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АНАЛИЗ И ПЕРСПЕКТИВЫ РАЗВИТИЯ ПОЛУПРОВОДНИКОВОЙ ПРОМЫШЛЕННОСТИ КИТАЯ

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Полупроводниковая промышленность является стратегической и ведущей в Китае. Стране необходимо воспользоваться возможностью для содействия дальнейшему развитию полупроводниковой промышленности. В исследовании собраны соответствующие данные о полупроводниковой промышленности Китая с 2014 по 2021 г., выбраны четыре основных фактора для создания регрессионной модели, выполнено ее тестирование. Проведенный анализ позволяет сделать вывод о том, что ключевыми факторами, влияющими на развитие полупроводниковой промышленности Китая, являются инвестиции в научно-исследовательские и опытно-конструкторские работы и промышленная агломерация. Исходя из этого, Китай должен сосредоточиться на указанных аспектах для содействия развитию полупроводниковой промышленности.

Ключевые слова: полупроводники; чипы; полупроводниковая промышленность; экосистема; факторы, влияющие на развитие.

THE ANALYSIS AND DEVELOPMENT PROSPECTS OF CHINA'S SEMICONDUCTOR INDUSTRY

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Semiconductor industry, as the basis of autonomy and controllability, is a strategic and leading industry of the country. China needs to seise the opportunity to promote the further development of the semiconductor industry. This article collects the relevant data of China's semiconductor industry from 2014 to 2021, selects four influencing factors to establish a regression model, and tests and revises the model. After analysis, it is concluded that the key factors affecting the development of China's semiconductor industry are research and development work investment and industrial agglomeration, and China should focus on these two aspects to promote the development of the semiconductor industry.

Keywords: semiconductors; chips; semiconductor industry; ecosystem; development factors.

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Introduction

With the strengthening of economic globalisation and the acceleration of the process of knowledge creation, countries around the world are accelerating the development of industries with high-tech content and high added value to optimise the industrial structure and promote national economic development. The semiconductor industry belongs to the electronic information industry and it is the foundation of the information age [1].

The semiconductor industry, which originated in the late 20th century, has become one of the most important components of the global economy. Nowadays, almost every electronic device has semiconductors, including mobile phones, automobiles and household appliances. Semiconductors have enabled almost every industry, with global sales exceeding 440 bln US dollars in 2020 alone[1].

Looking back on the growth of the United States, it is in the third industrial revolution to seise the opportunity to become the global centre of the information civilisation stage. The rise of the United States highlights the importance of scientific and technological strength to a country. Scientific and technological strength can greatly enhance a country's political status in the international arena.

Today, semiconductor companies are producing more chips than ever before. The success and growth of computers and software subsequently fueled the growth of the semiconductor industry. The US semiconductor industry is huge, directly contributing 24.6 bln US dollars to US GDP and directly employing 277 000 workers in 2020 (semiconductor companies)[2].

However, the economic contribution of the semiconductor industry goes far beyond the value brought by its design and production. Strong demand for all types of chips has fueled the need for a broader ecosystem of domestic support, including manufacturing equipment, materials, design services, test labs, and research and development activities. This ecosystem creates activities that generate added economic value throughout the US economy. The need to expand semiconductor research and development work (R&D), design, and manufacturing in the United States is greater than ever. By supporting the expansion of the semiconductor industry in the United States, almost all other industries in the United States will benefit. Whether the demand for semiconductor equipment, tools and materials increases or the supply of chips to downstream industries is more stable, semiconductor R&D, design and manufacturing are an integral part of the US economy.

In fact, it is estimated that more than 300 different downstream industries buy products from the US semiconductor industry and thus receive support from the US semiconductor industry. This is done by tracking the purchase of semiconductors as inputs for the production of other products – including aircraft manufacturing, automotive manufacturing and printing, design services, testing laboratories and research and development activities. This ecosystem created activity generates additional economic value throughout the US economy.

