in manufacturing equipment. Japan has also established itself as a global leader in semiconductor materials. Thus, the industry has evolved through a sophisticated division of labor that leverages the strengths of each country.

In recent years, however, geopolitical risks have emerged, and the fragility of supply chains has become apparent. Thus, countries have begun to restructure their supply chains. Against the backdrop of US-China trade tensions, the movement toward decoupling in this area is gaining momentum.

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[3] Fabless refers to a business model or company that does not have its own semiconductor manufacturing plant and specializes in product planning, design, development, sales, etc.
[4] A foundry is a company that specializes in the manufacture of semiconductors on consignment from semiconductor manufacturers and fabless companies.
[5] OSAT stands for Outsourced Semiconductor Assembly and Test and refers to companies that specialize in undertaking back-end processes such as assembly and packaging.
[6] EDA stands for Electronic Design Automation tools, a generic term for software and hardware to streamline the design of integrated circuits and semiconductor devices.
[7] IP is an acronym for Intellectual Property. In the semiconductor industry, companies that develop, license, and sell design assets that function as part of a chip are called IP vendors.

2. US AND CHINESE STRATEGIES

2-1. US strategy

The US is developing an aggressive policy based on two approaches: strengthening its own semiconductor manufacturing platform and preventing China from acquiring advanced technologies. First, as a measure to nurture domestic industry, the US enacted the CHIPS and Science Act (commonly known as the CHIPS Act) in August 2022, establishing a framework to provide US$39 billion in subsidies over the subsequent five years for the construction and expansion of advanced semiconductor manufacturing facilities and US$11 billion for R&D. It also introduced a 25% tax credit to promote private investment, which has caused not only US companies, such as Intel and Micron Technology, but also foreign companies, including Taiwan Semiconductor Manufacturing Company (TSMC, Taiwan) and Samsung (South Korea), to decide to build large-scale factories in the US. However, there is a rule prohibiting subsidy recipients from increasing production of advanced semiconductors in "countries of concern," such as China, for 10 years, and this has impacted the strategies of Samsung and other companies with bases in China. The US government aims to bring back advanced semiconductor manufacturing to the US and secure dominance over China through a combination of massive financial support and regulatory controls.

For example, TSMC has been offered up to US$6.6 billion in subsidies under the CHIPS Act, and the company's plans call for the construction of a second plant (3-nm process) and a third plant (2-nm or smaller process)[8] in the US state of Arizona, in addition to the first plant (4-nm process) that has already begun operations there. In addition, in March 2025, the company announced the construction of three additional advanced manufacturing plants, two packaging facilities, and one R&D center. This brings TSMC's investment in Arizona to US$165 billion, the largest foreign direct investment in US history. The subsidies will be used to form an advanced semiconductor industrial cluster in the US and revive semiconductor advanced process mass production, with the aim of ensuring a stable supply of 2-nm chips, the key to future industries in the fields of AI and high-performance computing (HPC).

At the same time, the US government is focusing on containing advanced technology transfers to China through export controls. In October 2022, the Biden administration significantly tightened restrictions on exports to China, imposing comprehensive restrictions on supplies of advanced semiconductors and the equipment and design software used for manufacturing those chips. As a result, the export of advanced semiconductors and equipment made in the US or containing US technology to China was effectively prohibited, and China's advanced semiconductor manufacturing industry suffered a major blow. In addition, the US is working with the Netherlands and Japan to form a network to limit China's access to cutting-edge chip technology. The Dutch government, under pressure from the then-Trump administration in 2019, restricted exports to China of ASML's state-of-the-art extreme ultraviolet (EUV) lithography equipment for semiconductor manufacturing, and has since expanded the export restrictions to include a range of technologies in the manufacturing process, including deep ultraviolet (DUV) lithography equipment and inspection equipment. In March 2023, the Japanese government announced its plan to add 23 items of advanced semiconductor manufacturing equipment to the export control list, making equipment for cleaning, deposition, and annealing, which were not previously controlled by restrictions, subject to a permit system (Figure 2). Through these coordinated actions by Japan, the US, and the Netherlands, China's access to cutting-edge equipment, which is essential for domestic production of advanced semiconductors, is being closed off.

[8] It is said that the second plant will be operational in 2028, and the third plant around 2030.

Figure 2: Semiconductor manufacturing equipment subject to the Japanese government export controls

Semiconductor equipment subject to export controls	Details
Cleaning equipment	Devices for removing foreign substances from wafer surfaces and for resist stripping
Deposition equipment	Devices for forming semiconductor films using methods such as CVD and ALD
Annealing equipment	A thermal treatment device that heats wafers to diffuse impurities and improve film properties
Lithography equipment	Devices for imprinting circuit patterns (including EUV lithography machines and high NA lithography machines such as ArF immersion)
Etching equipment	Devices that perform fine processing using plasma, such as dry etchers and ion milling machines
Inspection/measuring equipment	Equipment necessary to ensure high product quality, such as wafer visual inspection system, pattern dimension measurement SEM, mask inspection system, etc.

