Signal From Noise

June 20, 2024

Beyond Nvidia: Recent Developments in the Semiconductor Industry

This month we provide an update to our previous *Signal From Noise* focused on the semiconductor industry, published in November 2022.

The U.S. and Chinese government have at least one thing in common – a strong belief in the strategic geopolitical and economic importance of the semiconductor industry. Authorities in Beijing on May 28, 2024 announced a fresh subsidization effort to bolster China's domestic semiconductor industry, committing $47.5 billion of fresh investments from the country's six largest state-owned banks into the China Integrated Circuit Industry Investment Fund. This third phase of the initiative will focus on chip-manufacturing equipment and high-bandwidth memory chips. (The first phase was more generalized, while the second phase focused on companies involved in the various aspects of the fabrication process.)

Beijing's subsidies have already enabled some initial moves toward Chinese President Xi Jinping's objective of technology independence for China. Earlier this year, the country ordered its telecom companies to phase out the use of non-Chinese processors (notably, those made by Intel ($INTC) and AMD ($AMD)) in its communications networks by 2027. The government had previously issued procurement guidelines discouraging government agencies and state-owned enterprises (SOEs) from purchasing laptops and PCs powered by Intel and AMD processors.

It's reasonable to assume that Xi Jinping views this as a logical counter to U.S.-led efforts to impede China's ambitions to become a dominant technology power, even as the U.S. and its allies in Europe and Asia seek to boost their own respective semiconductor-manufacturing capabilities.

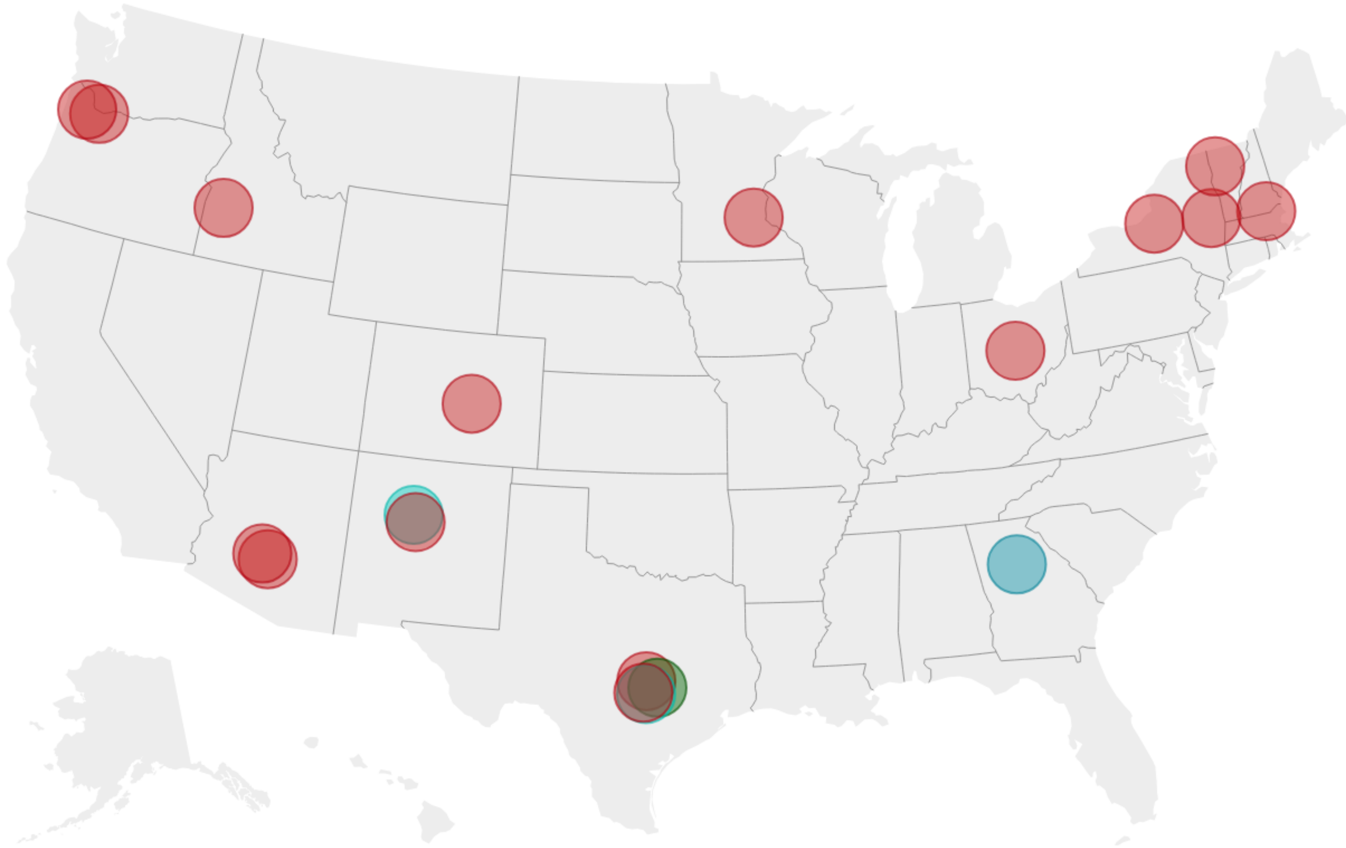
While semiconductors are obviously crucial to modern life, much of the impetus for these government efforts have been driven by Taiwan Semiconductor Manufacturing Corporation ($TSM), which a number of analysts have described as "the most important company in the world." As we have discussed previously, TSMC is by far the most advanced and most capable fabricator of semiconductors in the world – no rival even comes close. Its base in Taiwan, which China has long claimed as its territory, has made countries around the world nervous.