The semiconductor industry has a considerable economic contribution in the United States. In the 49 states of the country, nearly 27.7 mln people work in this industry, engaged in design, manufacturing, testing, and research and development[3]. The semiconductor industry's buying from suppliers in the manufacturing process (i. e., indirect influence) has further invigorated activity throughout the United States, sustaining thousands of jobs nationwide[4]. Finally, wages paid to employees and supply chain employees fund consumer spending (i. e., inducement effects), such as in retail and leisure establishments, and provide additional economic benefits to the state.

The trend of digitalisation has led to an increase in silicon content in various products. Semiconductors have driven advances in communications, computing, health care, military systems, transportation, clean energy, and countless other applications. They have spawned new technologies that promise to change society for the better, including brain-like computing, virtual reality, the Internet of things, energy-efficient sensing, automated devices, robotics and artificial intelligence. As the application scenarios of semiconductors become more and more abundant, semiconductors are linked with more and more industries, which is the fundamental reason why semiconductors can drive trillions of markets.

The development of the semiconductor market may be affected by many factors, for example, the epidemic has led to more and more common scenarios of working and studying at home, which has promoted consumer demand for electronic products, thus increasing the demand for related semiconductor products. Another obvious example is that after the development of automobiles towards intellectualisation, the demand for automotive chips is increasing from type to function. As we all know, the serious shortage of automotive semiconductors has forced many car factories to raise prices and stop production.

[1] Why should China develop semiconductors? [Electronic resource]. URL: https://baijiahao.baidu.com/s?id=1738408465759410631&wfr=spider&for=pc (date of access: 06.10.2022) (in Chin.).

[2] Ibid.

[3] Ibid.

[4] Ibid.

In addition to the basic role of semiconductors in the process of modernisation, the reason why all countries are actively developing the semiconductor industry chain lies in the driving role of semiconductors in the economy, one of the most direct impacts is the employment problem.

We can see that the landing of semiconductor factories can not only directly increase semiconductor-related jobs to attract semiconductor talents, but also promote employment in other industries. At the same time, due to the multiplier effect, the increase of manufacturing employment will also promote the development of local service industry. In the short term, the construction of a single semiconductor plant can directly stimulate the local construction industry. In the long run, when a region has a certain accumulation in a certain industry, it will attract more related industrial companies to form industrial clusters. Semiconductor industry as a high-tech industry, if a region forms a semiconductor industry cluster, it will attract more top-notch talents, make the region more competitive, and then drive the development of local GDP.

As a strategic pillar industry with high-tech content, its development is conducive to driving national economic development and ensuring national economic security. It has become a strategic area for countries around the world to invest in capital, technology and personnel. All countries in the world hope to seise the opportunity here, so as to adjust the layout of the global industrial chain [2]. Although China's semiconductor industry has achieved a certain degree of development, there is still a big gap with the United States, Japan, Europe and other countries and regions. Only by grasping the key factors affecting the development of China's semiconductor industry and making efforts in all key directions it is possible to better promote the development of China's semiconductor industry.

Semiconductor industry development in China

After years of efforts, especially with the support of major national science and technology projects, China's semiconductor product system has been continuously enriched and improved, forming one of the most complete semiconductor product systems in the world. It not only has strong competitiveness in the low-end semiconductor field, but also gets rid of the passive situation of relying on foreign products in the high-end semiconductor field. The products cover all fields such as digital, analog, digital-analog hybrid, radio frequency, power, computing, storage and connection. The development of China's semiconductor products has gone through a stage from scratch, and is working towards the goal of «from good to good» and «from good to excellent».

Semiconductor market. At the beginning of 2022, the conflict between Russia and Ukraine broke out, causing a sudden change in the international situation, and the new coronavirus mutant also made a comeback at the same time, making the world once again shrouded in the shadow of the virus. Whether it is war or epidemic, it has an indiscriminate impact on the economies of all countries, and the «black swan» has swept across the world. At present, there are many difficulties and uncertainties in the external development environment of China's economic development, but there are still new opportunities under the crisis. Adaption to the changes of the times and grasping the new development opportunities are a challenge faced by enterprises in all industries.

