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Exploration of International Division of Labor Model for Semiconductor Industry Development

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Abstract: Semiconductor design and manufacturing capabilities have become a significant indicator to measure a country's scientific and technological level. Currently, China's semiconductor industry is experiencing accelerated growth, but it still faces challenges such as low localization rates, inadequate long-term industry support and investment, limited independent innovation by enterprises, weak upstream and downstream collaboration, and insufficient talent cultivation and incentive mechanisms. This paper will carefully analyze the developmental traits of the worldwide semiconductor industry as well as its foremost enterprises, investigate the model of global specialization, and propose pertinent developmental suggestions concerning the crucial challenges confronting the domestic semiconductor industry at present.

Keywords: Semiconductor; International division of labor model; Industry.

1. Introduction

With China's increasing openness to the global market, the impact of international specialization and its progress on the growth of China's semiconductor industry has gained significant significance, and the semiconductor industry is a strategic industry of great importance to the national economy, it is, moreover, a core industry that supports the construction of China's "dual circulation" development pattern. On one hand, the semiconductor industry is supported by the domestic economy and its products are extensively utilized in various sectors, including communications, automotive, and E-commerce, establishing a solid hardware basis for the advancement of China's digital economy; on the other hand, the semiconductor industry is supported by the global economic cycle, and China's domestic semiconductor enterprises are closely integrated into the global semiconductor industry and innovation chain, rapidly advancing towards the middle and high end of the global semiconductor value chain.

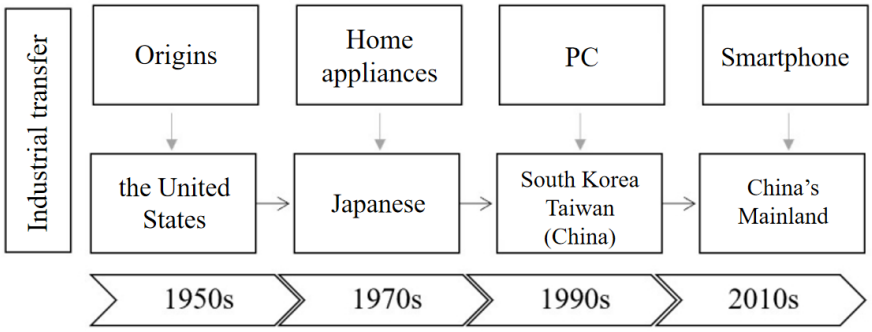

Figure 1. Transfer of Semiconductor industry

2. Concept of The Semiconductor Industry

The semiconductor industry is a part of the electronics industry that is primarily focused on hardware development, particularly in the field of semiconductors. These semiconductors find widespread applications in various fields including integrated circuits, consumer electronics, communication systems, photovoltaic power generation, lighting, high-power conversion. Semiconductors are of immense importance, both in terms of science, technology, and economic development. They play a crucial role in most electronic products, such as computers, mobile phones, and digital recorders, forming a critical component of their core units. Common semiconductor materials are silicon, germanium, gallium arsenide and others, silicon is a variety of semiconductor materials used in the most influential one. Since the 1950s, the semiconductor industry has become a driving force in promoting the global science and technology industry, as well as enabling various technological advancements. Semiconductors serve as underlying support for electric drives, signal transmission, photoelectric conversion, and data processing. This technology has led to the rapid development of integrated circuits, wireless communications, solar cells, LED lighting, new energy vehicles, and has significantly transformed the production and lifestyle of individuals worldwide. The design and manufacturing capacity of semiconductors are important indicators of a country's scientific and technological prowess.

3. Current Status of The Development of The Semiconductor Industry

3.1. Large domestic demanding

In recent years, aided by advancements in science and technology, China has spearheaded the shift towards a more sustainable model of economic growth and restructuring. As a result, the consumption of information has emerged as a