The U.S. came to see it as an important economic, military, and strategic priority to convince TSMC to diversify the geographical breadth of its operations and build facilities in the U.S. – not just to improve access to the company's expertise, but also to convince other semiconductor companies to make chips in the U.S. To those ends, the U.S. government passed the CHIPS and Science Act in August 2022. To date, it has resulted in roughly $45 billion in financial assistance, helping to fund and incentivize private investment in 19 projects in 12 states. Among the major recipients of this program thus far have been Intel ($8.5 billion in grants, $11 billion in loans), Global Foundries ($GFS, $1.375 billion in grants, $1.6 billion in loans), Samsung ($6.4 billion in grants), Micron Technology ($MU, $6.14 billion in grants, $7.5 billion in loans) – and of course, Taiwan Semiconductor Manufacturing Corporation ($6.6 billion in grants, $5 billion in loans). Collectively, these major recipients will use the government assistance to build as many as 16 new fabrication facilities and to modernize and expand others, including three new TSMC fabs in Arizona.

CHIPS Incentives Announcements

Preliminary memoranda of terms (PMTs) announced since December 2023

Equipment Materials Packaging R&D Semiconductors



Source: CHIPS Program Office • Created with Datawrapper

*Source: CHIPS Program Office, **Semiconductor Industry Association**. Data last updated June 12, 2024.*

In addition to trying to boost U.S. capabilities, the U.S. under President Biden has also enacted a series of export controls that restrict Chinese companies from the purchase of advanced chips and advanced chip-making equipment, such as those made by Nvidia ($NVDA) and ASML ($ASML). The new regulations also prohibit Americans (including green-card holders) from providing chipmaking expertise to Chinese companies.

While industry experts generally note that these new restrictions have had an immediate detrimental effect on China's domestic chipmaking ambitions, they have not halted it. Some observers were surprised, for example, when China's

Semiconductor Manufacturing International Corporation (SMIC) was able to manufacture semiconductors with a 7-nanometer node for Huawei's Mate 60 smartphone. (A node refers to the size of the transistors on a chip. Smaller nodes result in more capable chips because more transistors can fit on a chip of a given size. A 7-nm node is considered advanced, though not cutting edge.) News sources reported that SMIC is working to achieve a 5-nm chip.

Such resourcefulness was not surprising to some. Peter Wennick, CEO of ASML, had warned of using such tactics to counter China's rise. "There are 1.4 billion Chinese, many of them smart. They come up with solutions we have not yet thought of. You force them to become very innovative," he argued.

Still, SMIC's achievement in manufacturing what is considered an advanced processor is accompanied by a caveat – by relying on older tools and machines, SMIC's manufacturing costs probably rose by 40-50%, due in part to lower yields (the percentage of usable, largely error-free chips per wafer).