The semiconductor industry is an important driving force for the rapid development of the digital age, and it is also one of the important symbols to measure the comprehensive strength of a country. As the largest semiconductor market in the world, China's domestic semiconductor industry has a bright future under the «two-wheel» drive of good national industrial policy support and downstream demand stimulation.

The year 2021 is the first year of China's 14th five-year plan. Driven by the sound operation of the domestic macro-economy, the domestic integrated circuit industry continues to maintain rapid and steady growth. According to the statistics of China Semiconductor Industry Association, China's integrated circuit industry will break through trillion yuan for the first time in 2021, with sales reaching 1.05 trln yuan, an increase of 18.2 % over the same period. Among them, sales of design industry reached 451.9 bln yuan, an increase of 19.6 % over the same period. Manufacturing sales were 317.6 bln yuan, an increase of 24.1 % over the same period. Sealing and testing industry sales reached 276.3 bln yuan, an increase of 10.1 % over the same period[5].

According to data released by China's National Bureau of Statistics, China's semiconductor integrated circuit (IC) production will reach 359.4 bln pieces in 2021, an increase of 33.3 % over the previous year, more than double the growth rate of 16.2 %[6]. The Semiconductor Industry Association predicts that the share of Chinese enterprises in the global semiconductor market will increase from 9 % in 2020 to 17.4 % in 2024[7], which means that China will become the third largest semiconductor producer in the world after the United States and South Korea. China's integrated circuit is a rare industry in the world with five complete sectors of

[5]Brief analysis of the development status of China's semiconductor industry in 2022 [Electronic resource]. URL: https://zhuanlan.zhihu.com/p/571457857 (date of access: 11.10.2022) (in Chin.).

[6]Ibid.

[7]Ibid.

design, manufacturing, sealing and testing, equipment and materials. At present, China has formed a relatively complete industrial chain, with a large group of enterprises whose quality is constantly improving.

The rapid development of China's semiconductor industry is largely due to the long-term semiconductor investment mechanism. On the one hand, the China's National Integrated Circuit Industry Investment Fund has invested more than 340 bln yuan in the first and second phases, which has supported many growth-oriented enterprises to develop into industry leaders, covering multiple industrial chains of integrated circuits. On the other hand, the opening of the Science and Technology Innovation Board has provided financial support for the growth of enterprises by using the new resource of the market. According to the statistics of International Semiconductor Industry Association, as of 23 June 2022, 66 semiconductor enterprises have been listed on the Science and Technology Innovation Board, accounting for 15.4 % of the total number of listed enterprises[8].

With the huge market demand, the downstream application industry has developed rapidly. Under the background of stable economic growth and favourable policies, the scale of China's semiconductor industry has developed rapidly, from 98.6 bln US dollars in 2015 to 192.5 bln US dollars in 2021, with a compound annual growth rate of 11.8 % [6]. Table 1 presents the sales of China's semiconductors in 2015–2021[9].

Table 1

China's semiconductor market in 2015–2021

Year	Semiconductor sales volume, bln US dollars	Semiconductor equipment market size, 100 mln US dollars
2015	98.6	4.9
2016	107.5	6.5
2017	131.5	8.2
2018	157.9	13.1
2019	144.1	13.5
2020	151.5	18.7
2021	192.5	29.6

With the third transfer of the semiconductor industry, the rapid development of the semiconductor industry in mainland China has led to the development of the semiconductor equipment industry. According to SEMI data, the size of the semiconductor equipment market in mainland China rose from 3.65 bln US dollars in 2011 to 29.6 bln US dollars in 2021[10] (see table 1).

