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Chemicals Practice

Creating a thriving chemical semiconductor supply chain in America

Semiconductors are vital to some of the world's most important industries. What will it take to ensure US semiconductor manufacturers continue to have the chemical and material inputs they need?

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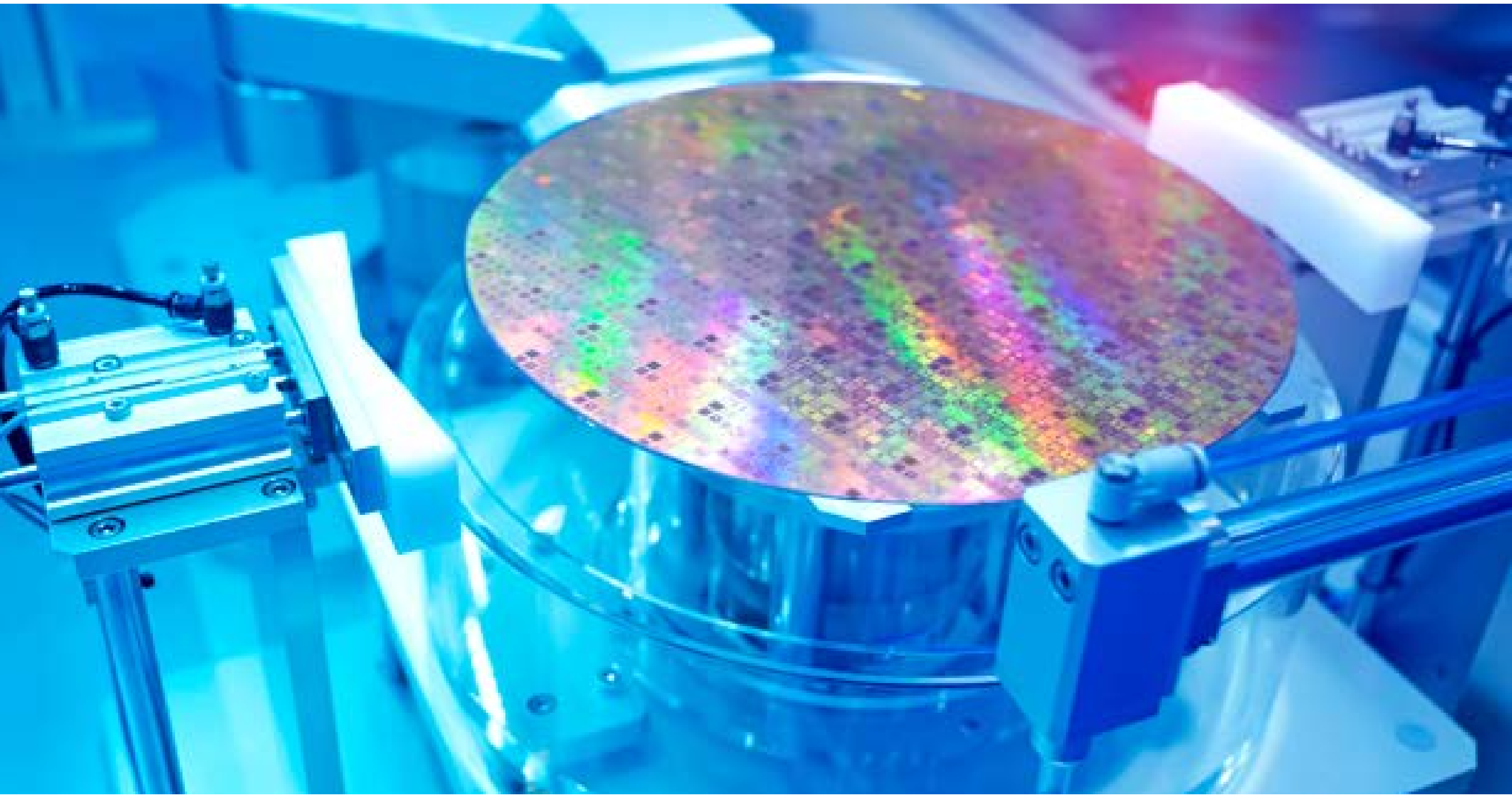

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Today, multiple regions around the world are seeking to build resilient, reliable, and largely self-sufficient sources of supply for semiconductors. The United States is no exception, with more than $450 billion in announced investments in semiconductor manufacturing capacity as of 2024.[1] As the country builds up existing semiconductor fabrication plants (fabs) and breaks ground on new ones, another equally important element needs to be considered: the materials and chemicals used to produce these chips.

