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A Strategic Analysis of China's Semiconductor Supply Chain

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Abstract

In the emerging hi-tech cold war, the United States government's chokepoint policy is to limit China's access to cutting-edge semiconductor technology. It is becoming increasingly important for China's future development that it establish an indigenous semiconductor supply chain. This section details China's policies and growth in the semiconductor industry, and assesses the strengths and weaknesses of major Chinese companies in the IC supply chain. Strategic supply chain analysis reveals that China's semiconductor sector is robust despite pressure from the United States.

Keywords: US-China Technology War, Semiconductor industry, China supply chain, Indigenous innovation

INTRODUCTION

Access to cutting-edge semiconductor technology has become a flashpoint in the growing technological competition between the United States and China in the year 2020, when a worldwide pandemic is in full swing (Feng and Li 2020). One year after adding Huawei on the BIS Entity List of export control, on May 15, 2020, the U.S. Department of Commerce restricted the Chinese tele-communication technology giant from obtaining semiconductors created and produced with American technologies. The Commerce Department tightened export limits on China's main chipmaker, Semiconductor Manufacturing International Corporation (SMIC), four months later, making it so that only businesses with the proper permits may sell certain technologies and equipment to SMIC. Targeting China's leading technology companies is clearly a dramatic escalation of existing tensions, even though the

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United States has previously issued export bans to Chinese semiconductor companies (for example, the addition of Fujian Jinhua to Entity List over alleged technology theft in October 2018). Consensus is building, both inside and outside of China, that cutting off China's access to cutting-edge semiconductor technology is the U.S. government's chokepoint plan to slow China's technical advancement and preserve America's industrial primacy.

Advanced information systems rely heavily on semiconductors. These microelectronic components are essential to the operation of virtually every aspect of contemporary life, from communications to transportation to household appliances to autos to robotics to the electrical grid itself. Despite China's status as the world's largest electronics producer, it must rely significantly on foreign firms for the provision of this essential technology. Since 2006, China's main imported commodity has not been crude oil but rather semiconductors like integrated circuits (IC) and other silicon devices. By 2013, China's annual IC import value had reached US$200 billion, and by 2018, it was expected to reach US$300 billion.

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The Chinese government has been working toward complete autonomy in semiconductor technology for quite some time (Hu 2006; Lazonick and Li 2013; Li 2016). China is likely to put even more effort into developing its homegrown industries as tensions rise with the United States. President Xi Jinping of China made the statement, "having key technologies owned by outsiders is the biggest concealed risk," in 2016. (Xi 2016). In 2020, President Xi reiterated his demand for the pursuit of "technology that is strategic and takes long-term commitment" in industries that "rely on imported components, parts, and raw materials" (Xi 2020).

In this chapter, we evaluate the state of the Chinese semi-conductor sector in 2020 and its preparedness to compete with the United States' increasingly aggressive strategy toward technology exports. Examining the semiconductor industry's progress across time might provide light on both its strengths and weaknesses in China today. In the sections that follow, I trace the evolution of China's semiconductor industry policies and infrastructure from the

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early days of the People's Republic to the current day. Then, I analyse the technological prowess and presence of major Chinese companies in the IC supply chain. The results of the analysis are used to suggest potential directions for future policy.

Policy and progress in China's semiconductor industry

When it came to investing in the study and advancement of semiconductor technology in the 20th century, China was among the very first countries to do so. The "March Towards Science" programme launched by the Chinese government in 1956 highlighted semiconductor as a crucial industry for China's development. Peking University, Fudan University, Jilin University, Xiamen University, and Nanjing University were only some of the top Chinese colleges to build departments of semiconductor physics after receiving returning Western experts in the 1950s. Seven years after Texas Instrument pioneered the IC in 1958, Chinese scientists created their first IC in 1965. (Li 2017).

