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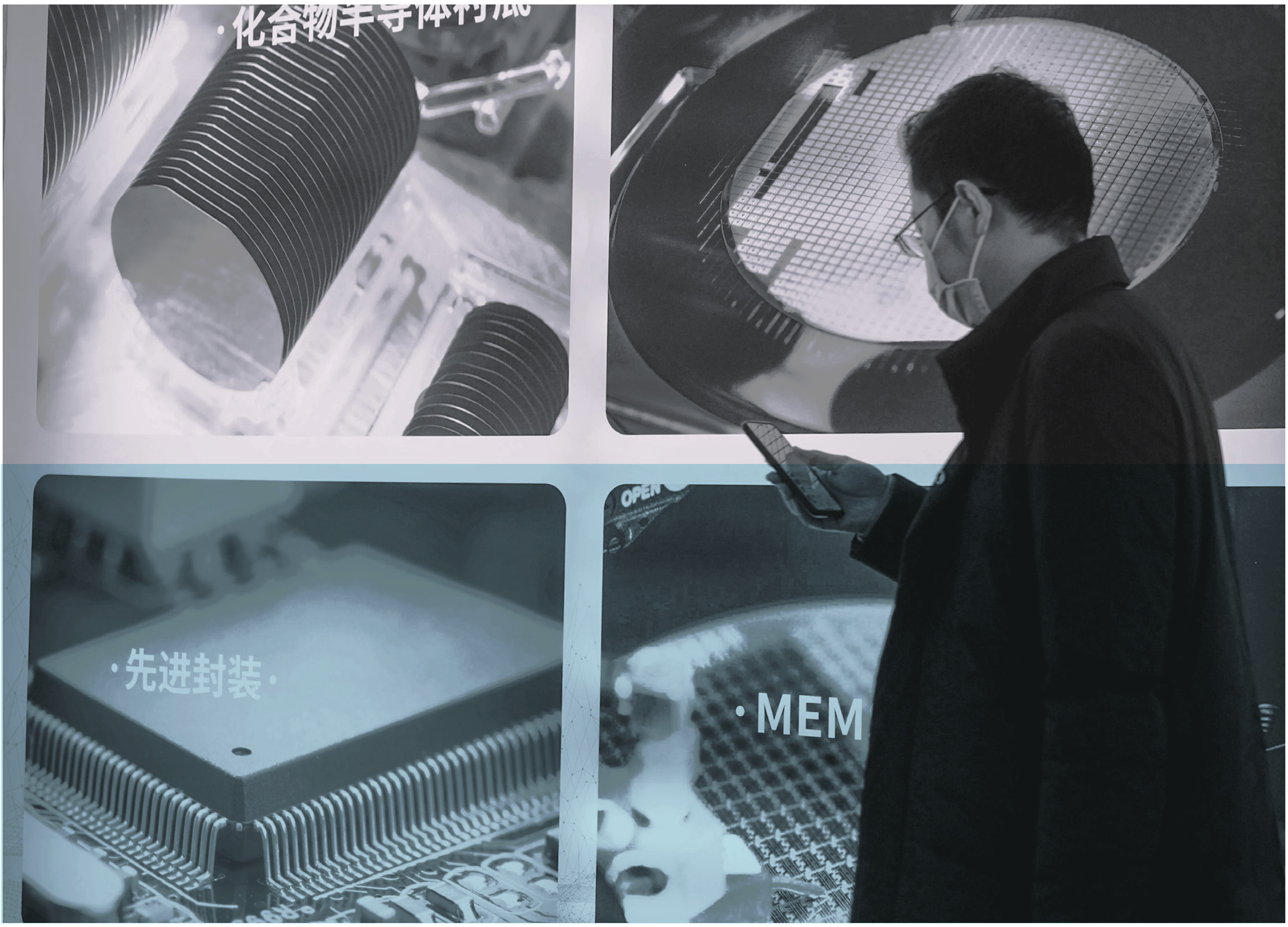
Understanding how China secured its chip stack

BY NATHAN PICARSIC AND EMILY DE LA BRUYÈRE



Contents

Introduction

China's semiconductor positioning covers the entire semiconductor value chain. Beijing has built capacity that extends from the very upstream of material inputs to the very downstream of semiconductor applications, securing both domestic self-sufficiency and international leverage.