The import and export volume of semiconductor industry. In 2021, while semiconductor production and export maintain high growth, the problem of high dependence on foreign countries in the upstream and middle reaches of China's semiconductor industry still exists. In 2021, only 16 % of China's semiconductors were purchased from China, and it is under great pressure to achieve 70 % of the chip self-sufficiency rate by 2025[11]. In December 2021, a total of 29.94 bln semiconductors were produced in China, up 1.9 % year-on-year. From January to December 2021, China produced a total of 359.43 bln pieces of semiconductors, up 33.3 % year-on-year, which is also higher than the 25.1 % growth rate of the global semiconductor industry[12].

Based on this data, South Korean media said that in 2021, China's semiconductor production capacity may have surpassed Europe and Japan, ranking third in the world, after the United States and South Korea. The two major memory bases, such as Changjiang Storage and Changxin Storage, gained a global share of about 3–4 % in 2021, which has reduced a large number of domestic imports of memory chips[13].

In recent years, China's imports and exports of semiconductors have generally shown an upward trend, with the total import amount reaching 462.3 bln US dollars by 2021, an increase of 23.78 % over the same period last year. Exports reached 202.6 bln, up 34 % year on year[14] (table 2).

[8] Brief analysis of the development status of China's semiconductor industry in 2022 [Electronic resource]. URL: https://zhuanlan.zhihu.com/p/571457857 (date of access: 11.10.2022) (in Chin.).

[9] Analysis of global and Chinese semiconductor market size, sales and import and export in 2021 [Electronic resource]. URL: https://caifuhao.eastmoney.com/news/20220521117348079259 90 (date of access: 11.06.2022) (in Chin.).

[10] Ibid.

[11] China's semiconductor self-sufficiency rate is less than 16 % [Electronic resource]. URL: http://www.iuechina.com/news/zixun/huizhan/72679.html (date of access: 07.10.2022) (in Chin.).

[12] Ibid.

[13] Ibid.

[14] Analysis of global and Chinese semiconductor market size, sales and import and export in 2021 [Electronic resource]. URL: https://caifuhao.eastmoney.com/news/20220521117348079259 90 (date of access: 11.06.2022) (in Chin.).

Table 2

The import and export volume of China's semiconductor industry in 2016–2021

Year	Import volume, bln US dollars	Export volume, bln US dollars
2016	247.0	85.3
2017	280.8	91.0
2018	333.7	111.2
2019	325.1	133.7
2020	373.5	151.2
2021	462.3	202.6

Source: [3].

Although mainland China is accelerating to undertake the third industrial transfer of the semiconductor industry, the self-sufficiency rate of China's semiconductor industry is still low, and it still relies heavily on imports. Since 2013, integrated circuit products have surpassed crude oil to become China's largest import commodity. According to the data of the General Administration of Customs, in 2021, the import amount of China's integrated circuit products reached 432.6 bln US dollars, an increase of 23.6 %, and the export amount was 153.8 bln US dollars, an increase of 31.9 %. The import and export deficit reached 278.8 bln US dollars and is still expanding [3].

As the underlying technology of science and technology industry, the importance and strategy of semiconductor are self-evident. The globalisation and division of labour of semiconductor supply chain also make it play multiple roles in the current international environment [4]. The conflict between Russia and Ukraine once again reflects that modern warfare is a competition in science, technology, economy and other aspects. The electronics industry led by semiconductors has become another new battlefield for countries to confront each other tit-for-tat. The «black swan» events represented by the conflict between Russia and Ukraine, the COVID-19 epidemic and the Sino-US trade war may reshape the semiconductor supply chain system. In this context, countries around the world have raised the semiconductor industry to the level of national security strategy, and China, the United States, Europe, Japan, South Korea and Belarus have issued a large number of relevant policies to support industrial development. Taking Belarus as an example, when the conflict between Russia and Ukraine broke out, many countries and regions led by the US government announced comprehensive sanctions against Russia, and global business giants also took sides. With «AMD», «Intel», «TSMC» and other chip companies announcing the cut-off of supply to Russia, this county's already weak chip industry is even worse. As «TSMC» announced the outage, Belarusian President A. Lukashenko said Belarus was ready to support Russian chip production as an alternative to foreign supplies. However, the largest microprocessor manufacturer in Belarus at present is «Integral» in Minsk, which highest process is only 350 nanometer process products, that can not meet the demand.