China's goal to swiftly create a modern semiconductor industry utilising foreign technology dates back to the era of economic reform and opening-up that began in 1978. Chinese central and local governments invested over 1.3 billion renminbi (about 150 million USD) in the early 1980s to purchase thirty-three sets of used semiconductor production equipment in order to modernise twenty-four significant firms. To promote the semiconductor sector, the State Council formed the Lead Group for Electronics, Computers, and Large-Scale IC in 1982. This was the first high-level government entity for inter-ministry cooperation and strategic industrial policy formulation. The Lead Group's original name was the State Council Lead Group for the Development of the Electronics Industry, but in 1984 it was changed to reflect its new role. The Lead Group decided, among other things, to focus the state's resources on a handful of market leaders in order to accelerate the modernization and expansion of vital industries. Huajing Electronics (Wuxi, Jiangsu), Huayue Microelectronics (Shaoxing, Zhejiang), Shanghai Belling, Shanghai Philips, and Beijing Shougang-NEC are only five of China's five relatively significant, major state-owned semi- conductor firms that were founded between 1988 and 1995. (Simon and Rehn 1987; Li 2017).

Project 908 was China's first government-sponsored initiative to advance the country's IC sector; it was initiated in 1990 with the goal of fostering the LSI (Large Scale Integration) technology of constructing transistors at sub-micron nodes. During the eight five-year plan, the Chinese government gave 2 billion renminbi to Huajing to construct an IC production line that could process 12,000 6-inch wafers per month utilising 0.8-1.2 um process technology

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transferred from AT&T-Lucent (1991–1995). There was a significant delay in the project's completion due to the government's painfully sluggish decision-making procedure. When the 6-inch fab finally went live in 1997, it was already years behind the times in terms of technology. Huajing was bought by China Resource Group in 2003 after years of joint venture with CSMC, a Hong Kong company (Fuller 2016; Mays 2013).

As part of its mission to modernise the country's semiconductor sector, the Ministry of Electronics Industry announced a massive new initiative in 1995 called Project 909. The main focus of Project 909 is the construction of an 8-inch production line with VLSI technology operating at 0.35-0.5 um process nodes, capable of producing 20,000 wafers per month. This line will require an investment of over 10 billion renminbi (or 1.2 billion US dollars). Shanghai Huahong Group and NEC of Japan formed a global partnership to complete the project. Despite Huahong's early reliance on Japanese management and engineers, the company has subsequently grown to become a prominent IC foundry (Hu 2006; Fuller 2016).

Document 18, titled "Several Polices to Encourage Software and Integrated Circuits Industry Development," was released by the State Council in July 2000 in preparation for China's entry into the World Trade Organization (WTO). Document 18 represented a dramatic shift in the policy instruments available for sector promotion. The new strategy placed an emphasis on broad-based tax incentives to stimulate entrances of private and foreign capital (Li 2016).

Following China's accession to the WTO, the semiconductor design, fabrication, packaging and testing industries all saw significant growth in the decade that followed. China has risen to prominence in the highly competitive yet labor-intensive packaging and testing sectors because to its enormous pool of trained and low-cost labour. There were fewer than a hundred companies in the IC design industries in 2000, but by 2004 that number had risen to about 500. While most Chinese IC design houses are still relatively tiny businesses competing in low-end market segments, a select handful have expanded into scale and narrowed gaps with international industry leaders. Several Chinese semiconductor design firms, notably Huawei's HiSilicon, Unigroup's Unisoc (a merger of Spreadtrum and RDA), and Sanechips, have emerged as market leaders thanks to the booming smartphone industry in the 2010s (ZTE Microelectronics).

The Semiconductor Manufacturing International Corporation (SMIC) has established themselves as the new industry leader in the production of integrated circuits. Richard Ru-Gin Chang and more than one hundred other foreign managers and engineers came together in the year 2000 to launch SMIC. The company's headquarters are located in Pudong, Shanghai.

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Chang has extensive knowledge in the construction of foundries because to his time spent working for Texas Instrument and launching his own startup businesses in the past. Initial funding of 1.48 billion US dollars came from the Chinese government as well as international investors. These investors included Goldman Sachs, H&Q Asia Pacific, Vertex Venture Holdings, and Walden International, among others. As of the year 2004, SMIC has already established itself as China's largest and most technologically advanced semiconductor foundry (Li 2016).

The Chinese government made "indigenous innovation" an official part of China's national strategy in 2006, when it published the "Outline of the National Medium- and Long-term Programme on Science and Technology Development (2006–2020)" (MLP), which outlined the country's plans for scientific and technological advancement between 2006 and 2020. (Lazonick and Li 2013). The Ministry of Science and Technology established a total of 16 National S&T Major Projects (also known as "Mega Projects") in key technology areas, including broadband mobile networks, advanced machinery, nuclear power, commercial aircrafts, and the development of new drugs, with the objective of making China an innovative nation by the year 2020. This was done in order to meet the goal of building China into an innovative nation by that year. One of the sixteen Mega Projects designed to advance the development of advanced chip technology and equipment with 45 nanometer or smaller process nodes is called "Ultra-Large-Scale Integrated Circuit Manufacturing Equipment and Technology." This Mega Project was initiated in 2012 and is one of the sixteen projects currently in progress. The initiative has provided funding for a wide variety of research and development projects that have been carried out by universities, research institutions, and local businesses.