In March 2025, a team from Peking University made waves when it announced an achievement that shattered semiconductor performance limits – without using silicon. The team's two-dimensional transistor reportedly operates 40% faster than leading 3-nanometer (nm) chips from global champions Taiwan Semiconductor Manufacturing Company (TSMC) and Intel Corp.[1]

Examples like this one suggest that China's tech innovative capacity, when paired with its dominant manufacturing strength, amounts to a formidable position to shape the next generation of the global semiconductor value chain.

Beijing's semiconductor ecosystem is accomplishing this despite American efforts both to compete with and to counter China's rise. US export controls restricting high-end technology exports to China does not appear to have stymied the efforts of Chinese researchers as much as the United States might have wanted. They have, as Chinese sources put it, encouraged Chinese innovators to "change lanes to overtake" – just as, in a different but related field, the Chinese AI firm DeepSeek has in large language models, with the potential to disrupt Silicon Valley.[2]

China's innovative and productive semiconductor capacity spells trouble for American efforts to promote supply chain security and an independent semiconductor ecosystem. None of this means that the United States, its allies, and its partners cannot still maintain their lead in high-end tech, rewire the global architecture, or develop independent supply lines. But developing an effective policy campaign to that end demands a far more robust understanding of China's current positioning and priorities.

That positioning includes a massive manufacturing advantage vis-à-vis other developed economies. It includes dominance in relatively unsophisticated but critical nodes of the semiconductor value chain from material inputs to packaging and testing. China's positioning also includes innovative capacity in under-scrutinized and asymmetric areas of the semiconductor ecosystem. And China is positioning with notable success for outright dominance in emerging, yet not quite cutting-edge, fields, like wide band gap or third-generation semiconductors that promise an important share of tomorrow's technological infrastructure.

Above all else, China's semiconductor positioning covers the entire semiconductor value chain. Beijing has built capacity that extends from the very upstream of material inputs to the very downstream of semiconductor applications, securing both domestic self-sufficiency and international leverage. As a result, any effort to compete with, and develop supply chains insulated from, China will require addressing that entire value chain, including the upstream segment of semiconductor materials.

The China challenge

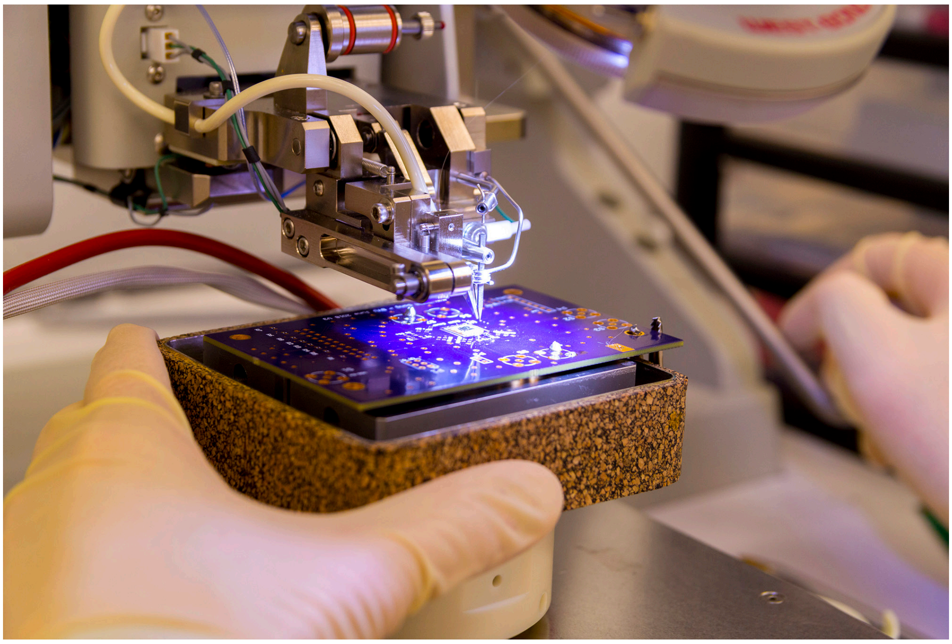
Beijing has long prioritized resolving the risks posed by foreign dependence in the semiconductor value chain and – as part of a larger industrial offensive oriented around securing asymmetric international leverage over strategic industries – has sought both to secure indigenous domestic capabilities across the value chain and to shore up nodes of absolute global dominance.