In recent years, driven by policies and demands, China's semiconductor industry has developed rapidly, and its technological level and industrial scale have improved, but there is still a certain gap compared with the markets of developed countries such as the United States, Europe, Japan and South Korea [5]. On the one hand, due to the late start and relatively weak foundation, China's semiconductor industry as a whole is relatively backward, and the industrial chain needs to be further improved. At the same time, due to the small overall scale of semiconductor equipment and the short time to pull the parts market, the supporting capacity of semiconductor equipment parts is weak, some core raw materials are still dependent on imports, and their technical indicators, delivery cycle and prices are uncontrollable, which limits the development of semiconductor equipment manufacturers to a certain extent [6].

On the other hand, China's semiconductor technology foundation is weak, especially in advanced technology, there is a big gap with developed countries, domestic semiconductor enterprises are weak in capital strength, insufficient investment in technology, in the competition with foreign enterprises, because of their advantages in business scale and market recognition, customers will still choose suppliers. With a certain degree of inertia and stickiness, domestic semiconductor equipment manufacturers are facing greater pressure and challenges in the process of competition with them, and market recognition still needs to be further accumulated [7].

The regression analysis of the factors affecting the development of China's semiconductor industry

Index selection. Semiconductors refer to materials with conductivity between conductors and insulators at room temperature, which are mainly used in integrated circuits, optoelectronic devices, discrete devices and sensors, and are the basis for the development of electronic information industry [8]. Integrated circuits, also known as chips, account for 80 % of the semiconductor market, and «integrated circuits» can represent the concept of semiconductor to a large extent. Therefore, the data used in this article are the relevant data of the integrated circuit industry under the semiconductor industry. There are many factors affecting the development of China's semiconductor industry, including fiscal policy, fixed asset investment, R & D investment, labour input, industrial agglomeration, import and export trade volume, social and geographical environment and other factors. Because there are many influencing factors and some qualitative factors that are difficult to quantify, this paper selects labour input, R & D input, industry concentration CR4 (share concentration index of the top four in the industry) and fixed assets investment as explanatory variables from 2014 to 2021, and integrated circuit output value as explanatory variables, and establishes multiple based on Cobb – Douglas production function. This paper makes an empirical study on the influencing factors of China's semiconductor industry.

Model construction. In this article, the output value of integrated circuit industry is taken as the dependent variable, and the investment in fixed assets of the industry, the R & D expenditure of high-tech industry of electronic device manufacturing industry, the number of R & D personnel of high-tech industry of electronic device manufacturing industry and the industrial concentration CR4 are taken as the explanatory variables. Establish a model for measurement inspection, and the model is as follows:

$$\mathrm{InY}_t = \mathrm{C} + \beta_1 \mathrm{InK}_t + \beta_2 \mathrm{InR}_t + \beta_3 \mathrm{InL}_t + \beta_4 \mathrm{InCR}_t + \mu_t,$$

where Y_t is the growth of the semiconductor industry in the year t, expressed by the industrial output value of that year; K_t is the fixed capital investment of the semiconductor industry in the year t, expressed by the fixed asset investment of that year; R_t is the R & D input of the semiconductor industry in the year t, which is expressed by the R & D expenditure of the high-tech industry of the electronic device manufacturing industry in that year; L_t is the labour input of the semiconductor industry in the year t, which is expressed by the full-time equivalent of R & D personnel of the high-tech industry of the electronic device manufacturing industry in that year; CR_t is the concentration level of the semiconductor industry in the year t, which is represented by the CR4 index.