The State Council released "Guidelines to Promote the National Integrated Circuit Industry" in June of 2014. One of the recommendations in this document is to concentrate government assistance on a few of successful domestic corporations.

The Ministry of Finance, China Development Bank Capital, and a number of state-owned investment funds and state-owned enterprises like China Tabaco, China Mobile, and China Electronics Technology Group contributed to the establishment of the National IC Industry Investment Fund (also known as the Big Fund) three months later. As of the end of 2018, the first round of investments from the Big Fund had been made across the entire semiconductor value chain, including IC design (19.7%), IC fabrication (47.8%), packaging and testing (11%), semiconductor materials (1.4%), semiconductor equipment (1.2%), and industry ecosystem

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(19%). Tsinghua Uni-group, specialising in IC design and manufacturing, received 10 billion RMB; Yangtze Memory Technologies Co (YMTC), specialising in memory chip manufacturing, received 19 billion RMB; SMIC, specialising in IC foundry, received 21 billion RMB; and Jingsu Changjiang Electronics Technology, specialising in IC packaging and testing, received 4.6 billion RMB. In addition, the first stage of the Big Fund has attracted 541.5 billion RMB in funding from sources such equity investment, corporate bonds, and bank loans, as well as from a number of other Local IC Funds set up by regional governments. The National IC Fund plans to begin its second round of investment by the end of 2019, at which point it will have raised over 200 billion RMB. The second round of investment will focus on semiconductor equipment and materials, two areas that were identified as weak links in China's IC supply chain.

As discussed in Chapters 1, 2, and 9, "Made in China 2025" is a plan that was introduced by the Chinese government in 2015 with the intention of developing ten advanced manufacturing sectors by the year 2025. These sectors include next generation information technology, controlling instruments and robotics, aerospace and aviation equipment, maritime equipment and shipbuilding, railway equipment, energy-efficient and new-energy vehicles, electrical equipment, new materials, medical devices, and agricultural machinery. It was determined that semiconductors, and integrated circuits in particular, would serve as the basis for the next generation of the information technology sector. The State Council issued a Technical Roadmap for the implementation of the plan in October 2015, establishing goals for the semiconductor sector to "develop the IC design industry, grow the IC manufacturing industry, upgrade the advanced packaging and testing industry, and facilitate breakthroughs in the key IC equipment and materials." These goals were established by the State Council in order to "develop the IC design industry, grow the IC manufacturing industry, upgrade the advanced packaging and testing industry" (State Council 2015).

A policy document titled "Several Policies for Promoting the High-Quality Development of the Integrated Circuit Industry and the Software Industry in the New Era" was published by the State Council in July 2020. This document serves to reaffirm the Chinese government's commitment to the industry in the face of increasing pressure from the United States. On the one hand, this new policy document will continue one of the highest tax benefits for semiconductor businesses that have pioneered sub-28 nano-meter node technology. On the other side, it will offer government support to semiconductor enterprises to simplify equity financing. SMIC, the national champion of the semiconductor industry in China, conducted an

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initial public offering (IPO) on the STAR Market of the Shanghai Stock Exchange in the same month. SMIC was delisted from the NASDAQ in 2019. SMIC was successful in raising 53 billion RMB in the nation's largest initial public offering (IPO) during the past decade, which has provided the company with adequate funds to invest in additional fabs and research and development.

