

Study on the Supply Issue of Vehicle Microcontroller Chips in Post-pandemic Era in China

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Abstract. As the pandemic subsides, there's a noticeable revival in the automotive consumer market. China's automobile industry, now at a pivotal moment, is making strides on the global stage, spurred by its transition towards new energy. While the world's car market has been historically dominated by German and Japanese brands, Chinese automakers were often labeled as mere imitators producing inferior quality vehicles. But this narrative is changing. Now equipped with advanced battery technologies and innovative designs, Chinese carmakers are poised to redefine the global automotive landscape. Their progress challenges the deep-seated dominance of traditional automotive powerhouses. However, this ascent is not without hurdles. External pressures, such as ongoing trade tensions, weigh on the industry. Moreover, there's an internal challenge to grapple with: the critical semiconductor sector, particularly the micro-control chips essential for modern vehicles, has yet to achieve self-sufficiency. Production constraints persist, and the desired levels of self-reliance remain elusive. This paper delves deep into the automotive microcontrol chip industry, with an emphasis on the upstream and midstream sectors of the supply chain. By shedding light on the current situation and drawing from global best practices, we aim to propose actionable recommendations. These suggestions will be aimed at enhancing production capacities, improving quality, and ultimately driving China's automobile industry towards a more self-reliant and globally competitive future.

Keywords: Post-pandemic era, Trade war, Automotive-grade microcontroller chips, Industry chain.

1. Introduction

Since 2015, China has become the world's largest market for new energy vehicles, and it has held the top position in the global production and sales scale of new energy vehicles for eight consecutive years. The sales share of China's own brand of new energy vehicles far exceeds that of joint-venture brands, showing strong potential for growth. New energy vehicles are revolutionizing the automobile industry, replacing traditional fuel vehicles. As a leader in new energy vehicles, China should seize this opportunity to reverse its declining momentum in the automobile industry. The needs for microcontroller units in new energy vehicles differ from those of traditional cars. For example, battery management, drive control, and highly integrated sensors all require the support of high-performance microcontroller units. With the growth of the new energy vehicle market and the trend towards vehicle electrification, the demand for microcontroller units has increased accordingly. There is an increasing demand, especially for high-performance, low-power microcontroller units.

According to data from the Donghai Securities report, in 2021, China's self-sufficiency rate for automotive chips was less than 5% [1]. Whether for power semiconductors or microcontroller units, China's self-sufficiency rate is low, making chip supply security particularly necessary and urgent. Zhang Yongwei, Deputy Director, and Secretary-General of the China Electric Vehicle 100 (CEV100), stated at the 2022 Global Intelligent Automotive Industry Summit: "In the past three years, chip shortages have resulted in a global reduction of approximately 15 million vehicles, with over 2 million in China, reflecting the profound impact of chip shortages on the automotive industry." China's demand for automotive chips mainly relies on companies from Japan, the U.S., and Europe, while Chinese companies only account for 3%. This means foreign chip manufacturers almost monopolize domestic chip supply, resulting in China's limited ability to control and adjust its vehicle production. Moreover, there is a significant gap between China and global manufacturers of high-end

chips. Neither in terms of computing power nor chip manufacturing can they meet the demands of high-end automotive products.

However, in recent years, the United States has intensified restrictions on chip exports to China, increasing the risk of chip supply disruptions for China. In addition, due to the pandemic, domestic automotive chip supply has faced the dual challenges of global capacity shortages and U.S. chip export restrictions. In general, the crux of China's unresolved chip shortage lies in its inability to break the technological barrier of high-end chips and, under the influence of the pandemic and sanctions, its inability to obtain enough chip supplies from abroad to meet the demands of Chinese automakers in the context of new energy vehicle development. The problem of chip shortages in China is particularly evident in the microcontroller chip industry. To meet these needs, microcontroller unit manufacturers need continuous innovation and technological advancement. This paper aims to analyze the industry chain of automotive-grade microcontroller units to pinpoint the deficiencies in China's supply chain and provide suggestions for the entire chain's improvement. Given that the supply issues with China's vehicle micro control chips predominantly stem from a reliance on foreign technology, and because the provision of finished products affects the capability of downstream electronics manufacturers to produce the required market devices, this article will focus on the midstream and upstream industries.