Front-end semiconductor manufacturing (creating a wafer) takes a steady supply of more than 100 chemicals and materials over the course of weeks or months, and missing any can significantly delay or disrupt the entire process. Our analysis included current domestic availability of these chemicals and materials, as well as the ability of the industry to scale supply by 2030, to assess the robustness of the US semiconductor supply chain. Under the current investment trajectory, the United States is expected to face a meaningful supply gap for many materials by 2030, with approximately 60 percent of materials supply chains relying on imports.

This article explores the US situation in depth, although similar dynamics and outcomes can be expected in other regions. The analysis shows that it will likely require an investment of approximately $9 billion in one-time capital expenditures to close the materials gap and match the pace of semiconductor manufacturing capacity buildup in the United States. This will be a critical component of building regional independence, although it is important to note that materials for front-end semiconductor manufacturing are only part of a broader picture. Areas such as intellectual property (IP), equipment, upstream raw materials, and back-end packaging value chains will need similar investments and collaborations among leading companies, technology owners, policymakers, and others.

The importance of a robust semiconductor chemical supply

Many of today's most important consumer and industrial technologies, including fast-growing applications in AI, depend on semiconductors. Scaling these vital industries will require increased volumes of semiconductors. As a result, it is estimated that the overall US semiconductor market will reach more than $140 billion by 2030, more than doubling from $68 billion in 2024 (Exhibit 1).[2] Because of this demand for semiconductors, demand for associated chemicals and materials is expected to more than triple by 2030, growing to approximately $13 billion from $4 billion today ($3 billion from domestic supply and $1 billion imported).

To support this increase in demand, various incentives in the United States have been launched to stimulate private investment in domestic fabs, including grants, tax credits, and loans. Recent years have also seen a boom in investment: Since 2022, seventeen projects with combined private investment of more than $450 billion have been announced across 28 states, as well as $32.5 billion in direct grants and $28.8 billion in loans.[3]

Thanks to this buildup, the United States is expected to account for about 30 percent of global advanced-node (less than ten nanometers [nm]) semiconductor fabrication capacity by 2032.[4] This is likely to include investment across the country, as seen with newly announced capacity in more than a dozen states. Several of these projects have already begun production. For example, the Taiwan Semiconductor Manufacturing Company fab in Arizona started producing four-nm node chips in 2025, with initial yields on par with existing, mature fabs.[5]

However, simply building fabrication capacity does not entirely address the need for chemical and material inputs. Some of the more than 100 different

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[1] "The CHIPS Act has already sparked $450 billion in private investments for U.S. semiconductor production," Semiconductor Industry Association, updated August 28, 2024.

[2] Market size is based on semiconductor device (chip) value.

[3] "The CHIPS Act has already sparked $450 billion in private investments for U.S. semiconductor production," Semiconductor Industry Association, updated on August 28, 2024.

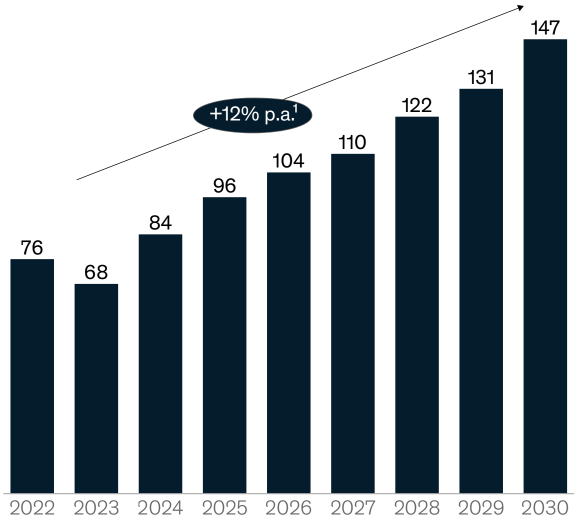
[4] "Two years later: Funding from CHIPS and Science Act creating quality jobs, growing local economies, and bringing semiconductor manufacturing back to America," US Department of Commerce, August 9, 2024.