pivotal catalyst in promoting China's steady economic progress. As early as 2013, China has issued the "State Council on accelerating the promotion of information consumption to expand domestic demand"[1] requiring the enhancement of the supply capacity of information products, and cultivating information consumption demand. The demand for information consumption is closely related to the semiconductor industry, and the domestic semiconductor market demand and industry scale are rapidly expanding under the strong support of the government. According to data from IcInsights, in 2010 the size of China's semiconductor market and the scale of domestic semiconductor production were $57 billion and $5.8 billion, respectively. The domestic rate of semiconductor production was only 10.2% at the time. Since then, China's semiconductor market size and production capacity have consistently increased. As of 2021, the size of China's semiconductor market is $187 billion with a domestic semiconductor product size of $31.2 billion, and the domestic rate of semiconductor products has reached 16.7% (see figure 2)[2]. Based on this data set, it is evident that China's semiconductor industry market size and production capacity have been increasing over the past 11 years. However, despite this growth, the current domestic semiconductor production capacity is still insufficient to meet the country's demand. According to the China Semiconductor Industry Association's statistics (see figure 3) [3], the projected sales for China's semiconductor industry in 2021 are 1,045.8 billion yuan, with design industry sales comprising 451.9 billion yuan; the manufacturing sales amount to 317.6 billion yuan, while the packaging and testing industry shows sales of 276.3 billion yuan, establishing China as the world's largest semiconductor market. The immense demand for semiconductors indicates that China's semiconductor industry holds vast potential for market growth. Additionally, being in close proximity to the domestic market has the added benefit of minimizing production costs, making it a crucial foundation for the new stage of development in China's semiconductor industry breakthrough.

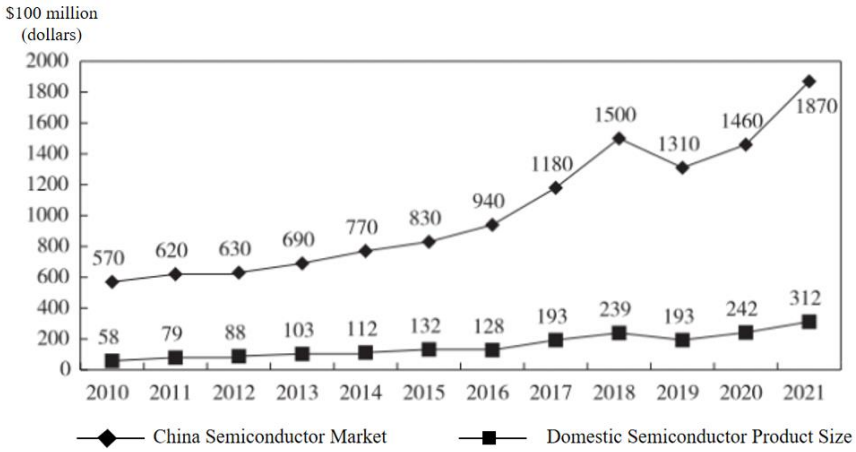

Figure 2. China Semiconductor Market Size and Domestic Semiconductor Product Size, 2010-2021

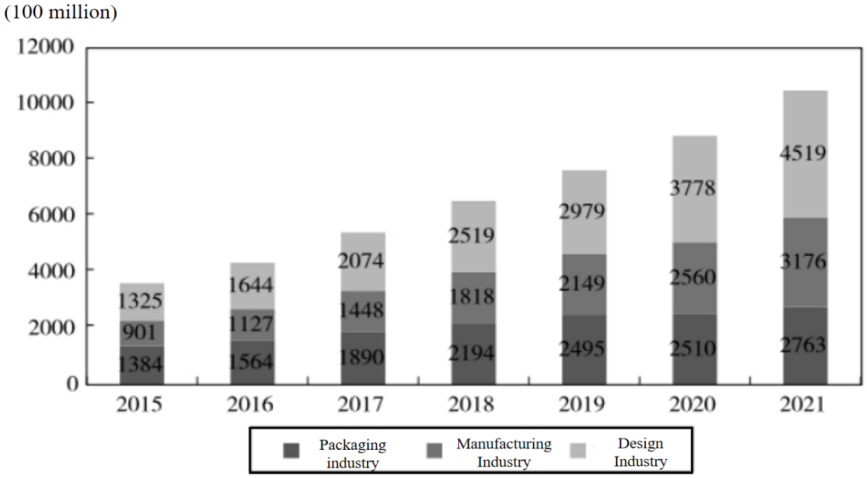

Figure 3. Scale of China's Semiconductor Industry, 2015-2021

3.2. Enhanced policy support

With increasing maturity in the semiconductor industry, the competitive landscape has undergone significant changes. Various countries, including the USA, Europe, Japan, and South Korea, have introduced intensive policies to promote the sector's growth, such as the CHIPS Act, Semiconductor Digital Industry Strategy, K-Semiconductor Belt, among others. Semiconductor industry in our Country is still in a catch-up position, according to data released by the U.S. Semiconductor Industry Association (SIA). In terms of the value of the annual semiconductor industry in 2021, the U.S. accounted for 46%, South Korea accounted for 21%, Japan and Europe accounted for 9% each, and China accounted for only 7%. Therefore, to achieve a breakthrough, it is important to have support from industrial policies. In fact, as early as 1956, China would develop semiconductor technology as one of the country's four major emergency measures, clearly proposed to develop the semiconductor industry at the state level. After decades of arduous exploration, China's semiconductor industry is gradually on track, 2000 to the present, China has continued to introduce a series of policies