THE STATE OF THE CHINESE SEMICONDUCTOR INDUSTRY

Despite the fact that China has not yet produced any global semiconductor leaders, the country has built a foothold in practically every phase of chipmaking due to decades of investment and development. To be honest, there are several vulnerable points in the Chinese domestic semiconductor supply chain, notably in ancillary sectors like IC production equipment, materials, and Electronic Design Automation (EDA) tools. China's semiconductor industry, even at its most cutting-edge, is dwarfed by its foreign rivals in terms of scale and technological prowess. Developing a robust semiconductor sector in China will be difficult if the United States becomes more inclined to limit Beijing's access to cutting-edge technology. Supplying the enormous domestic market may be the best opportunity for Chinese semiconductor businesses and equipment suppliers, despite the fact that the presence of a comprehensive local semi-conductor supply chain boosts the odds for Chinese enterprises to thrive under hostile U.S. policies. The manufacturing model in the worldwide semiconductor industry is briefly presented before moving on to an analysis of the capabilities of prominent Chinese enterprises in the supply chain.

As was noted in the previous paragraph, the current semiconductor business is divided into three distinct subfields that correspond to the three main stages in the production of IC chips: IC design, IC fabrication, and IC packaging and testing (Fig. 8.1). Many other industries provide the hardware, software, and materials necessary for the semiconductor business to function. For instance, IC design requires the use of specific EDA tools and IP (intellectual property) software.

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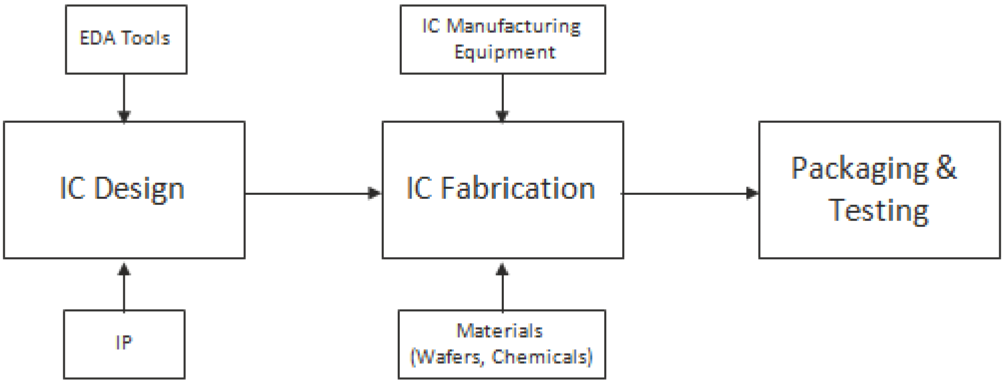

Fig. 8.1 Integrated circuits industry supply chain. (Source: Author's compilation)

Cores provided by specialised software firms, while IC fabrication facilities rely on specialised equipment manufacturers for cutting-edge tools like lithography machines and on specialised material suppliers for things like high-purity silicon wafers and a wide range of specialised chemicals.

The worldwide semiconductor business has been significantly fragmented during the 1990s, with the three stages of chip production being handled by separate, specialised corporations that are often spread out across the globe. The United States is home to some of the world's most innovative IC design firms like Qualcomm, Nvidia, and AMD, whereas East Asia is home to the majority of the world's most advanced IC foundry services, led by businesses like TSMC and Samsung. There used to be many semiconductor businesses that could handle everything from IC design through manufacture, but now that paradigm of vertical integration known as IDM (Integrated Device Manufacture) has mostly fallen out of favour. Memory chip (i.e. NAND flash memory and DRAM) makers that demand close integration between design and production fall outside this rule, as does Intel, which designs and manufactures high speed computer CPUs.

Processing and Evaluation

In recent years, China has accounted for more than half of worldwide output in the IC packaging and testing business. The labor-intensive nature of packaging and testing helps explain China's success in this area, and the country's proximity to the world's largest electronics supply chain also plays a role. Jingsu Changjiang Electronics Technology (JCET), Tianshui Huatian Microelectronics (TSHT), and Tongfu Microelectronics are the three biggest Chinese packaging and testing companies (TFME, formerly Nantong Fujitsu

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Microelectronics). All three of these corporations have their origins in the reform and privatisation of state-owned electronics factories in China's pre-reform industrial foundation. National IC Fund investments have allowed China's top packaging and testing firms to swiftly develop, acquire their global competitors' Chinese operations, and undergo a considerable technological upgrade in recent years. Since 2018, Apple has relied on JCET, China's largest and most technologically advanced packaging and testing organisation, as one of its suppliers.

Silicon Chip Foundry

The semiconductor industry's IC production process requires the most advanced and costly equipment and machinery. Building a cutting-edge IC fab that can handle 12-inch wafers and produce chips at the 7-nanometer node will cost you somewhere between $10 and $15 billion USD. A small number of contract manufacturers, often known as integrated circuit (IC) foundries, control the vast majority of the world's foundry capacity because of the prohibitive cost of entry.