[5] Anton Shilov, "TSMC's Arizona Fab 21 is already making 4nm chips — yield and quality reportedly on par with Taiwan fabs," Tom's Hardware, January 11, 2025; Katie Tarasov, "Tech TSMC says first advanced U.S. chip plant 'dang near back' on schedule. Here's an inside look at the Arizona fab," CNBC, December 13, 2024; Amanda Liang and Mavis Tsai, "TSMC begins 4nm chip production in Arizona, a first for the US, says Commerce Secretary," DIGITIMES Asia, January 13, 2025.

Exhibit 1

Many of today's most important and fastest-growing end markets depend on semiconductors.

US semiconductor market size forecast, based on device (chip) value, $ billion



End market	Selected use cases
Automotive electronics	Advanced driver-assistance system, infotainment, battery management, inverters
Computing and data storage	Central and graphical processing units, solid-state drives, network flash storage
Consumer electronics	Smart-home devices, wearables
Industrial electronics	Robotics, automation, grid management, medical devices
Wired communications	Routers, modems, fiber optic communications
Wireless communications	Internet of Things, base stations, antennas, smartphones

[1] Per annum.
Source: "Semiconductors – United States," Statista, 2025

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types of chemicals and materials for semiconductor manufacturing need to have ultrahigh purity (purity in the parts per trillion) or require precise formulation of specific inputs. For example, tungsten hexafluoride gas with six-nines purity (6N, more than 99.9999 percent) is used to deposit thin layers of tungsten, while hydrogen fluoride (HF) with ultrahigh purity is used to etch away silicon dioxides. Because many of these chemicals and materials are highly specialized and have no alternatives or substitutions, a disruption in the supply of any of these chemicals could potentially stall the entire chip manufacturing process.

Currently, the United States relies on importing the majority of the materials required for semiconductor production. For example, nearly all ultrahigh-purity HF used to fabricate advanced semiconductor devices in the United States is imported from Asia. Such reliance on a concentrated supply chain could pose threats to the resilience and reliability of the semiconductor chips supply, as observed historically.[6] For this reason, greater regionalization in supply chains is expected in the future, including in Europe and Asia.

A diversified chemicals supply chain could support the US semiconductor manufacturing industry and the broader US economy without greatly affecting overall manufacturing costs. Costs at semiconductor fabs are largely driven by fixed costs such as labor, maintenance, and deprecation (more than 60 percent of costs), while raw materials make up only a small portion of total cost (less than 5 percent), according

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[6] See, for example, Elisabeth Krausmann and Ana Maria Cruz, "Impact of the 11 March 2011, Great East Japan earthquake and tsunami on the chemical industry," *Natural Hazards*, March 2013, Volume 67, Number 2; Samuel M. Goodman, Dan Kim, and John VerWey, *The South Korea-Japan trade dispute in context: Semiconductor manufacturing, chemicals, and concentrated supply chains*, Office of Industries working paper ID-062, October 2019; "China restricts exports of high-tech metals in a slap at Washington ahead of Yellen's visit," Associated Press, July 4, 2023; Elaine Kurtenbach, "China bans exports to US of gallium, germanium, antimony in response to chip sanctions," Associated Press, December 3, 2024.

to McKinsey analysis. This means that maintaining supply chain stability and minimizing production interruptions is a critically important factor to generating an attractive ROI from fabs.

The supply gap challenge: Seven semiconductor chemical archetypes

When looking at current domestic supplies, McKinsey estimates that approximately 60 percent of the materials and chemicals required in semiconductor manufacturing do not currently have sufficient domestic supply to support scaling US semiconductor production (Exhibit 2).

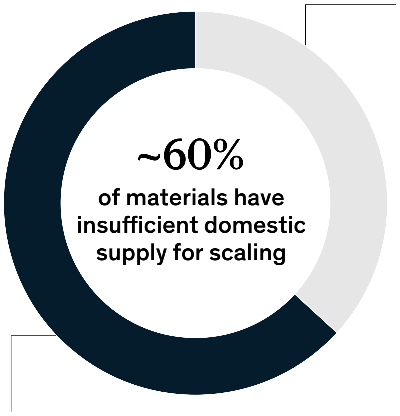
In addition, a funding gap is expected to form by 2030. The analysis estimates that a total investment of $9 billion in one-time capital expenditures is likely necessary to match the pace of semiconductor manufacturing capacity buildup in the United States. Of this, approximately $5 billion is likely to be funded by companies with leading positions in the United States, leaving a $4 billion capital gap. Additionally, an ongoing $1 billion of annual operating expenditures is anticipated to be required to offset the higher operating costs in the United States compared with other regions.