Correlation analysis. Before the regression analysis, the correlation coefficient of explanatory variables was tested, and the results are shown in table 3. It can be considered in the correlation coefficient matrix that, except for InCR_t, other explanatory variables are highly correlated with each other. In order to eliminate the influence of multicollinearity on the results of model analysis, the stepwise regression method was used to deal with multicollinearity.

Table 3

The correlation analysis of ICT industry output value and influencing factors

Index	InK_t	InR_t	InL_t	InCR_t
InK_t	1	0.924	0.896	–0.246
InR_t	0.924	1	0.968	–0.387
InL_t	0.896	0.968	1	–0.361
InCR_t	–0.246	–0.387	–0.361	1

The analysis of regression results. *The establishment of initial model.* Eviews software was used to do the univariate regression of the explained variable and the single explained variable: in the univariate regression of InY_t and InR_t, $R^2 = 0.991$, and $t = 20.729$, the t-test was significant, which was in line with the economic significance test. Therefore, $\mathrm{InY}_t = 1.443 + 1.181\mathrm{InR}_t$ is selected as the initial model.

Stepwise regression results. Other explanatory variables are introduced into the initial model respectively: InK, InL, and InCR_t are introduced into the initial model respectively, and when the explanatory variable InCR_t is introduced, the model R is 0.995, which is the highest. At this time, the model had the best goodness of fit, and the two explanatory variables passed the t-test, the model passed the F-test, the parameter symbols were in line with economic significance, and InCR was retained. On the basis of this model, the other two variables

are introduced respectively. The ROF model is not improved and the significance test is not passed. Therefore, only InR_t, $InCR_t$ retained in the model, and the other two variables are removed. The fitting regression equation is:

$$InY_t = 0.756 + 1.213InR_t + 0.597InCR_t.$$

Stepwise regression results correspond to $R^2 = 0.995$, indicating that the regression fitting results are good, and the coefficients of the two variables pass the significance test.

Conclusions and recommendations

Conclusion. This article collects the relevant data which affect the development of the semiconductor industry, and gets the key factors which affect the development of China's semiconductor industry, that is, R & D investment and industrial agglomeration, and gets the regression equation which affects the output value of China's semiconductor industry. In view of the fact that the output value of China's semiconductor industry is affected by many factors, and there are social factors, policy factors and other factors that are difficult to quantify, there will be a certain error between the model's prediction for the future and the real value. However, the model in this paper passes the multicollinearity test and heteroscedasticity test, and the model passes the serial correlation test after further modification, and has practical economic significance, so the model in this paper can be used as a reference for the development of China's semiconductor industry. Under the background of China's domestic and international double cycle development, China should seise the opportunity to accelerate the development of the semiconductor industry, lay a good foundation for the development of the information industry, master independent intellectual property rights and core technologies, realise the layout of the whole industrial chain, reshape the international division of labour, and enhance the core competitiveness and comprehensive national strength of China's development [6].

Recommendations. *Strengthening semiconductor research and development.* The latest annual analysis of R & D spending in the global semiconductor industry. Despite political and national security concerns about domestic semiconductor production, US companies still account for more than half of total R & D spending in the global chip industry, the report noted. About 56 % of global semiconductor industry R & D spending in 2021 comes from companies headquartered in the Americas, almost all of which are American companies, a large part of which comes from «Intel»[15].

In 2021, Asia – Pacific companies (including foundries, fabless and IDM) spent more than 29 % of the global total on semiconductor R & D, followed by European companies with about 8 %, Japan with nearly 7 % of industry spending, and Asia – Pacific (including China) with 29.5 %. Global semiconductor companies spent 13.1 % (80.5 bln US dollars) of total sales on R & D in 2021, compared with 15.5 % in 2011[16], excluding other companies and organisations involved in semiconductor related technologies. Examples include suppliers of production equipment and materials, packaging and testing service providers, universities, government-funded laboratories, and industry cooperatives.