Source: Compiled by MGSSI

2-2. Chinese strategy

China's long-term national strategy is to increase the domestic production and self-sufficiency of semiconductors, and it continues to invest heavily in this area. Its core policy is "Made in China 2025," announced in 2015, which set a goal of achieving 40% self-sufficiency in the semiconductor sector by 2020 and 70% by 2025. As a specific measure, the China Integrated Circuit Industry Investment Fund, a government-led initiative established to promote China's advanced technology industry, injected RMB 140 billion (approximately 2.8 trillion yen) in 2014 for the first phase and RMB 200 billion (approximately 4 trillion yen) in 2019 for the second phase into a group of semiconductor companies. Under such generous support, Chinese companies have been nurtured in various segments of the semiconductor supply chain, including the fields of memory and logic devices[9], equipment, and materials.

Of particular note are developments in the field of advanced logic semiconductors by Semiconductor Manufacturing International Corporation (SMIC), China's largest foundry company, and telecommunications equipment giant Huawei. Huawei has been exploring domestic production in collaboration with its own design subsidiary HiSilicon and SMIC, and the result is the 7-nm process Kirin 9000S chipset installed in Huawei's new Mate 60 Pro smartphone, which was announced in August 2023. This development shocked the world as the emergence of high-end chips made in China that have circumvented the US semiconductor blockade, and according to CNN, the US Department of Commerce immediately set out to collect detailed information. As SMIC has been unable to obtain EUV lithography equipment, it is said to be realizing circuit patterns equivalent to a 7-nm process through multi-patterning using DUV lithography equipment. As a result of the increase in the number of exposure processes compared to normal, production efficiency and yield significantly decrease, leading to costs that are 40-50% higher compared to TSMC's manufacturing of the same process, and it is said that production yield is inferior by roughly one-third. Considering that TSMC began mass production of its 7-nm process in 2019, it is believed that SMIC is still more than five years behind.

So, how will China fill this technology gap in the future? The key to this is the 5-nm challenge. SMIC is developing its own 5-nm process and is reportedly aiming to complete development of 5-nm chips by around 2025. However,

[9] Memory and logic devices are types of semiconductors. Memory chips are used to store data and logic devices are used to perform advanced operations and control functions and include CPUs and GPUs. Other examples include power semiconductors, which are indispensable for such things as air conditioners and automobiles and handle large voltages and electric power.

further process complexity is inevitable for scaling down to 5 nm with multiple exposures. The fundamental challenge is still China's inability to obtain EUV lithography equipment. The Chinese authorities are aware of this point and are rushing to produce EUV lithography equipment domestically. According to media reports, Huawei-affiliated research institutes and optical machinery manufacturers are developing prototypes, and the first EUV lithography system in China may be put into test operation in the third quarter of 2025[10].

3. FUTURE OUTLOOK

3-1. US-China decoupling and supply chain fragmentation

The fragmentation of supply chains is impacting corporate strategies. Semiconductor manufacturers are under pressure to review their portfolios of production sites and sales destinations, while keeping a close eye on regulations and incentives in both the US and China. For example, although Samsung has a large-scale chip factory in China, it is reportedly developing a plan to reduce its dependence on China in the medium to long term and, instead, obtain an exemption to US export controls through negotiations with the US government. TSMC is also diversifying its investments to the US and Japan markets.

There has been a rush to build new semiconductor plants around the world as a result of governments' massive budgetary allocations to strengthen their own semiconductor industries in the interest of economic security, and production bases that were previously concentrated in Taiwan, South Korea, and China are now being distributed to other countries to a certain extent. At the same time, the intensive investment competition among countries also poses the risk of creating oversupply in the future.

3-2. Prospects going forward

Figure 3: Countries' market shares of the advanced semiconductor global production capacity

Country/Region	Market share in 2023	Market share in 2027 (estimate)
Taiwan	68%	60%
South Korea	12%	13%
US	12%	17%
Japan	0%	4%
Mainland China	8%	6%

Source: Compiled by MGSSI based on Voronoi data

Figure 3 shows the countries' current and projected shares of global production capacity of advanced semiconductors. At present, mainland China accounts for no more than approximately 8% of the market, and even in the medium to long term, progress in advanced fields is expected to be limited due to regulations. Meanwhile, the US is expected to gradually increase its market share, supported by the CHIPS Act, to produce approximately 17% of the world's advanced semiconductors by 2027. Japan is also projected to achieve a market share of about 4% through mass production by Rapidus, but the situation in which TSMC and Samsung remain the major suppliers of advanced processes is still the most likely scenario. During this period, China will likely be shifted to focus on legacy areas that use mature technology rather than cutting-edge technology, and the Chinese government is reportedly shifting its strategy to expand its market share in this area. With Western regulations blocking China's advancement into leading-edge technology fields, if China further strengthens its presence in legacy areas, there is a risk of increased dependence on China in these areas.

[10] The third quarter refers to July-September, based on the Chinese fiscal year.

In general, a prolonged tug-of-war between the US and China in the semiconductor industry is inevitable. Although each country is establishing a system favorable to itself through massive investment and institutional design, complete decoupling is unrealistic, and a "New Cold War" structure is taking root in which competition and restraint continue, leaving rather complex interdependencies. In this context, it is important for Japan to establish an advanced technological foundation based on Rapidus and to maintain its strength in both the equipment and materials fields. Semiconductors are being called "the new oil" in the 21st century, not only because of their economic value but also because they are a strategic commodity that will determine the fate of nations. The competition for supremacy in the field of advanced semiconductors, revolving around a showdown between the US and China, will continue, and countries and companies will be tested on their wisdom and cooperative relationships to weather the stormy seas.