After TSMC, Samsung, Global Foundries, and UMC, SMIC is the world's fifth-biggest IC foundry and the largest in China. As a globally focused start up funded by Silicon Valley, SMIC has access to cutting-edge American equipment unavailable to its Chinese competitors. By the middle of the 2000s, SMIC had reduced its technological deficit with the world's top powers to a single generation (or less than two years). However, technological development at SMIC has been substantially slowed by a slew of litigation initiated by TSMC over intellectual property rights violation and the challenges in moving to FinFET technology for sub-14/16 nano-meter process nodes. By the middle of the 2010s, SMIC had fallen behind foreign technological frontrunners by three generations of process nodes (or 5–7 years) (Li 2016). With the help of the National IC Fund's financial backing, SMIC was able to restart its technological catch-up efforts. SMIC is now conducting research and development for the 7-nanometer production node as well as increasing production at the 14-nanometer production node.

Due to the exponential rise in prices and technical difficulties, only three firms in the world have produced or are developing a 7-nanometer or lower process node: TSMC, Samsung, and Intel. Intel, the undisputed leader in American technology, is having trouble scaling up production of its 7-nanometer computer processors to meet demand. Therefore, research and development of 7 nano-meter technology would be quite difficult for SMIC. In addition, SMIC's exposure to hazards increases because of the company's reliance on U.S.-made equipment. Currently, the U.S. government is preventing SMIC from obtaining a licence from

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the Department of Commerce so that it may provide foundry services to Huawei, a key domestic user of advanced node. Also, the Dutch company ASML's EUV lithography equipment is essential for mass producing 7-nanometer chips, but SMIC is having significant issues importing it. ASML need a U.S. export licence since the EUV machines contain American-made components.

Circuit Board Layout

Separating IC design from foundry costs has freed semiconductor design firms from making costly capital expenditures on machines and facilities as foundries have risen in price. Start ups in China's semiconductor industry have sprung out in recent years thanks to the country's adoption of the fabless business model. These companies specialise in chip design but outsource manufacture to local and foreign foundries. With the electronics manufacturing business in China experiencing explosive growth, a growing number of fabless design houses in the country have developed the skills and international competitiveness necessary to compete on a global stage. Omni Vision Technologies, a division of the Shanghai-based Will Semiconductor Group, supplies major smartphone manufacturers including Apple, Huawei, and Xiaomi with CMOS image sensors. Goodix Technology, established in 2002 and located in Shenzhen, is a leading global provider of biometric authentication solutions.

HiSilicon's ability to produce the Kirin 9000, the world's second 5-nanometer smartphone chipset (manufactured by TSMC), clearly demonstrates the company's technological prowess. HiSilicon relies on foreign supply chains for sophisticated chip fabrication from TSMC, chip design tools from American companies Cadence and Synopsys, and intellectual property cores from the United Kingdom's ARM. The U.S. export restriction on Huawei has made it difficult for HiSilicon to do business as usual, let alone take the technological lead. Unisoc, part of the Tsinghua Unigroup, is China's number two semicon- ductor manufacturer. When it first opened in Shanghai in 2001 to develop semiconductors for mobile phones, it went under the name Spreadtrum Communications. Unigroup purchased RDA Microelectronics in 2014, and the two companies combined to form Unisoc in 2018. Two of China's most successful fabless firms, Spreadtrum and RDA, mimicked MediaTek's strategy of offering complete solutions (including hardware, software, and expertise) to mobile phone makers. Spreadtrum and RDA, two Chinese smartphone component manufacturers, both saw considerable increases in their market shares by focusing on the midrange and budget segments of the Chinese market. By combining the two and receiving additional funding from Unigroup, Unisoc has a great chance

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to become a national leader in IC design. However, it is difficult for Unisoc to improve its technology because it has not yet broken into the supply chains of any major smartphone makers.