to support the development of the semiconductor industry, from the finance and taxation, research and development, human resources, intellectual property rights, imports and exports and the market and other aspects of the semiconductor industry to further increase the support for the semiconductor industry, and to cultivate a number of strength and influence of the integrated circuit industry enterprises. Based on national policies, local governments have implemented corresponding measures to provide targeted support for the development of the semiconductor industry. These measures aim to provide favorable conditions for industry growth at all levels.

3.3. Deep integration of technology and capital

After years of diligent research, China's level of semiconductor technology has significantly elevated, along with the financing amount, providing a sound basis for the advancement of China's semiconductor industry. In particular, the semiconductor industry in China has made significant advancements in technology, which has greatly contributed to the overall development of the industry in the country. The technical capabilities achieved in this sector provide a solid foundation for future growth and expansion of China's semiconductor industry. Patent is an important indicator of technological innovation, and according to the "2019 Global Semiconductor Technology Invention Patent Ranking (TOP100)" released by IPRdaily and incoPat Innovation Index Research Centre, the top ten companies on the list mainly came from seven countries and regions. Among them, Japan ranked first with a share of 38%, followed by China with 27%, then the US (19%), South Korea (6%), Germany and the Netherlands (both with 4%), and Switzerland (2%). On the other hand, the amount of financing for semiconductors in China has increased significantly, providing solid financial support for the development of China's semiconductor industry. According to QICHACHA Tech Co., Ltd., China's semiconductor industry has witnessed 3,169 investment and financing events since 2011, with a total amount of investment and financing exceeding 602.5 billion yuan. Since 2014, investment and financing activities in the semiconductor field have significantly increased, with 187 investment and financing events and a total amount of over 35.3 billion yuan achieved in the same year. The chip semiconductor industry witnessed a total amount of 2015 billion yuan of investment and financing in 2017, the highest peak in a decade. 2015 billion, the highest peak in ten years. In 2021, China's semiconductor industry received a total of 80 A-round and Pre-A round financings, accounting for approximately 34% of all financings. There were 232 investment and financing events, with a total value of 76.704 billion yuan. [4] Investment and financing in the chip semiconductor sector exceeded amounts and quantities of the past four years. Overall, funding and project numbers in the semiconductor industry have shown a consistent upward trend, bolstering large financial support for high-quality development and accumulating strength for breakthroughs in China's semiconductor industry.

4. Exploring the International Division of Labor Model for the Development of the Semiconductor Industry

4.1. Integrated device manufacture (IDM) Model

The IDM (integrated device manufacturer) model incorporates chip design, chip manufacturing, chip packaging, testing, and other manufacturing processes. This model was predominantly used by early integrated circuit enterprises, and due to its high costs, only a few companies, such as Samsung and Texas Instruments (TI), opted to use it. The advantage of the IDM model is that it permits synergistic optimization of design, manufacturing, and other links, which is conducive to fully exploring the potential of technology. Moreover, it allows companies to lead in experimenting with and implementing new semiconductor technologies. For instance, the FinFET chip is a product of the IDM model. The disadvantage, however, is that the large size of the enterprise often results in high management costs and operating expenses, which can lead to a low return on invested capital and high risk.