2. Problem Interpretation

The National New Energy Vehicle Technology Innovation Center has gathered data indicating that China's current automotive chip shortages mainly lie in microcontroller chips, communication chips, drive chips, power device chips, and power chips. Among these, the microcontroller chip (MCU) is one of the most significant parts facing the largest scale of shortage. The demand for microcontroller chips in new energy vehicles is 4.3 times that of traditional gasoline vehicles [1]. This data suggests that with the development of domestic new energy vehicles, the demand for microcontroller chips will further increase. The current slow development of microcontroller chips cannot meet the future growth in demand for new energy vehicles in China. The Donghai Securities report indicates that the domestication rate of automotive-grade microcontroller chips in China is around 5% [1]. Amid the tensions of the China-US trade war, many semiconductors raw materials are being forced to be produced by overseas manufacturers. This makes it challenging for China to continue the development of automotive-grade microcontroller units from the raw material level. Furthermore, given China's weak independent technological capabilities and the limited production capacities of major manufacturers in Europe and the U.S., it's hard to ensure that the domestic demand for microcontroller units is met. To meet these needs, microcontroller unit manufacturers need continuous innovation and technological advancement. This paper aims to analyze the industry chain of automotive-grade microcontroller units to pinpoint the deficiencies in China's supply chain and provide suggestions for the entire chain's improvement.

2.1. Upstream Raw Materials

The raw materials for the microcontroller unit are divided into seven categories, including silicon wafers, photoresists, photomasks, specialty electronic gases, Process Chemicals, sputtering targets, packaging materials, and polishing materials. The specific analysis of the problems faced by the above materials is as follows.

2.1.1. Silicon Wafers

The 2-inch silicon wafer is a primary object of scarcity for us. Although the self-sufficiency rate of 8-inch silicon wafers has been steadily increasing, many manufacturers have to opt for 12-inch silicon wafers due to their ability to produce more bare wafer chips and achieve a better yield, thus maximizing profits. There is still a significant gap between domestic enterprises in terms of industrial scale, technological level, and profitability compared to leading international enterprises. Major foreign companies have a 12-inch silicon wafer production capacity of more than 1 million

wafers/month. Among them, Shin-Etsu Chemical Co., Ltd. of Japan has reached a capacity of 3.1 million wafers/month. By the end of 2022, the maximum output of domestic enterprises does not exceed 300,000 wafers/month. Advanced process products are still primarily in the research and development phase, and there's a considerable technological gap compared to leading international standards. The range of products is limited, quality stability still needs improvement, and China's 12-inch silicon wafers have not yet made it into the top 10 semiconductor chip manufacturing companies like Samsung [2]. The 12-inch silicon wafer is the foundation for the manufacture of microcontroller chips and requires attention from both the country and the entire supply chain.

2.1.2. Photoresist

China has made certain progress in the research and production of photoresists. In recent years, with the rapid development of China's semiconductor industry, domestic photoresist companies have been continuously increasing their R&D investments to improve product quality and technical levels. However, compared with international advanced standards, there is still a gap in China's photoresist industry. The self-sufficiency rate of low-end photolithographic resins is low, offering a vast space for domestic substitution. Regarding IC photoresists, in 2020, China's self-sufficiency rate was low, with g/i line photoresists at less than 10%, KrF photoresists around 5%, and higher-end ArF and EUV photoresists almost non-existent [3]. In 2019, Japan suddenly stopped exporting photoresist to South Korea, leading to a collapse in South Korea's semiconductor industry. This incident serves as a warning for the whole industry chain to prepare in advance for similar situations to avoid being strangled in critical supply chains. Therefore, the Chinese government needs to plan as soon as possible for the development of mid-to-high-end photoresists, including KrF, ArF, and EUV.

2.1.3. Photomasks

For automotive microcontrollers, the primary photomask used is a semiconductor mask, essentially acting as a template during the photolithography process. The cost of photomasks accounts for about 15% of the semiconductor materials sector, far exceeding other materials such as electronic specialty gases and photoresists. Apart from silicon wafers, it's an essential material that demands significant attention in the production of microcontroller units. The current situation in China is that the manufacturing precision of semiconductor masks is not on par with foreign manufacturers, with a self-sufficiency rate of only 22.4% [4]. With the slow growth rate of downstream manufacturers abroad, many mask industries have not prepared sufficient production volumes, leading to shortages in China. Therefore, more domestic third-party mask manufacturers need to join the competition to fill the gap.

2.1.4. Specialty Electronic Gases

Electronic specialty gases play a crucial role in semiconductor manufacturing. The purity, stability, and impurity content of these gases can affect the performance and yield of microcontroller units. In the coming years, due to the halt of production by Ukrainian neon gas manufacturers, which might be a permanent cessation, and the potential interruption of helium supplies by the U.S. Department of the Interior, there hasn't been any increase in the production capacity of helium and other electronic specialty gases apart from Russia in the past year. However, with the rapid growth of domestic new energy vehicles, the production capacity will soon fall short of demand. As the second-largest consumable in the wafer (required for microcontroller units) manufacturing process, electronic specialty gases demand the attention of domestic companies. It is vital to break through technological barriers promptly, enabling the production of high-purity specialty gases without depending on imports.