Semiconductors are critical in existing and emerging technologies including artificial intelligence. They are critical to national security: Semiconductors are essential in military hardware ranging from unmanned aerial vehicles (UAVs) to fighter planes.[3]

In microelectronics, perhaps more so than in any other technological domain, economic and supply chain security are intertwined with national security. Semiconductors are inherently dual-use. Sophisticated military systems rely on the same semiconductors that fuel civilian consumer goods.[4] All semiconductors rely on a complex, global, and interconnected value chain.

The semiconductor production process is comprised of three main steps: Design, fabrication, and assembly. Every step requires its own set of technological, equipment, and chemical and material inputs. No single country has every element of the semiconductor production stack within its borders. Rather, production of these critical goods depends on a multi-step value chain that integrates the United States, Taiwan, South Korea, Japan, Europe, and China. This global value chain – developed over generations of globalization, technological progress, firm-level capital expenditure, and production scaling – constitutes a relatively efficient global division of factors of production.

But those efficiencies sacrifice policy effectiveness. They introduce resilience concerns, shocks ranging from geopolitical conflict to logistics snafus to 'black



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swan' phenomena. For example, the Covid crisis saw downstream manufacturers in the West strained for integrated circuit supply as global supply lines fractured. Geopolitical concerns abound as well: Taiwan is a key node in the global semiconductor value chain. Taiwan's pure-play foundry, TSMC, holds an unrivaled position in that value chain. This introduces a single point of geographic failure – and a vulnerable one considering China's designs on reunification with the island it considers a "renegade province" – that could shut down the world overnight.

Beijing has long prioritized resolving the risks posed by foreign dependence in the semiconductor value chain and – as part of a larger industrial offensive oriented around securing asymmetric international leverage over strategic industries – has sought both to secure indigenous domestic capabilities across the value chain and to shore up nodes of absolute global dominance. As early as 2006, China's National Medium- and Long-Term Science and Technology Development Plan Outline, issued by the State Council, established two semiconductor-focused National Major Science and Technology Projects. The first was oriented around developing new technological advantages to "catch up with the rapid development of international technology and industry in the field of chips, software, and electronic devices" in order to "form a high-tech research and development and innovation system with international competitiveness." The second prioritized self-reliance. Its goal was to "master complete sets of advanced technology and related new material technologies" in order to "break China's dependence on imports of high-end integrated circuit manufacturing equipment and processes."

The goal of this Chinese approach is to ensure that the world depends on China for semiconductors but that China does not depend, or depends much less, on the rest of the world. Should Beijing succeed, it would secure a trump card in international competition –the ability, effectively, to turn off, or threaten to turn off, the industrial and technological capacity of an opposing party.

As this effort has progressed, the United States and the West have begun to wise up to the risks. They have begun to make corresponding investments in securing domestic capability. The CHIPS and Science Act and corresponding US government support for fab expansion in the United States stand out as US attempts to reduce exposure to China in semiconductor supply lines. On the defensive side, the United States has drastically expanded export controls on the flow of US-generated and -controlled technology to China.

Despite US government interventions, Beijing has only continued to expand its capabilities and leverage. The global semiconductor layout has a dangerous reliance on China hardwired into it. And US government efforts thus far have not changed that.