The titans in the semiconductor industry have largely continued to thrive despite prohibitions on sales to China. Giants like Nvidia and ASML are far from being able to keep up with demand from non-Chinese customers as it is. That is just one reason why investors' enthusiasm for Nvidia appears to be growing at an unabated pace.

Yet like China, a number of non-Chinese tech giants appear to have become wary of their all-but-total reliance on Nvidia and its high-priced chips. Many have taken to developing their own proprietary chips for AI research and data centers – both for in-house use and for customers, clients, and partners. For example:

- **Google ($GOOG)** has designed its own Axion CPU for data centers and AI research
- **Amazon ($AMZN)** offers a series of custom chips under the Graviton brand, designed for data centers and cloud-based services. Through Amazon's own cloud-service offerings, Graviton chips are used in the services of Amazon partners such as Elastic ($ESTC) and Datadog ($DDOG).

Microsoft ($MSFT) recently announced its Maia 100, designed for AI and machine learning; its Cobalt 100 chip, which powers Microsoft's Azure cloud platform.

Thematic Stock Ideas!

Granny Shots

With the possible exception of the Maia, the custom chips referenced above were all designed based on architectures licensed from ARM Holdings ($ARM). (An architecture refers to the high-level aspects of a chip's plan – its overall structure and organization, defining how major components are to be laid out and will communicate with each other. In contrast, a chip's design involves the implementation of the chip architecture, including determining the actual circuits and connections.)

In fact, ARM architectures have long been part of modern technology. Many of Apple's custom chips have been based on architectures licensed from ARM, and the vast majority of Android-based smartphones have ARM technology inside as well. ARM architectures have long been respected for their power efficiency and broad scalability.

However, ARM, which went public in September 2023, has benefited from the quest for alternatives to Nvidia's hard-to-get high-end chips. Importantly, ARM is not a competitor to Nvidia – Nvidia itself also uses ARM architecture in its advanced processors, and so does Intel.

It also recently changed its business model. Before, the company's revenues were generated from royalties – generally under $1 – collected for each and every chip using its designs. Recently, however, the company began charging royalties on a per-core basis. As ARM CEO Rene Haas explained, under the new business model, "if you put in 100 cores, we are getting north of $100." As an example, he pointed out that "what Nvidia has done with [its new Grace Hopper superchip] is essentially taken 72 to 144 Arm CPU cores, and bolted it to an H100."

It is worth noting that while Meta ($META) is also designing its own custom chips, its chips are designed around a RISC-V architecture rather than ARM. An increasing number of chip designers are turning to RISC-V for its customizability and cost effectiveness, not just because RISC-V architectures are open source, but because their structures tend to result in a simpler manufacturing process.

Meanwhile in Europe

The European Union is also seeking to bolster its homegrown semiconductor industry and reduce its reliance on semiconductors made by facilities in Asia. In addition to new fabs planned for Arizona, the EU has convinced TSMC to start construction of a plant in Dresden, Germany, scheduled for late 2024.

The biggest advantage for European countries seeking to boost their semiconductor industry lies in ASML, based in the Netherlands. ASML is the only company in the world that makes extreme ultraviolet (EUV) lithography machines required for the manufacture of leading-edge semiconductors. U.S. and European authorities have made blocking China's access to the company's most advanced machines a priority, not just due to ASML's current dominance, but due to the likelihood that it will maintain that position.

ASML's machines are sophisticated. complex, and expensive. Its latest lithography machine costs $300 million, but that is hardly surprising when you consider that it can (among other things) accelerate blank silicon wafers more powerfully than a rocket engine and bring them to a stop at the same spot every time with nanometer precision.

Consider its next generation of machines, which are about to begin testing. One arrived at an Intel facility in Oregon in April 2024. It was shipped in 250 crates, weighs 330,000 pounds (149,685 kg), and will take a team of 250 engineers six months to install before weeks of calibration can begin. (Among the things to calibrate is the gravity where the machine is installed: because the Earth rotates and is not a perfect sphere, gravity is not precisely uniform throughout the planet.)

(For those interested, the latest machine aims to enable the manufacture of semiconductors with nodes of 1.4-1.6 nm. (The current leading edge chips have nodes of 3 nm, with the technology for 2-nm chips nearly ready for market.) After having developed ways to harness ultraviolet light of extremely short wavelengths to improve resolution, ASML is seeking further improvements by using lenses with higher numerical aperture ("high NA") to focus the light.)

