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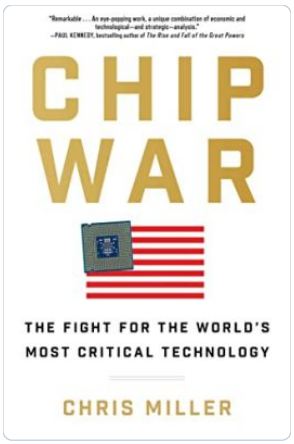

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Chip War

The Fight for the World's Most Critical Technology

Chris Miller • • 463 pages

Industries / Technology Industry
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Take-Aways

- The miniaturization and fabrication of silicon chips – semiconductors – eclipses every engineering feat in modern history.
- A series of discoveries and inventions built the semiconductor industry.
- Starting in 1963, US chip companies opened production facilities in Asian nations offering lower labor costs than domestic manufacturers.
- The US Defense Advanced Research Projects Agency (DARPA) supported chip development to build military advantage.
- Leading advanced chip maker TSMC is a subsidized success story that makes Taiwan increasingly important, internationally.
- More and more firms are designing semiconductors and outsourcing their production to TSMC and other fabricators.
- China depends on chips and other tech products designed in Silicon Valley.

Recommendation

The chip industry's importance extends beyond consumer electronics. Historian Chris Miller argues that integrated circuits or silicon chips – semiconductors – are critical to strong national economies and modern militaries. As of the 1960s, many US firms began making chips in East Asia, notably Taiwan. Miller says the island's future and the possibility of conflict with China may hinge on how China pursues its goal of reducing its reliance on imported chips and other tech. Though he does not shy away from technical details, even nontechies will appreciate and understand his cogent analysis.

Summary

The miniaturization and fabrication of silicon chips – semiconductors – eclipses every engineering feat in modern history.

In 1961, Fairchild Semiconductor, a company located south of San Francisco, California, in the area that would become Silicon Valley, introduced a silicon chip with four transistors. Today, the silicon chip in the Apple iPhone 12 has 11.8 million transistors.

Only a few companies control production of advanced silicon chips, also known as integrated circuits or semiconductors. China is spending heavily to develop its domestic semiconductor industry in hopes of loosening the "stranglehold" the United States and its allies enjoy over the global supply of microchips.

> *"China was disadvantaged... by the government's desire not to build connections to Silicon Valley, but to break free of it."*

Silicon Valley remains the "epicenter" of the chip industry. But the Taiwan Semiconductor Manufacturing Company (TSMC) now fabricates nearly all the most sophisticated processor chips.

A series of discoveries and inventions built the semiconductor industry.

In 1945, William Shockley, a physicist from Palo Alto, California, first theorized that the qualities of semiconductors could make them a better alternative to mechanical switches.

John Bardeen, the only two-time winner of the Nobel Prize in Physics, and physicist Walter Brattain proved Shockley's theory in 1947 by controlling electric current across a piece of germanium at AT&T's Bell Labs subsidiary. The company called the device a transistor. When Shockley won a Nobel Prize in 1956 for his semiconductor theory, its practical application remained unclear, however.

In 1958, Jack Kilby, an engineer at Texas Instruments in Dallas, discovered that, instead of making a separate semiconductor for each transistor, many transistors could reside on the same piece of germanium or silicon as an "integrated circuit," known as a "chip."

After Jay Lathrop joined Texas Instruments in 1958, he and his assistant James Nall used the lens of a microscope and photoresists – chemicals activated by light – to "print" patterns on germanium. With this

process, which he called photolithography, Lathrop made transistors that were substantially smaller than any previous versions.

Starting in 1963, US chip companies opened production facilities in Asian nations offering lower labor costs than domestic manufacturers.

Fairchild Semiconductor shipped chips to Hong Kong for assembly in 1963, thus becoming the first of many US semiconductor firms to send chip assembly offshore to Asia. Fairchild initially paid its Hong Kong workers 25 cents an hour.

In 1965, Fairchild semiconductor co-founder Gordon Moore predicted that the maximum number of transistors on a single computer chip would double every year until 1975. His predicted growth rate in chip power, known as "Moore's Law," has proven true for more than 50 years.