The vulnerability in the semiconductor value chain

At a surface level, the United States is a leader in the international semiconductor industry, boasting major, downstream, high-tech brand names like Intel, Micron, and Qualcomm. Intel has led the industry for a generation; it still registers among the world's largest semiconductor companies by revenue. In a different segment of the semiconductor value chain, US companies also maintain a near-monopoly over global Electronic Design Automation (EDA) software tools, on which leading-edge chip design depends.[5] And the United States is home to some of the world's

US semiconductor national champions depend on Chinese production, testing, and packaging as well as Chinese downstream electronics product assembly. This grants Beijing the ability to disrupt the operations of US champions as well as influence their boardrooms.

major equipment vendors, including Applied Materials, KLA, and Lam Research.[6] In 2023, the United States claimed more than 50% global market share of integrated circuits, based on total sales.[7]

But this superficial downstream leadership belies a set of major dependencies. First, US semiconductor national champions depend on Chinese production, testing, and packaging as well as Chinese downstream electronics product assembly. This grants Beijing the ability to disrupt the operations of US champions as well as influence their boardrooms. Second, the upstream of the international semiconductor value chain disproportionately relies on Chinese inputs. This means that the industry is built on a foundation controlled by Beijing. Third, China is actively targeting and developing a dominant position in emergent semiconductor fields likely to have outsized future industrial applications.

And finally, across the board, even in areas where the United States does have an advantage, the trends are not in its favor: China is eating away at the US edge. For instance, in 2020, China's semiconductor design market share was 9% of the global total, compared to 46% for the United States. According to the Semiconductor Industry Association, those figures are projected to be 23% and 36%, respectively, in 2030.[8]

China's strongholds

China has built a dominant position in semiconductor-relevant raw materials, the outsourced assembly and test market, and select legacy logic chip fabrication nodes of the semiconductor value chain. At the same time, Beijing has been rapidly expanding its position in memory chip fabrication and its localization of production by international players. The result is a pincer of dependence whereby

Taiwan's pure-play foundry, TSMC, holds an unrivaled position in the semiconductor value chain. This introduces a single point of geographic failure – and a vulnerable one.

China dominates international production of electronic components and the sub-systems and commercial products built on top of them. As a result, most US and international semiconductor vendors have some degree of dependence on manufacturing facilities in China.

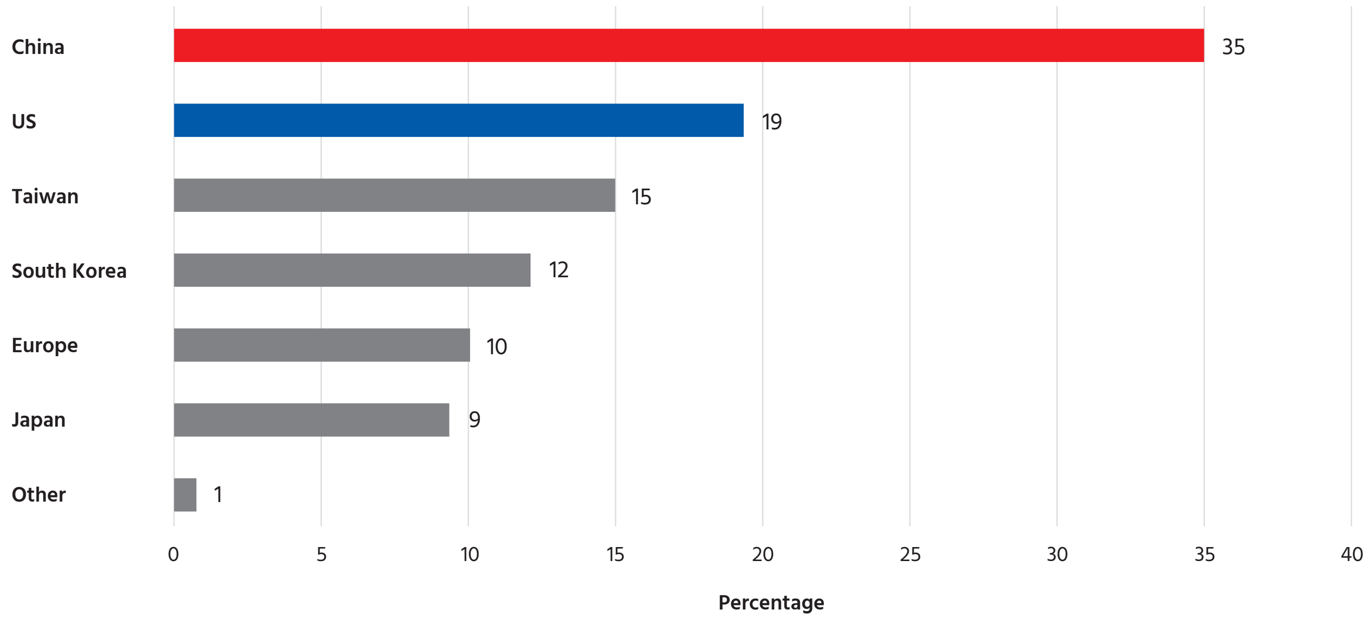
the Chinese economic system enjoys leverage over the global semiconductor value chain by virtue of both supply and demand. For all the cutting-edge capability of US and other international champions, they overwhelmingly depend on China for upstream materials, manufacturing facilities, packaging and testing, and, ultimately, their sales.