Increasing the domestic supply of these materials to support scaling and reduce reliance on imports will require a concerted effort, especially because each material has unique considerations. To assess how best to move forward, the analysis considers the economics—as expressed through project-

Exhibit 2

About 60 percent of the materials and chemicals required for semiconductors have insufficient domestic supply in the United States.

Scalability of semiconductor chemicals and materials in the US



Sufficient supply to scale (nonexhaustive)

- Chemical mechanical planarization (CMP) pads
- Silicon (Si) wafers
- Dichlorosilane
- Phosphine
- Arsine
- Krypton
- Tetraethyl orthosilicate
- Neon
- Tantalum sputtering targets
- Titanium (Ti) sputtering targets
- I-line photoresist
- Argon fluoride and krypton fluoride
- G-line photoresist
- 248-nanometer photoresist
- Nitrous oxide and nitric oxide
- Nitrogen
- Trichlorosilane
- Diborane
- Helium
- Boron trichloride
- Hydrogen
- Xenon

Constrained with foreign or import reliance (nonexhaustive)

- Bottom antireflective coating
- Top antireflective coating
- Spin-on carbon
- Developers
- High-purity hydrofluoric acid
- High-purity hydrochloric acid
- High-purity hydrogen peroxide
- High-purity solvents
- Sulfur hexafluoride
- High-purity sulfuric acid
- Germane
- Tungsten hexafluoride
- Hexafluorobutadiene
- Boron trifluoride
- Hafnium precursors
- Zirconium precursors
- Nitrogen trifluoride
- Octafluorocyclobutane
- Hydrogen bromide
- Deep ultraviolet photoresist
- CMP slurry: copper (Cu) bulk
- CMP slurry: barrier
- CMP slurry: tungsten (W)
- CMP slurry: cerium-based
- CMP slurry: polycrystalline Si
- Fluoromethane
- Silane
- Ti precursors
- Cu sputtering targets
- Tetrafluoromethane
- Aluminum sputtering targets
- Extreme ultraviolet lithography photoresist
- W sputtering targets

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level ROI—and availability of each material (Exhibit 3). Chemicals and materials were categorized along those two dimensions, and seven different archetypes were developed based on their challenges to scale.

Archetype 1: Attractive domestic supply
In the first and least domestically constrained archetype, neither cost nor access to raw materials and technology are limiting factors to securing supply. One example is chemical mechanical planarization (CMP) pads, used in wafer polishing, which are typically made from inputs that are widely accessible in the United States at low cost.

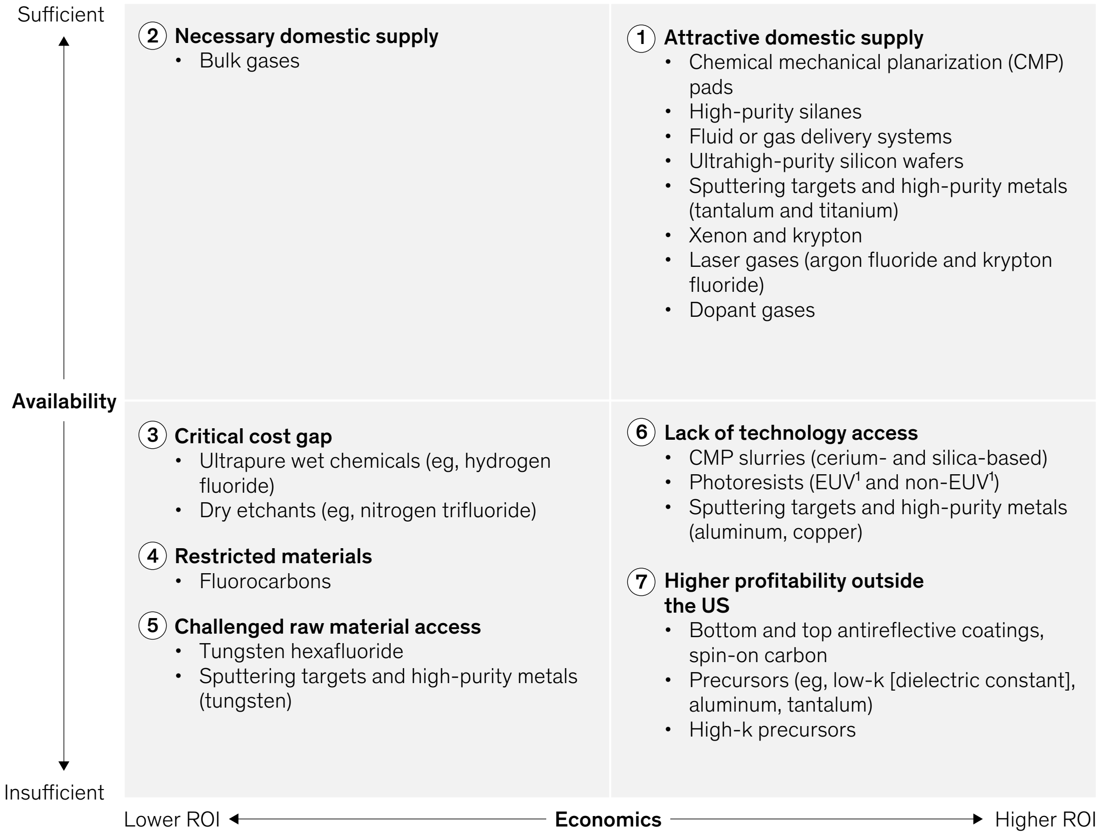
Significant technological knowledge is required for proper formulation of the materials in this group, which is not broadly available to companies in low-cost regions, increasing the security of domestic supply in the United States.