Part of the reason for ASML's edge is its experience and data collection. The company remotely collects data from every machine it ever manufactured, using it to constantly refine and improve its technology. (This remote access also reportedly includes a kill switch, making it possible for the company to remotely disable its machines – a capability that undoubtedly comforts those concerned about the possibility of China gaining access to TSMC's ASML machines by invading Taiwan.)

Small wonder that G. Dan Hutcheson, vice chair of semiconductor industry research firm TechInsights and a longtime ASML watcher, estimates that it would cost any single entity trillions of dollars to develop comparable EUV machines from scratch, not counting the fees associated with licensing the essential underlying technologies.

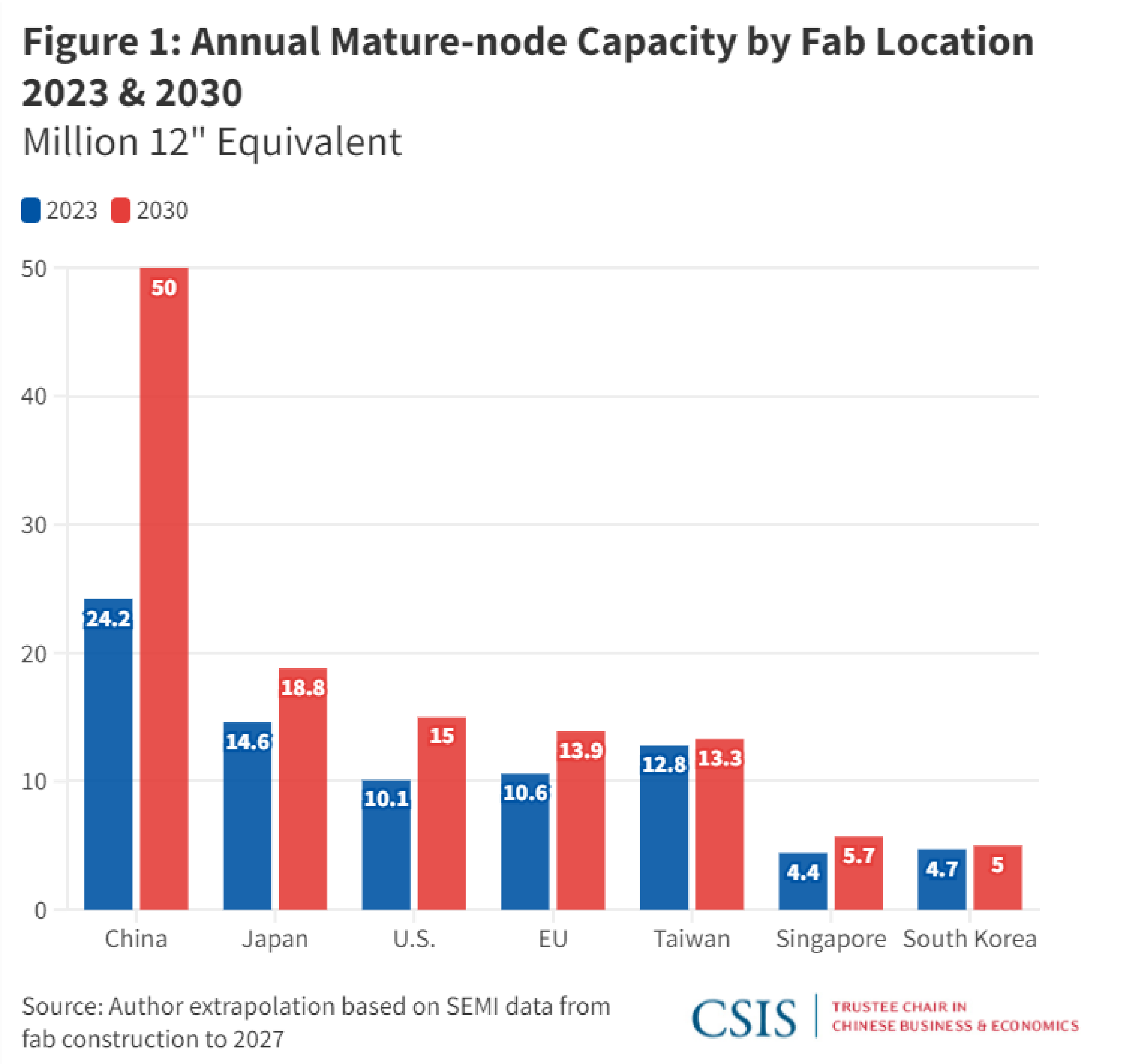
Potential gaps in U.S. semiconductor strategy