Creating Memory Chips

Among the most ubiquitous types of semiconductors in today's electronics are memory chips like NAND flash memory and DRAM (dynamic random access memory). It stands to reason that memory chips, being produced in such high quantities, would be a prime candidate for import replacement. Many initiatives have been made over the years by China to increase local manufacture of memory chips, but the country has had only little success so far. Both Huahong-NEC and SMIC experienced significant losses from the DRAM market's extreme volatility in its early stages, prompting them to withdraw from the industry altogether (Li 2016). Earlier this year, Fujian Jinhua, supported by the provincial government of Fujian, planned to enter the DRAM market through a joint venture with UMC. Jinhua's inclusion in the Entity List in 2018 put an end to the project.

Two Chinese startups—Yangtze Memory Technology Co. (YMTC) and ChangXin Memory Technologies—are responsible for China's recent success in domestic fabrication of memory chips (CXMT). Formerly known as Wuhan Xinxin Semiconductor Manufacturing Co. (XMC), YMTC is an IC foundry founded in 2006 under SMIC's management and a contract manufacturer of NAND flash memory for the American firm Spansion (Li 2016). In 2014, XMC began researching and developing 3D NAND flash memory, but the company didn't have enough money to invest in factories until 2016. Tsinghua Unigroup purchased XMC in 2016, becoming YMTC. Unigroup and the National IC Fund provided YMTC with a substantial investment, allowing the company to rapidly expand its research and development and production capabilities. As of the year 2018, YMTC had begun manufacturing 32-layer 3D NAND memory on a large scale. YMTC's 128-layer 3D flash memory, created in-house and on par with that of top Korean manufacturers, will be released in 2020.

A leading independent device manufacturer (IDM), CXMT focuses on producing DRAM. The Hefei city administration and the Beijing-based NOR flash mem- ory design business GigaDevice formed the company in 2016. CXMT created 19-nanometer DRAM chips by combining that company's in-house R&D with the technology and patent portfolio it bought from Qimonda, a bankrupt German DRAM manufacturer. China's first DRAM chip on par with

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international standard technology, the 8Gb DDR4 DRAM module, went into mass production at CXMT in September 2019.

Semiconductor Fabrication Tools

Over the last three decades, China has built a reasonably full semiconductor supply chain, but the country has paid far less attention to its capital equipment sector. As a result, Chinese chipmakers have had to rely on foreign machinery. This is in part due to the relatively tiny local market for equipment. In its initial phase, the National IC Fund made investments in a variety of equipment manufacturers; in its second phase, the Fund intends to direct a large portion of its resources into the semiconductor equipment industry. There are already a few Chinese semiconductor equipment manufacturers, although they are still far behind industry giants like Applied Materials, ASML, and LAM Research.

In 2019, NAURA Technology Group's sales topped 4 billion RMB, which is equivalent to over 700 million USD. This makes it the largest manufacturer of semiconductor equipment in China. In 2017, NAURA was established via the consolidation of several significant pre-reform era capital equipment clusters in Beijing, all of which produced semiconductor equipment. Leading Chinese foundries including YMTC, SMIC, and Huahong rely on NAURA for oxidation/diffusion furnaces, various etchers, and cleaning equipment in IC manufacturing.

Yet another prominent Chinese semiconductor equipment manufacturer is Advanced Micro-Fabrication Equipment Corporation (AMEC). Since China is the world's largest producer of both LEDs and solar photovoltaic cells, the company was founded in Shanghai in 2004 by a group of returnees from Applied Materials. The company's main business is supplying etchers and MOCVD machines, though a large share of its sales goes into LED and photovoltaic chip fabrication. However, AMEC invests substantially in R&D with the money it makes from the LED and PV sectors, and it has created cutting-edge etching equipment for a cutting-edge 7-nanometer production process.

The lithography machine is a crucial tool for integrated circuit production. EUV technology, utilised for the 7-nanometer process node and lower, is exclusive to lithography machines manufactured by ASML of the Netherlands. Shanghai Micro Electronics Equipment Co. (SMEE) is the most cutting-edge of China's lithography equipment manufacturers; it offers machines with a 90-nanometer process technology. The technology behind SMEE's promised 28-nanometer lithography will not have been put through its paces due to the company's low production, but that shouldn't stop you from getting excited about 2021.

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The Elements Necessary to Create Semiconductors

China has recently invested heavily in semiconductor materials in order to meet the rising demands of domestic foundries. Many established chemical producers have branched out into providing the electrical specialised gases required for IC fabrication, and a number of new businesses have developed in this space. ZingSemi, headquartered in Shanghai, was formed in 2014 by Richard Ru-Gin Chang, the creator of SMIC. They are the largest Chinese silicon wafer manufacturer. ZingSemi introduced China's first domestically produced 12-inch silicon wafers in 2018, ending China's utter reliance on imported 12-inch wafers for IC fabrication. National Silicon Industry Group (NSIG) is now the largest semiconductor material provider in China, formed by the merger of ZingSemi and many wafer producers and chemical suppliers in 2015.