China is the leading international producer and processor of a wide range of semiconductor-relevant raw materials, including gallium, germanium, magnesium, natural graphite, scandium, tungsten, and the entire range of rare earth elements.[9] In the mature process market (>22 nm), China is nearing parity with Taiwan with upward of 30% of global market share. That standing is projected to reach nearly 40% and likely overtake Taiwan by 2030.[10] In packaging and testing, China is similarly rising toward convergence with Taiwan, with the mainland expected to account for nearly 23% of the global market by 2027.[11] And in packaging alone, China leads the world with a 38% market share.[12]

China's true strength in numbers registers even more clearly downstream. China dominates international production of electronic components and the sub-systems and commercial products built on top of them. As a result, most US and international semiconductor vendors have some degree of dependence on manufacturing facilities in China. They also sell their products back into the Chinese market.

Intel offers an example. Intel is an American corporate success story. The company has expanded production facilities in the US. Intel directly supplies the Department of Defense;[13] it also cooperates with key defense contractors, like Lockheed Martin, on military technologies.[14]

Figure 1 – Global semiconductor sales by location of assembly



Source: US Comtrade; BCG x SIA: Strengthening the Global Semiconductor Supply Chian in an Uncertain Era

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At the same time, Intel's business layout reflects the globalized nature of the semiconductor value chain and China's enduring, central role therein. Intel's website lists 12 campuses in China.[15] In October 2024, Intel announced that it intended to invest US$300 million to expand its chip packaging and testing base in Chengdu – despite one month earlier having paused plans for new factories in Germany and Poland.[16] Intel also relies on a host of Chinese suppliers. In 2023, China accounted for 27% of Intel's revenue, compared to 26% for the United States.[17]

These ties in terms both of production and sales grant China's semiconductor value chain proximity to Intel's operations and therefore access to downstream US industrial applications built on top of them. Disruptions to the semiconductor value chain in China impact Intel production: In September 2021, forced power shutdowns imposed by the Chinese government compelled key Intel suppliers in China to shut down their facilities.[18] And Intel's revenue stream requires that it remain in favor with the Chinese Communist Party. In January 2022, Intel removed reference to Xinjiang, a sensitivity for Beijing, from its annual letter after facing backlash from China.[19] Nor is this a vulnerability unique to Intel. Micron, the major US manufacturer of memory chips, had to halt production at its Xi'an, China, manufacturing facility in December 2021 as Covid-19 shut down the city.[20]

Nor are these dependencies on China limited to US-domiciled companies. Other international semiconductor companies risk even greater exposure to Chinese industrial influence. Take, for example, TSMC, the world's most valuable semiconductor company by market capitalization, much lauded as a CHIPS Act success for launching new facilities in Arizona.[21] China serves as a critical manufacturing hub and revenue generator for TSMC; the company has supply relationships with customers across China's downstream markets; and TSMC invests in and alongside semiconductor-relevant Chinese government-guidance funds.

The China exposure of stalwarts like TSMC and Intel should come as no surprise. The semiconductor value chain was globalized over the past generation, prior to widespread alarm over the supply chain security and geopolitical risks posed by China. But those dependencies appear not to be fully factored into Western industrial strategy on either the offensive (promote) or defensive (protect) sides of effort.

A leapfrog gambit

The elevation of wide bandgap semiconductors in China's highest-level blueprint for strategic development kicked off a wave of supporting, operationalizing policies and plans. These have outlined financial support measures for companies, market share and technological targets, and industrial initiatives.