2.1.5. Process Chemicals

Process Chemicals are one of the essential key materials in the manufacturing processes of display panels, semiconductors, solar cells, and the like. The quality of wet electronic chemicals not only directly affects the quality of electronic products but also has a significant impact on the industrialization of microelectronics manufacturing technology. Currently, for the manufacturing of

6-inch and smaller wafers, the domestication rate of wet electronic chemicals is 80%. However, for the electronic chemical market used in the manufacturing of 8-inch and 12-inch wafers, the domestication rate is only around 10%. Overall, the domestication rate of wet electronic chemicals used in semiconductor wafer manufacturing is about 25% [5]. Therefore, we should continue our research and development efforts in the mid and high-end markets. We aim to ensure the supply of process chemicals in the high-end market.

2.1.6. Sputtering Targets

Chinese target material companies have a low market share and are primarily concentrated in the mid-to-low-end markets. The technological barriers for target materials are high, and it's challenging for domestic companies to achieve breakthroughs in purity standards. Silicon wafers require high purity, and as an auxiliary material, target materials cannot afford to have low purity either. Additionally, the certification process for target materials is lengthy, with a typical cycle from new product development to mass production taking about 2 years. Once domestic manufacturers manage to obtain these difficult certifications, they still face competition from foreign suppliers before turning a profit in the market. Globally, countries like the US and Japan, leveraging their first-mover advantages and technological patent barriers, occupy a dominant position in the supply chain due to their advanced purification technologies and strong bargaining power. Chinese target material supplies to Japanese and American manufacturers account for about 90% of the market share [6]. After years of advancements in target material technology, some companies have made breakthroughs in metal purification and are progressing toward domestic alternatives. However, the self-sufficiency rate for high-end materials remains low, indicating an urgent need to boost supply.

2.1.7. Packaging Materials

In the packaging process of microcontroller chips, packaging materials are needed, which include packaging substrates, lead frames, bonding wires, packaging resins, ceramic packages, chip bonding materials, and cutting materials, among others. These materials are essential for completing the packaging and are a guarantee for chip output. There is a noticeable gap between domestic packaging substrates and bonding materials and those of international major manufacturers. In 2017, domestic semiconductor sales amounted to about 281.7 billion yuan, of which domestic packaging material sales were about 116.4 billion yuan, resulting in a domestication rate of 29.3% [7]. The purity of high-precision materials such as copper alloys produced domestically still can't meet the standards of high-end products and requires substantial imports. China's plastic sealing materials can't meet the demands of the packaging industry, and the development cycle for new materials is long, with a significant talent gap in research and development.

2.1.8. Polishing Materials

Polishing materials can be divided into polishing pads and polishing slurries. The overall trend for polishing slurries is positive. In 2021, domestic company Anji Technology already accounted for 33% of the domestic market share, breaking the foreign monopoly on CMP polishing slurries [8]. The situation is similar for polishing pads; overall development is promising. Even though demand still outstrips supply, leading enterprises have mastered the core technology and manufacturing techniques for polishing pads and have already received certifications from some downstream customers. In summary, both polishing pads and slurries need to increase production and establish cooperative relationships with downstream enterprises as soon as possible to ensure continued production and research and development.

2.2. Midstream Manufacturing Equipment

Manufacturing equipment mainly includes single crystal furnaces, thin film deposition equipment, wire bonders, testing equipment, etching machines, photolithography machines, resist application developers, and cleaning machines. Although in recent years, China's semiconductor equipment has made significant progress toward domestic production, on the whole, China's semiconductor

manufacturing still relies heavily on imported equipment. Although domestic equipment has gradually gained market share in some areas, in the global semiconductor supply chain, the overall level of domestic production still needs improvement. Semiconductor manufacturing equipment accounts for 80% of the capital expenditures in newly built wafer fabs, which is the most significant capital expenditure item. Among wafer processing equipment, etching machines, photolithography machines, and thin film deposition equipment account for 30%, 27%, and 25%, respectively, while other equipment accounts for 18% [9]. Therefore, China should prioritize solving the supply problems of thin film deposition equipment, etching machines, and photolithography machines

2.2.1. Thin Film Deposition

Thin film deposition equipment is one of the core steps in semiconductor manufacturing, second only to the photolithography machine. As the technology of microcontroller chips becomes more complex, the demand for high-performance thin film deposition equipment is also constantly increasing. According to data from Dong Fang Securities, the domestic production rate of thin film deposition equipment is estimated to be only 5.5% (by equipment number) [4]. This indicates that there is still room for improvement in domestic production. Although the R&D of thin film deposition equipment has made significant progress in China in recent years, it is still insufficient to cope with future market conditions.