In 1968, Bob Noyce and Gordon Moore left their jobs at Fairchild and founded the semiconductor company Intel in Silicon Valley. Two years later, Intel introduced its first product: a dynamic random access memory (DRAM) chip. Intel expanded its semiconductor product line to include the 4004, which it identified as the first microprocessor: a "computer on a chip" that combined the functions of a logic chip and a memory chip.

By the end of the 1970s, semiconductor assembly plants were operating in Asian countries that hosted US military bases, including the Philippines, Singapore, South Korea and Taiwan.

United States government policy after World War II supported Japan's redevelopment as a center of science and technology in "an American-led system." However, when Japan surpassed the United States in chip production in 1986, the Defense Department saw semiconductor producers subsidized by the Japanese government as a threat to US national security. By then, Japan controlled 70% of the global market for lithography equipment. US companies sought less expensive chip suppliers than those from Japan.

Samsung's leader, Lee Byung-Chul, developed the company into a leading force in the semiconductor industry after 1983, when South Korea's government pledged to invest $400 million in its developing domestic chip industry. Intel and other Silicon Valley companies reduced their dependence on Japanese chip manufacturers by arranging for Samsung to make chips under their brand names.

The US Defense Advanced Research Projects Agency (DARPA) supported chip development to build a military advantage.

Silicon Valley businessman William Perry foresaw the transformative military potential of microprocessors in 1977, when he joined the US government as undersecretary of defense for research and engineering. He pushed for upgraded weaponry, including improved guided missiles, through the agency known as DARPA, the Defense Advanced Research Projects Agency.

Physicist Carver Mead worked with Lynn Conway, a computer architect at Xerox, to develop the rules-based foundation for the computer software that automates the task of designing chips. Conway taught this methodology at MIT. Each student designed a chip and sent it to a fabrication facility, or "fab," which turned the designs into "fully functioning chips."

DARPA responded to this technological milestone, known as the "Mead-Conway Revolution," by financing a program that enabled researchers at universities to design chips for production in highly advanced fabs. Sustaining a military advantage for the United States motivated DARPA to "keep Moore's Law alive."

In 1963, the KGB established a new division, Directorate T. According to a CIA report, its mission was to acquire Western technology and equipment, with a focus on the production of integrated circuits. The Soviet Union stole semiconductors to copy their designs, but failed to achieve large-scale production. This failure led its military leaders to minimize the use of electronics in military gear. The USSR's "copy it" strategy backfired because it cemented the United States's technological lead.

> *"Key chipmakers from America's Intel to Taiwan's TSMC have now cut off the Kremlin."*

America showcased the chip enhanced power of its military at the start of the Persian Gulf War on January 17, 1991, when F-117 bombers entered Iraqi airspace and targeted Baghdad. The bombers used Sidewinder air-to-air missiles with semiconductor driven guidance systems that were six times more accurate than the Vietnam era version of the Sidewinder.

Leading advanced chip maker TSMC is a subsidized success story that makes Taiwan increasingly important, internationally.

Starting in the 1960s, Taiwan took deliberate steps to join international supply chains for semiconductors and fortify its security arrangement with the United States. By the 1990s, the dazzling development of Taiwan Semiconductor Manufacturing Company was well under way. TSMC emerged as a government backed success story that has made Taiwan increasingly important to the rest of the world.

> *"'Globalization' of chip fabrication hadn't occurred; 'Taiwanization' had."*

Morris Chang was 54 when he left Texas Instruments to take charge of the chip industry in Taiwan on behalf of its national government. In 1985, he became the leader of the most advanced electronics research institute in Taiwan. Chang envisioned developing a semiconductor company that would fabricate chips that its customers designed, a "foundry" serving "fabless" chip design firms. At his urging, the Dutch semiconductor company Philips acquired a 27.5% stake in TSMC, and the Taiwanese government pressured rich Taiwanese citizens to invest in the company.