China's extant semiconductor production capacity is primarily dedicated to mature node and consumer electronics applications spaces. That foundation is formidable. Recent South Korean analysis has found that, for example, China's memory chip capacity has overtaken a field previously led by Korea's Samsung and SK Hynix.[22] Beijing is also adept at identifying in-demand growth areas like data centers and artificial intelligence, toward which it can direct its mature node technologies, and do so on a relatively blank competitive canvas, and then scaling to that end.

Third-generation semiconductors constitute a compelling case. Third-generation semiconductors refer to materials, and integrated circuits made with them, that have wide energy bandgaps – and that are therefore able to handle higher power levels, temperatures, and voltages than silicon semiconductors. Common examples include gallium nitride, silicon carbide, and indium phosphide. The performance characteristics of these materials make them particularly well-suited to emergent and high-growth applications including electric vehicles, data centers, and renewable energy production.[23] As a result, third-generation semiconductors present billion-dollar addressable markets in the immediate term and are projected to see considerable growth rates in the years ahead.[24]

While third-generation semiconductors constitute a relatively new field and one with applications to new industries, their properties are not necessarily at the bleeding edge of design and fabrication. And Beijing has prioritized the field. In a May 2023 speech, Xiang Libin, vice minister of China's Ministry of Science and Technology (MOST), highlighted China's emphasis on and support for third-generation semiconductors:

> "Third-generation semiconductors represented by silicon carbide and gallium nitride have excellent performance and have huge potential in new energy vehicles, information communication, smart grids, and other fields. The Ministry of Science and Technology has always attached great importance to the technological innovation and industrial development of third-generation semiconductors and has given the field long-term continuous support since the Tenth Five-Year Plan period."

This emphasis and support are reflected in China's 14th Five-Year Plan period (2021 to 2025), which explicitly elevated wide bandgap semiconductor materials, namely silicon carbide and gallium nitride, to the level of national strategy, calling to "develop silicon carbide, gallium nitride, and other wide bandgap semiconductors."

Prioritization in government strategy has translated into competitively oriented action. The elevation of wide bandgap semiconductors in China's highest-level blueprint for strategic development kicked off a wave of supporting, operationalizing policies and plans. These have outlined financial support measures for companies, market share and technological targets, and industrial initiatives. They have prioritized the entire wide bandgap semiconductor value chain, including applications. For example, Shanghai's 2022 "Action Plan to Build a Future

The reliance of US data center hyperscalers on a Chinese third-generation semiconductor company could bind an increasingly critical element of the US tech ecosystem to Chinese supply, and in a field that is at present well below the radar of US "chip war" discussions.

Industrial Innovation Highland to Develop and Expand Future Industrial Clusters" described an end-to-end focus from upstream to downstream:

> "Promote the development of silicon carbide, gallium nitride, and other wide bandgap semiconductor compounds; improve the energy level and mass production scale of crystal preparation technology of wide bandgap semiconductor compounds; actively lay out the wide bandgap semiconductor wafer manufacturing technology; enhance the product design ability of wide bandgap semiconductor chips; and expand the application fields."

Chinese policies, plans, projects, and discourse have also been clear about the objective: to establish Chinese dominance in the wide bandgap semiconductor industry. For example, the Shenzhen Action Plan to Cultivate and Develop Semiconductor and Integrated Circuit Industry Clusters (2022-2025) describes a gallium nitride and silicon carbide project intended to "seize the commanding heights of the industry and enhance product market dominance and voice." Beijing's Zhongguancun Science Park has declared its intention to accelerate the construction of Zhongguancun Shunyi Park as a third-generation semiconductor industry cluster with global influence," with an emphasis on silicon carbide, gallium nitride, gallium oxide, and diamond."

China's industry discourse parallels national and local policy. Zhang Rujing, the founder of state-owned chip foundry Semiconductor Manufacturing International Corp., has called third-generation semiconductors an area in which China can "overtake on the straight."[25] And Yu Chengdong, former chief executive officer of Huawei's consumer business, said that China hopes to "achieve leadership in a new era" of third-generation semiconductors.[26] Founder Securities Research Report, an industry analyst, wrote in a 2020 report that: "The gap between third-generation

Beijing is adept at identifying growth areas like data centers and artificial intelligence, toward which it can direct its mature node technologies, and do so on a relatively blank competitive canvas.