4.2. Fabless chip supplier (Fabless) Model

The fabless chip supplier model is only responsible for the circuit design and sales of the chip, and outsources the production, packaging, testing and other aspects of the chip to other companies, this pattern, was utilized by enterprises such as HiSilicon, MediaTek (MTK), Broadcom, and others. The advantages of such a fabless chip supplier model are asset-light operation, smaller initial investment, lower operating costs, and relatively flexible transformation; however, their co-optimization is more unaccessible compared to IDM, that's one of the disadvantages, so it is difficult to complete the design with the stringent indicators; knowing that once the fault occurs, the companies and enterprises are bound to suffer severe losses, and bear a higher-level of various risks compared to the Foundry model. [5]

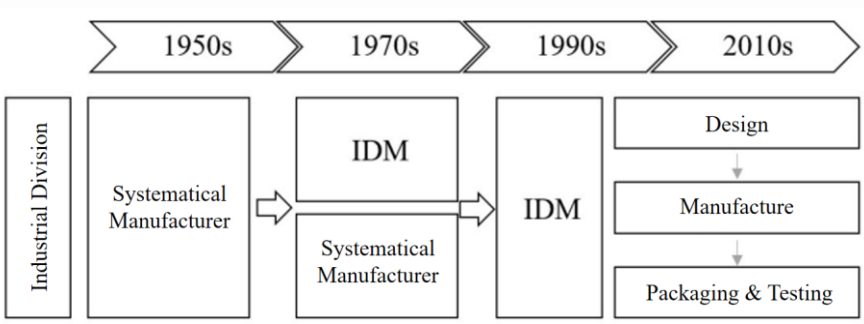

Figure 4. Evolution of business division patterns in the global semiconductor industry

4.3. Foundry model

Enterprises under the foundry model are not responsible necessarily for chip design, but only for manufacturing, packaging or testing, and can provide services to multiple

design companies at the same time, but this pattern is very much at the mercy of the competitive relationships among customers, which is represented by SMIC and TSMC. The foundry model offers the advantage of alleviating the risks associated with inaccurate market research and product design defects. However, there are several drawbacks to this model, including the substantial investment required for large-scale production, high costs for maintaining the production line, and the need for continual investment in R&D to maintain technological superiority. Falling behind in technology can be challenging to overcome once it occurs (As show in table 1).

Table 1. Comparison of different business models in the semiconductor industry [6]

	IDM	Fabless	Foundry
Features	An all-in-one mode includes chip design, chip manufacturing, chip packaging and testing and other manufacturing processes; early adopted by most integrated circuit enterprises, at present, only a few companies choose this model, due to the high cost.	Responsible for circuit design and sales of chips; outsourcing production, testing and packaging.	Special tache for manufacturing, packaging or testing, chip design is not included; providing products for multiple companies at the same time, but it's easy to be subject to competitive relationships between customers.
Advantages	Synergistic optimization of design, manufacturing and other processes helps to fully exploit technical potentials power.	Asset lightness makes it relatively less difficult to start a business; low operating expenses and relatively flexible for transition.	No decision-making risks due to market research, product design, and others. to be assumed.
Disadvantages	Large business size and high overhead costs; high operating expenses and low return on invested capital.	Compared to IDM, there is no way to optimize with the process to achieve demanding designs, and compared to Foundry, there are various market risks to be taken.	Large investment scale, high cost for maintain the normal operation of the production line; the need for continuous R & D investment to maintain the level of technology, once fall behind, is of great difficulty to catch up.
Representative companies	Samsung, Texas Instruments (TI)	HiSilicon, MediaTek (MTK), Broadcom	SMIC TSMC

4.4. Shared commons CIDM model

The CIDM model enables the delivery of superior products to end-users by seamlessly integrating chip design (of the essential component for integration), R&D of chip process technology, chip manufacturing, and chip packaging and testing businesses. Specific practice refers: through the establishment of joint ventures in the form of multi-party integration, IC design companies, IC manufacturers, end-use enterprises is able to participate in the project investment. Advantages such as, the production capacity and technical support for IC design companies provided by IC manufactures; reduction on product sales' uncertainty of the direct docking between IC manufactures and end-customers can be achieved under this mode, guarantee of which can improve the efficiency of product design, and ultimately realize the resources sharing, capacity synergies, capital and risk-sharing.

5. Conclusion

The disadvantage faced by latecomers is especially apparent in the semiconductor industry due to its rigorous exclusionary policies, the high degree of innovation coherence at the product level, and the guarded nature of knowledge at the technology level. This paper contends that China possesses the world's largest unified market, and the robust development of local industries including household appliances, electronics, communications, intelligent automobiles, and others, coupled with the extensive promotion of Internet of Things and cloud technologies, solidifies China's position as the world's foremost chip market. Moreover, rather than exclusively focusing on technological innovation, latecomers should prioritize innovation of their business models. China must actively participate in the global semiconductor industry chain and accelerate the establishment of a domestic semiconductor industry chain.

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