As a percentage of semiconductor sales, R & D spending by companies headquartered in the Americas region averaged 16.9 % in 2021. In 2021, the R & D to sales ratio of semiconductor suppliers in the Asia – Pacific region was 9.8 %, compared with 14.4 % for European companies and 11.5 % for Japan. Suppliers account for about 55 % of global semiconductor R & D spending, compared with 18 % in the Asia – Pacific region (including China)[17].

Chip production is not a simple matter; it requires technology, high initial investment and cutting-edge knowledge in this field. These obstacles currently put China in a difficult position in the production of chips known as «new oil». China wants to continue to advance and improve its production model in order to become a developed economy. In this strategy, the production of chips occupies an important position. In implementing the double cycle strategy, China strives to reduce its dependence on foreign countries as much as possible, and does not want to import semiconductor products from abroad except when necessary. To do this, China needs to manufacture these integrated circuits itself, and now China must buy a large number of such products from abroad.

Companies make semiconductors continue to thrive as electronic devices proliferate. These companies seek to produce smaller, cheaper and more efficient semiconductors (chips) to maximise the performance of electronic devices while making them more powerful and cheaper.

Mainland China is one of the three largest semiconductor equipment consumer markets in the world, but the market share of local equipment manufacturers is very low. Taking 2020 as an example, the total amount

[15] In 2021, China accounted for 3.1 % of the total global semiconductor R & D expenditure [Electronic resource]. URL: http://news.sohu.com/a/575220976_121325427 (date of access: 07.10.2022) (in Chin.).

[16] Ibid.

[17] Ibid.

of equipment purchased by domestic wafer factories (including wafer factories of «Samsung», «TSMC», «SK Hynix» and other large international factories in mainland China) is about 15.40 bln US dollars, of which the amount of domestic equipment purchased is only 0.99 bln US dollars, accounting for only 7 %[18]. The situation of low localisation rate and monopoly by foreign giants is very obvious.

Before 2008, China's semiconductor equipment was basically imported, so the state set up a major national science and technology project – the large-scale integrated circuit manufacturing equipment and complete process technology project to develop domestic equipment. However, due to the high demand for technology and capital in equipment manufacturing, only a few key enterprises such as «North Huachuang», «Zhongwei Semiconductor» and «Shanghai Microelectronics» can undertake the special research and development work, and the concentration of the whole industry is relatively high. China's semiconductor equipment has grown from scratch, compared with the huge domestic market scale, but the self-sufficiency rate is seriously inadequate.

Even in the field of IC packaging and testing with a relatively high level of development, there is still a big gap between China and the advanced international level. The market of monocrystalline furnace, oxidation furnace, chemical-mechanical planarisation equipment, magnetron sputtering coating equipment, chemical vapor deposition equipment, lithography machines, coating (developing) equipment, inductively coupled plasma etching systems, probe stations, etc. is almost occupied by foreign enterprises.

At present, domestic semiconductor equipment is in a state of partial breakthrough, but relatively backward as a whole. Especially compared with international giants, the strength of local equipment enterprises is still weak, most of them can not reach the level of 7 nanometer process which has achieved mass production in the world, and some enterprises break through to 28 nanometer or 14 nanometer process, but there is a big gap in the stability of use with international giants, it is difficult to enter the mass production line in large quantities, and it is also difficult to enter the production line of international foundry giants.

The technical barriers of semiconductor equipment industry are very high. With the process becoming more and more advanced, the performance and stability of semiconductor equipment are put forward higher and higher requirements, and a large amount of R&D funds are needed. «Applied materials» has always maintained a high investment in R&D, with 30 % of its employees being professional R&D personnel, holding nearly 12 000 patents[19], and applying for more than 4 new patents every day on average. It is this sustained high R&D investment that contributes to the internal innovation of applied materials and constitutes a higher technical barrier.