The utility of third-generation semiconductors for processing aligns neatly with the demands of contemporary critical, and growing, applications. And China has been quietly developing a decisive upper hand in third-generation semiconductors for years. This presents Beijing with a leapfrog opportunity.

semiconductors at home and abroad is not as obvious as that of first- and second-generation semiconductors. Domestic manufacturers hope to catch up with foreign manufacturers and complete domestic substitution."[27]

China's emphasis on third-generation semiconductors has yielded domestic champions in the field. Take, for example, the photonic integrated circuit module company Zhongji Innolight (Innolight). Unlike companies like SMIC and Huawei, Innolight is far from a household name in the West. But, building on third-generation semiconductor technology, and indium phosphide in particular, it is the world's leading provider of optical module solutions, small hardware that helps to network data centers and transmit high-throughput data flows that propel cutting-edge artificial intelligence applications. Innolight is also the only manufacturer in China that mass-produces and supplies 100-gigabit data center optical modules, occupying the industry's technological upper bound. Innolight has also become a key provider for major US and other international tech, including Big Tech companies developing data centers. As a Chinese industry observer put it, "Innolight has made a full-scale layout in going overseas and finally achieved counterattack." That source explained that Innolight began by "seizing overseas demand, then 'bound' overseas key customers as they sought to take advantage of the cloud computing era, and now is cementing this positioning through capacity expansion and organizational adjustments.[28] This reliance of US data center hyperscalers on a Chinese third-generation semiconductor company, could bind an increasingly critical element of the US tech ecosystem to Chinese supply, and in a field that is at present well below the radar of US "chip war" discussions.

The third-generation semiconductor ecosystem also provides examples of Beijing using its underappreciated semiconductor dominance for offensive geopolitical ends. Gallium nitride is a key material in third-generation semiconductors. And China is the dominant global gallium producer, accounting for approximately 98% of the world's supply. For years, China has cultivated this advantage and described it as a trump card in the evolving semiconductor competition.

More recently, as that competition has heated up, Beijing deployed this advantage. In December 2024, in retaliation against United States technology restrictions, Beijing imposed export restrictions on gallium to the United States.[29]

In short, third-generation semiconductor technology does not rely on the most cutting-edge of ever-shrinking transistor size. It does not represent a foray into the technological unknown. The utility of third-generation semiconductors for processing aligns neatly with the demands of contemporary critical, and growing, applications, like data centers and electric vehicles. And China has been quietly developing a decisive upper hand in third-generation semiconductors for years, leveraging its materials advantages, its manufacturing capacity, and an emphasis on cultivating research and commercial champions. This presents Beijing with a leapfrog opportunity. It threatens both to exacerbate and lock in global dependence on Chinese semiconductor inputs in some of today's hottest technological and industrial domains. Across the board, the third-generation semiconductor case underscores the futility of a US semiconductor industrial policy that does not account for China's layout.

The path ahead

If the United States is able to better understand China's capabilities and positioning, it will conclude that the current semiconductor contest is not simply one for the cutting edge of the value chain's downstream, like chip design capabilities, or even for midstream nodes of that value chain, like chip production. Rather, Beijing is competing for the entire value chain.

What, then, does this mean for the United States as it attempts to face down the China challenge?

The first deficit that United States policy, and investment, needs to address is inadequate understanding of the Chinese semiconductor and microelectronics ecosystem. At present, the United States does not sufficiently understand how China is positioned, what China is doing, or to what end. Rather, Washington has a propensity to mirror-image. Washington assumes that Beijing and its corporates approach the semiconductor, and larger technological contest, the same way that Washington and its private sector do; that challenges will be symmetric; that the two sides are running in the same direction in a straightforward race.