Shifts in the geographic distribution of chip fabrication reduced the share of chips made in US fabs from 37% in 1990 to 13% in 2010, as Taiwan, Singapore and South Korea spent heavily to boost their domestic semiconductor industries.

More and more firms are designing semiconductors and outsourcing their production to TSMC and other fabricators.

In 1992, John Carruthers, an Intel research and development leader, realized the industry would need new types of lithography tools to make transistors small enough for the next generation of semiconductors. He wanted to use extreme ultraviolet (EUV) light – with a wavelength of 13.5 nanometers – to make chips.

Intel never made its own EUV lithography tools. American manufacturers withered in competition with their Japanese rivals, Nikon and Canon. However, neither Nikon nor Canon developed these tools using extreme ultraviolet light. The Dutch company ASML thus became the sole producer of EUV lithography tools.

Japan surpassed the United States in memory chip production in the late 1980s. More recently, the US share of global production of logic chips has plunged. Today, building an advanced logic fab costs $20 billion, an enormous capital investment that few firms can afford.

"Fabless" chip firms that design semiconductors and outsource production to TSMC and other foundries have proliferated since the late 1980s. Apple has gained more than any other company from this outsourcing trend. Apple relied on Samsung to design and produce chips for initial versions of the iPhone. It relied on other companies to design chips for such functions as memory, audio processing and signal amplification.

Intel, Samsung and TSMC had ample financial strength to integrate EUV-based lithography successfully into their foundry operations. But Intel fumbled an opportunity to become a dominant chip company in the EUV arena. By 2020, TSMC had half of the EUV lithography tools in the world, and Intel had "barely begun" to use EUV at its chip fabrication facilities. As a result, only Samsung and TSMC produce today's most sophisticated processors.

China depends on chips and other tech products designed in Silicon Valley.

China remains deeply dependent on chips and other products tech companies design in Silicon Valley and manufacture in the United States or in US allied nations. For example, the Chinese government uses artificial intelligence to track dissidents, but its surveillance technology relies on chips from such American companies as Intel and Nvidia.

China's government devised a plan, called Made in China 2025, with a goal of increasing domestic chip production and reducing reliance on imported chips over 10 years ending in 2025. Taiwanese tech company leaders worried that China would extend its "red supply chain" to include a bigger piece of the semiconductor industry. The Chinese state owns and finances many entities that portray themselves as private equity investment firms, but constitute a collective effort to "seize foreign chip firms."

Huawei is a Chinese maker of telecom devices that form the infrastructure of mobile online communications, including radios on cellular phone towers. The company was once a leading seller of smartphones. Huawei is now among the three largest sellers of cell tower equipment, along with Nokia in Finland and Ericsson in Sweden.

> *"China looks likely to play a much bigger role in producing non-cutting-edge logic chips."*

China has made major investments to develop technologically sophisticated weapons since the US military demonstrated its heightened precision in attacking targets during the 1991 Persian Gulf War. Chinese advances in military technology include anti-ship missiles and anti-satellite weapons.

US national security concerns drove the Donald Trump administration to ban exports of US chips to Huawei; that move devastated the company. The US Commerce Department compounded the destruction

in May 2020 by banning exports of products made with US technology to Huawei. Lack of access to chips ultimately forced Huawei to sell part of its smartphone business and divest itself of its server business.

TSMC has agreed to open a new fab in Arizona, but US national security officials have strategic concerns about the Taiwanese chip fabricator. For example, they debated about such actions as pressuring TSMC to deploy new technologies in the United States and Taiwan at the same time, or to match capital expenditures in Taiwan, dollar for dollar, with those at TSMC facilities in Arizona, Japan and Singapore. In the absence of such actions, the world's dependence on Taiwan only deepens.

About the Author

Chris Miller teaches international history at Tufts University's Fletcher School of Law and Diplomacy. He is also the Jeane Kirkpatrick Visiting Fellow at the American Enterprise Institute and Eurasia Director at the Foreign Policy Research Institute. He has written several other books including: *We Shall Be Masters: Russian Pivots to East Asia from Peter the Great to Putin* and *Putinomics: Power and Money in Resurgent Russia*.