2.2.2. Etching Machine

The etching machine is one of the three core technologies in the front-end manufacturing of chips. Data consolidated by Tou Bao Research Institute shows that China's domestic production rate of etching machines is only 15%, and it cannot compete with foreign manufacturers in the high-end field [9]. With the robust growth momentum of electric vehicles, there is a need to continue developing etching machines to ensure supply.

2.2.3. Photolithography Machine

The photolithography machine is the core equipment in semiconductor manufacturing, responsible for transferring the circuit pattern onto the silicon wafer. As of 2021, although China has made progress in domestic production of semiconductor equipment, there is still a significant gap between domestic technology and international advanced levels in the high-end photolithography machine sector. Among the seven major equipment in the front-end IC manufacturing process, including photolithography machines, etching machines, plating equipment, measurement equipment, cleaning machines, ion implanters, and other equipment, the photolithography machine is the most crucial link in IC manufacturing. Two Chinese companies have made achievements in this area. The global wafer foundry industry is highly concentrated, with SMIC ranking fifth globally in revenue and a 9% market share. Benefiting from domestic photolithography machine production and product technology optimization, its market share in the global mature process sector is expected to further increase. Shanghai Microelectronics, a rising star in the global front-end IC manufacturing photolithography machine sector, has gradually narrowed its gap with international photolithography giants over 20 years of development and holds a 40% market share in the global back-end testing and packaging photolithography sector [9].

2.3. Midstream

Starting from the midstream, the steps in the manufacture of microcontroller chips are involved, which include manufacturing links and operating modes. The manufacturing link includes chip design, single-crystal silicon wafer manufacturing, wafer manufacturing, and chip packaging and testing. The two operating modes are IDM and Fabless. Both the manufacturing and testing of microcontroller chips in China need development. At present, the microcontroller unit (MCU) supply is predominantly controlled by specific MCU suppliers. While there's an urgent need to speed up China's MCU research and development, challenges still persist.

2.3.1. Wafers

A worldwide wafer shortage adds another layer of complexity. Wafers, as a critical element in the upstream automotive chip industry, necessitate a broader range of Chinese manufacturers to gain certification and achieve higher qualifications. Thankfully, with the government's support, an increasing number of companies have secured these certifications. This suggests that, in the near future, China might achieve greater self-reliance in wafer production.

2.3.2. Chip Packaging and Testing

Testing and certification serve as a crucial bridge connecting the semiconductor and automotive industries. On one end, these processes address the quality of outputs from the semiconductor sector, while on the other, they cater to user inspections and inventory checks. For China's automotive chip industry to grow and excel, mastering these foundational steps is of paramount importance [10]. Currently, when adhering to automotive standards, domestic chip sealing and testing facilities continue to rely on expensive gold wires, making them largely uncompetitive. In stark contrast, leading global manufacturers have transitioned to using copper wires, ensuring both reliability and cost-effectiveness. Consequently, domestic manufacturers face an uphill battle in meeting packaging standards. Both the quality control and efficiency of domestic packaging cannot yet match that of their international counterparts, resulting in a pronounced discrepancy between quality and cost.

3. Conclusion

In the upstream stage of microcontroller units, the domestic rate of localization in China remains relatively low, especially in the supply of high-end, high-precision, high-purity raw materials. Moreover, there are significant challenges in equipment supply. For instance, in lithography technology, both the high-end photolithography machines and raw materials like photoresist, fall far short of international standards. This leads to a deficiency in China's microcontroller chips right from the beginning of the supply chain. We need to address the interruption in the supply of high-end materials and machinery from the root. In the midstream segment, while there have been breakthroughs in wafer manufacturing, further policy support is needed to boost domestic firms' research motivation and trading activities during the packaging and testing stages. In general, the current stage demands rapid development of the entire supply chain to promote the growth and supply of automotive microcontroller chips. This article proposes the following suggestions:

1) Promote a Supply Chain Information Sharing Platform

The government can encourage the collaborative development of enterprises in the chip industry chain, establish industry alliances, achieve resource sharing, and improve the overall competitiveness of the industry. The entire supply chain for automotive microcontroller chips in China needs to share data in real time to ensure synchronization of the information flow. All stages of the domestic microcontroller chip industry, from upstream to downstream, should share information promptly. This would help reduce the bullwhip effect and unnecessary stockpiling, which could cause losses for the Chinese automotive industry. Furthermore, the entire industry chain should prioritize supplying domestic brands and catering to domestic demand before collaborating with foreign manufacturers.

2) Increase Incentives

The state should also invest more in supporting the development of the entire high-end microcontroller chip industry chain in China. There should be encouragement for more automotive companies to use domestic chips, ensuring an abundant supply of raw materials for the microcontroller chip industry and boosting their confidence to venture into high-end markets. This would necessitate the government to introduce relevant policies, supporting the chip industry's growth and providing fiscal and financing benefits for chip enterprises.

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