If the United States is able to better understand China's capabilities and positioning, it will conclude that the current semiconductor contest is not simply one for the cutting edge of the value chain's downstream, like chip design capabilities, or even for midstream nodes of that value chain, like chip production. Rather, Beijing is competing for the entire value chain. Beijing is also competing to scale relatively proven technologies and processes, like third-generation semiconductors and chip packaging and testing, that have clear market demand, growing market demand, and, in many cases, a relatively low profit margin that decreases overall competition and allows China to cement a monopoly. And throughout, Beijing is prioritizing the upstream: both innovation in and production of the material foundation for semiconductors.

At present, the United States does not sufficiently understand how China is positioned, what China is doing, or to what end. Rather, Washington has a propensity to mirror-image.

If Washington is going to respond to the reality of China's semiconductor challenge, it will have to change the overall economics of the domestic, and international, semiconductor industry. It will have to guarantee the long-term economic viability of trusted semiconductor research, development, and production all along the value chain.

US policy is out of touch with this competitive reality. None of these are directions that Washington has prioritized to date. Beijing's approach and positioning create a challenge too big to be addressed by the sort of direct subsidies and grants laid out in recent US policies like the CHIPS Act.

If Washington is going to respond to the reality of China's semiconductor challenge, it will have to change the overall economics of the domestic, and international, semiconductor industry. It will have to guarantee the long-term economic viability of trusted semiconductor research, development, and production all along the value chain – so that those projects can attract capital and be scaled along economically viable paths. The way to do this is not direct government support.

Rather, this is a defensive project as far as government intervention is concerned. The effective government policy is to increase the costs of dependence on China, for inputs or for sales, such that capital is incentivized to support US and other trusted alternatives.

The United States already has the toolkit to do this, including tariffs and import restrictions that have already been deployed. But Washington needs to better enforce that toolkit. And that toolkit needs to be paired with bilateral trade deals with US partners that include market defenses against China such that Washington is building a robust, trusted, global trade network rather than letting the global trade network undermine its defenses.

At the same time, the government does have a role to play in more actively promoting a trusted foundation for the semiconductor supply chain; and in investing in the upstream inputs that Beijing threatens to monopolize. This is an area for direct government support because it is an area of targeted priority – and because, without rapid inroads at the upstream, the semiconductor supply chain risks locking in dependence on a China-controlled foundation. The importance of energy dominance and the role of government in securing it provide a template for government investment in the upstream of the semiconductor supply chain – the core of future energy dominance and of outsize influence in an array of downstream critical technologies like AI.

The CHIPS Act is by now likely a closed chapter in US semiconductor policy.[30] The next chapter of US tech policy should center on investments in the fuel of the semiconductor supply chain and on building a domestic and international trade system protected, in action as in name, from China's distortions.

Researchers' bios: Nathan Picarsic and Emily de la Bruyère

Nathan Picarsic

Senior Fellow, Foundation for Defense of Democracies, and Co-Founder, Horizon Advisory

Nate Picarsic is a co-founder of Horizon Advisory, a leading geopolitical and supply chain intelligence provider. His commentaries on strategy, technology, and investment have been published in outlets ranging from Bloomberg to TechCrunch.

Nate manages Futura, a fund that invests in early stage industrial innovation, and advises start-ups at Carnegie Mellon's Project Olympus. He is a Senior Fellow at the Foundation for Defense of Democracies and a Senior Visiting Fellow at the Krach Institute for Tech Diplomacy at Purdue.

He holds a BA from Harvard College and has completed executive education programs through Harvard Business School and the Defense Acquisition University.

Emily de la Bruyère

Senior Fellow, Foundation for Defense of Democracies, and Founder, Horizon Advisory

Emily de La Bruyère is a senior fellow at the Foundation for Defense of Democracies (FDD), and co-founder of Horizon Advisory, a strategic consultancy focused on the implications of China's competitive approach to geopolitics.

Emily has pioneered novel data collection and analysis tools tailored to Beijing's strategic and institutional structures. She has extensive Chinese language research and program management experience.

She has testified before the Senate Banking Committee and US-China Economic and Security Review Commission. Emily's work was the first Western analysis to document Beijing's China Standards 2035 national plan. She is at the cutting edge of US analysis on China's military-civil fusion strategy and platform geopolitics, as well as their implications for global security and the economic order. She uses primary-source, Chinese-language materials to provide insight on geopolitical, technological, and economic change for decision-makers.

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