Because the research and development cycle of semiconductor equipment is long and the investment is large. Although domestic equipment companies have made breakthroughs in the research and development of technological processes, there is still a certain distance from stable mass production. The key point is to have trial and error opportunities. The trial and error cycle is usually as long as one year or even several years. Because the market has been occupied by large international manufacturers for a long time, it is difficult for domestic equipment manufacturers to get application opportunities and development space. Therefore, the Chinese government needs to increase support for semiconductor-related enterprises, guide these enterprises to strengthen semiconductor R&D investment, and then enhance semiconductor.

Exerting the agglomeration effect of the semiconductor industry. Under the industrial cluster effect, China's domestic semiconductor industry is rising. At present, Shanghai's «14 nanometer advanced technology» has achieved mass production, and breakthroughs have been made in 90 nanometer lithography machines, 5 nanometer etching machines, 12 inch large silicon wafers, domestic central processing units (CPUs) and 5G chips. As of September 2022, the scale of Shanghai's integrated circuit industry has reached 250 bln yuan, accounting for about 25 % of the country's total, gathering more than 1000 key enterprises and attracting 40 % of the country's integrated circuit talents[20].

14 nanometer is the boundary and threshold of high-end chips and low-end chips. The mass production of this process represents that we already have the basis to achieve autonomy in the low-end process. We should know that although the advanced process has high added value, it has few application scenarios, far less than the low-end process. Once independence is achieved in this field, the problem of chip manufacturing will be solved for the most part.

Lithography machine is the core equipment of chip manufacturing, and EUV lithography machine is the key to the production of advanced technology chips. We have been unable to break through the process below 14 nm for a long time, precisely because the EUV lithography machine is stuck. The good news is that «Shanghai

[18] With China's efforts, the craziness of semiconductor equipment will continue [Electronic resource]. URL: https://baijiahao.baidu.com/s?id=1734970745120072210&wfr=spider&for=pc (date of access: 05.10.2022) (in Chin.).

[19] Ibid.

[20] Under the industrial cluster effect, Shanghai has achieved a major breakthrough in the semiconductor industry, and breaking through the blockade is just around the corner [Electronic resource]. URL: https://baijiahao.baidu.com/s?id=1744124186977252284&wfr=spider&for=pc (date of access: 07.10.2022) (in Chin.).

Microelectronics» is accelerating its R&D and manufacturing, and the 28 nanometer domestic lithography machine is expected to be independent. At that time, through $N + 1$, $N + 2$ technology, the chip performance can be improved to 7 nanometer level.

Etching machines and large silicon wafers are also important links in the chip manufacturing process, which have been stuck for a long time before, and are now moving towards autonomy one by one.

Domestic CPU and 5G chips are even more surprising. You know, CPU and graphics processing units are the key core of electronic consumer products and the cutting-edge technology of the chip industry. 5G chips, which have long been a headache for Chinese companies such as «Huawei», are now making progress and are believed to bring new vitality to the market in the future.

The scale of Shanghai's integrated circuit industry has reached 250 bln yuan, accounting for about 25 % of the country's total, gathering more than 1000 key enterprises and attracting 40 % of the country's integrated circuit talents[21]. The combination of these data shows us the hope of a semiconductor capital.

Under the industrial cluster effect, supply chain, market, talent and other issues will be able to be better solved. In addition to semiconductors, the six major industrial clusters created by Shanghai electronic information, life and health, automobiles, high-end equipment, advanced materials, fashion consumer goods will also play a role in promoting the semiconductor industry, which is conducive to the healthy development of the upstream and downstream industries.

To sum up, the chip industry is slowly changing from doing everything everywhere in the past to concentrating on doing big things. This is good news, giving China's semiconductor upstream and downstream enterprises more platforms and opportunities for cooperation, which is of great help to ecological construction.

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