Archetype 2: Necessary domestic supply
The second archetype includes materials that have a readily accessible domestic supply but that are economically challenged from an ROI perspective. One such example is bulk gases, such as CO_2, nitrogen, hydrogen, helium, or argon, which are critical throughout the semiconductor fabrication process (such as inert carrier gases). Large,

Exhibit 3

The chemicals and materials used in the semiconductor chip manufacturing process can be largely categorized into seven archetypes.

Feasibility of semiconductor chemicals and materials in the US



② **Necessary domestic supply**
- Bulk gases

① **Attractive domestic supply**
- Chemical mechanical planarization (CMP) pads
- High-purity silanes
- Fluid or gas delivery systems
- Ultrahigh-purity silicon wafers
- Sputtering targets and high-purity metals (tantalum and titanium)
- Xenon and krypton
- Laser gases (argon fluoride and krypton fluoride)
- Dopant gases

③ **Critical cost gap**
- Ultrapure wet chemicals (eg, hydrogen fluoride)
- Dry etchants (eg, nitrogen trifluoride)

④ **Restricted materials**
- Fluorocarbons

⑤ **Challenged raw material access**
- Tungsten hexafluoride
- Sputtering targets and high-purity metals (tungsten)

⑥ **Lack of technology access**
- CMP slurries (cerium- and silica-based)
- Photoresists (EUV[1] and non-EUV[1])
- Sputtering targets and high-purity metals (aluminum, copper)

⑦ **Higher profitability outside the US**
- Bottom and top antireflective coatings, spin-on carbon
- Precursors (eg, low-k [dielectric constant], aluminum, tantalum)
- High-k precursors

[1] Extreme ultraviolet.

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continuous volumes of these gases are required for manufacturing. Historically, semiconductor fabs have worked with suppliers to build bulk gas production facilities onsite or nearby so these gases could be directly piped into fab processes. Building production facilities close to fabs requires significant capital expenditures, and these materials may still be subject to high transportation costs if they are not directly piped. Leading producers have announced bulk gas capacity builds in Arizona to support announced fabs in the region,[7] but continued build-out of co-located bulk gas facilities will likely be necessary to support fab production.

Archetype 3: Critical cost gap
The third archetype is defined by chemicals with readily available IP and raw materials but the most highly challenged economics. Typical examples of such chemicals include high-purity HF and nitrogen trifluoride. High-purity HF is produced by purifying and diluting anhydrous HF, which is formed by reacting fluorspar and sulfuric acid. Fluorspar and sulfuric acid are globally available, including in North America, but China has larger integration and scale, producing more than 70 percent of the anhydrous HF and fluorspar in the world,[8] leading to the lowest cost position. Key suppliers in South Korea, Japan, and Taiwan have leveraged supplies of low-cost anhydrous HF to develop leading positions in high-purity HF supply, the import of which the United States has relied on to support its own semiconductor fabs. Building domestic capacity to manufacture high-purity HF is challenged because of unfavorable anhydrous HF costs as well as the high capital and labor costs to create and operate HF purification plants. Similarly, nitrogen trifluoride requires high-purity ammonia and anhydrous HF as its raw input materials, which are broadly available but have lower cost positions in other regions.