Design and Development Instruments

China's development in building a software sector to assist integrated circuit design is even more halting than the country's small but rising presence in semiconductor equipment and materials. U.S. firms Synopsys, Cadence, and Mentor Graphics hold a near monopoly on the global EDA tools industry. Among the many Chinese design firms that rely on the three firms' EDA tools is Huawei's HiSilicon. In Beijing, you'll find Huada Empyrean, China's largest and most advanced EDA firm; it's possible that Huada is the only Chinese firm able to provide full-stack toolsets for IC chip design. Despite Huada Empyrean's growth, it is still a tiny player compared to the largest three vendors. However, the leading American firms have a distinct advantage that the leading Chinese firms cannot quickly replicate: the leading EDA vendors have close relationships with foundries, allowing them to take part in the development of new, advanced process nodes and thus maintain their leads in EDA software (Fuller 2021).

Internet Protocol Central Processors

For its IP core, China depends largely on foreign technology. Only one business based in China Mainland, VeriSilicon, is among the top 10 semiconductor IP providers in the world. A group of former Silicon Valley residents settled in Shanghai in 2001 to launch a startup called VeriSilicon. The company's primary focus is on the provision of image processing IPs; this is a profitable market, but it is not particularly important to China's efforts to achieve technical autonomy.

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When designing processor chips, most Chinese semiconductor companies rely on IPs given by ARM, a UK-based company controlled by Japan's Softbank. This reliance puts the world at risk if the United States places export limitations on ARM's intellectual property or if an American business acquires ARM (as Nvidia is cur- rently in talks of acquiring ARM). Adopting the open-sourced CPU architecture RISC-V, in the development of which Chinese enterprises have played an active role, is one way to lessen reliance on foreign suppliers.

CONCLUSION

China's semiconductor sector is on the rise thanks to decades of investment and growth. It is shown in this chapter that the Chinese semiconductor industry has a foothold in all three stages of IC production: design, fabrication, and packaging and testing. Given that the United States has continually restricted the shipments of modern machinery to China, it is surprising that China has established such a full supply chain for semiconductors, even if not all of its capabilities are cutting edge or even mainstream. However, the supporting industries of capital equipment and software tools are particularly weak links in China's semiconductor supply chain.

American superiority in capital equipment and EDA tools, in contrast to Chinese inferiority, has been exploited by the United States government in its current chokepoint policy. Implementation of such measures through a significant increase in export limits on chips and equipment to China is guaranteed to impede China's technical growth and reduce the commercial competitiveness of Chinese businesses. However, Chinese firms will have enough short-term resilience thanks to a reasonably full local semi-conductor supply chain. The irony is that Chinese businesses are now more in line with their government's aim of indigenous innovation than they were a decade ago, thanks to the pressure of current U.S. policies. Over time, the Chinese government and businesses would hasten the process of de-Americanizing technology.

However, if China wants to rule the global semiconductor sector, it may face some difficulties in the near future. China faces substantial challenges in catching up in sophisticated semiconductor production, despite the fact that Chinese enterprises stand to gain more from the huge local market since they are more likely to acquire chips, equipment, materials, and software from domestic sources. Whether it's TSMC's state-of-the-art foundry, ASML's lithogra- phy machine, or American-made EDA tools, the technological advantages now held by the industry's top companies are extremely difficult to replicate. China has an advantage in

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the U.S.-China technological race because to its whole supply chain, but it can't and shouldn't aspire to control the entire semiconductor market. While semiconductor technology will remain crucial during the next decade, it's possible that the race between the United States and China in the field of technology won't be decided by the diminishing nodes of silicon-based transistors. Innovating quantum computers and third-generation semiconductors may hold the greatest promise and danger for both China and the United States (also called wide band gap semiconductors). As a result of the architectural shifts necessitated by these new technologies and materials, the technological advantages of currently dominant businesses in the information technology sector will quickly become obsolete. This suggests that the United States and China should compete with one another in the realm of research rather than in the realm of trade policy.

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