Much of U.S., European, and Japanese focus on countering China's semiconductor ambitions have focused on the design and manufacture of the most advanced chips. This makes sense, given the importance of such chips to AI research, machine learning, and powerful data centers. Yet less advanced, more mature semiconductors and related technologies remain strategically important.

The vast majority of semiconductors needed in our lives are not cutting edge. Hundreds of less-advanced, legacy chips are used to control the systems of modern automobiles. They are also prevalent in medical devices, in home appliances – basically any device with a screen or a sensor.

Many advanced military systems and weaponry use legacy chips with 90 nm and 180 nm nodes. (Such chips are typically considered more reliable in challenging environments.) For those who view China as a potential military threat (and to be clear, we have no opinion on this), this could be concerning. There is little data regarding the origin of semiconductors used in generic components such as microcontrollers, but some experts estimate that 20-40% of the chips used in U.S. military systems (including weapons) come from China.

China has devoted extensive resources to bolstering its capabilities with regard to such mature semiconductor technologies, subsidizing its domestic manufacturers in an effort to grow its market share of legacy-chip manufacturing – possibly at the expense of non-Chinese companies in this low-margin space.



Source: Paul Triollo, Center for Strategic and International Studies

This potentially could lead to opportunities for companies more suited toward the design and manufacture of older, more mature-technology chips.

Some of these include:

- **Global Foundries ($GFS)**, a foundry based in upstate New York with facilities in Singapore, Europe, and the United States. Global Foundries was the recipient of $1.4 billion in grants and $1.6 billion in loans to build a new mature-node fab in Malta, New York, and to expand and/or modernize two more. It is a trusted supplier to the U.S. Department of Defense.

Cadence Design Systems ($CDNS), Synopsys ($SNPS), and Siemens EDA (a business unit of Siemens $SIEGY). These are three of the largest companies in the electronic design automation space, providing software tools that are used to facilitate the semiconductor design process. (Cadence is currently a Granny Shot.)

Another possibility is a (sort of) new lithography method known as advanced nanoimprint lithography (NIL). Although current research suggests that advanced NIL cannot match the leading edge resolutions achieved through ASML's cutting edge optical-based lithography, it can provide an advantageous alternative in the manufacture of less advanced chips.

Where ASML combines a complex system of ultraviolet light, lenses, and mirrors with lasers to etch silicon wafers, nanoimprint lithography (NIL) works like a highly refined, 21st century version of an old-style printing press, physically stamping a pattern on the wafers. A low-viscosity liquid (the "resist") is sprayed onto the substrate, the stamp (also known as the mask) is pressed into the liquid, and UV light is then used to harden the liquid to set the desired pattern before the stamp is removed.

Advanced NIL has several advantages, including:

A simpler process with fewer steps – thus potentially faster

Lower energy requirements – no lasers required

More compact machinery (which means a greater number of machines can be installed in a given facility to increase output.)

Most agree that even advanced NIL cannot match optical lithography when it comes to chips and processors that require numerous patterns layered on top of each other – a common feature in leading-edge devices. However, for flatter, simpler semiconductors, advanced NIL machines such as those made by Canon Inc. ($CAJPY) could become a viable alternative. Canon, perhaps best known for making cameras and printers, claims to be nearly ready to bring to market an NIL machine that can achieve results comparable to 10-nm optical lithography. (These claims have not been independently verified.)

Conclusion

As the world's major powers contend amid a backdrop of a quickly innovating Technology sector, opportunities in the semiconductor industry might not be confined to more obvious household names such as Nvidia. This piece was intended to update readers on some of the developments that have taken place since we first discussed the semiconductor industry, roughly 19 months ago. The companies mentioned above should not be viewed as investment recommendations, but rather as suggestions for further research.

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