Archetype 4: Restricted materials
In the fourth archetype, some chemicals have direct restrictions on production. For example, many chlorofluorocarbons and hydrofluorocarbons, such as hexafluorobutadiene, tetrafluoromethane, and fluoromethane, are regulated to protect the planet's ozone layer.[9] As a result, overall accessibility to fluorinated gas facilities and technologies is expected to be limited as the United States moves toward phasing out fluorocarbon production to protect human health and the environment. While alternatives to fluorocarbons in semiconductor production, such as the use of HF for cryoetching NAND devices,[10] are in development and could address raw material challenges, they are still nascent in technological maturity and adoption. Furthermore, investments would still be required to overcome capital and ongoing production cost challenges.

Archetype 5: Challenged raw material access
The fifth archetype is characterized by challenged access to IP and raw materials, including increased time and cost to access, or simply overall unavailability. One example is high-purity tantalum sputtering targets, which experience sourcing challenges and long production times. The Democratic Republic of Congo and Rwanda produce more than 60 percent of global tantalum ores,[11] which are typically shipped to China, Europe, and Japan for refining and purification to produce high-purity metals. These high-purity metals are then annealed and machined to sputtering targets after a lengthy and complicated production process.

Another example is that of tungsten hexafluoride, for which the raw materials are generally unavailable. China and Russia produce more than 90 percent of the global tungsten supply,[12] and the demand

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[7] "Linde signs long-term agreement to supply new world-class semiconductor manufacturing complex in the U.S.," Linde, September 8, 2021; "Air Liquide announces long term agreement to supply semiconductor manufacturing site in Arizona," Air Liquide, January 25, 2022.

[8] S&P Global Chemical Economics Handbook report on fluorspar, fluorosilicic acid, hydrofluoric acid and inorganic fluorine chemicals, July 2023.

[9] "Phasedown of hydrofluorocarbons: Establishing the allowance allocation and trading program under the American Innovation and Manufacturing Act," US Environmental Protection Agency (EPA), October 5, 2021; "Frequent questions on the phasedown od hydrofluorocarbons," EPA, updated on December 18, 2024; "The Montreal Protocol on Substances That Deplete the Ozone Layer," US Department of State, accessed on March 10, 2025; "Amendment to the Montreal Protocol on Substances That Deplete the Ozone Layer," United Nations Treaty Collection, October 15, 2016.

[10] "Cryogenic etching – Tokyo's Electron's 'digital and green transformation' of semiconductor process equipment," Tokyo Electron, October 21, 2024.

[11] "Mineral Commodity Summaries: Tantalum," US Geological Survey, January 2024.

[12] "Mineral Commodity Summaries: Tungsten," US Geological Survey, January 2024.

for tungsten in semiconductor manufacturing far exceeds the current production of tungsten from other regions. Therefore, any export disruption or restriction of tungsten would significantly challenge supply for US semiconductor manufacturing.

Archetype 6: Lack of technology access

In the sixth archetype, critical IP or raw material availability (or both) limit domestic supply. An illustrative case of this is cerium-based CMP slurries, in which a key raw material is high-purity cerium dioxide granules. The United States produces about 15 percent of global cerium ores,[13] with downstream granulating and mixing capabilities broadly accessible. However, the technology to separate and purify these ores is primarily located in China, making transportation the key bottleneck in the value chain. To achieve scale in the United States, technology owners can work with fabs to establish more-resilient local supply chains that further reduce transportation costs and safety concerns associated with transporting chemicals.

Archetype 7: Higher profitability outside the United States

The seventh archetype includes materials that have sufficient domestic IP or raw material availability (or both) but that also have more-attractive economics outside the United States, such as bottom and top antireflective coatings for lithography. For these materials, US companies possess the technology and IP for production, but it is more attractive to build capacity in other regions because of lower operational costs.

Where do we go from here?

Closing the chemicals supply gap will be critical to creating a reliable source of semiconductors in the United States. Similar efforts will also be important to countries and regions around the world as they look to build resilient local supplies of these strategic assets.

To ensure the supply of these important materials, companies could consider several steps, including entering into trade agreements, developing and securing access sources of critical raw material, and working toward close investment and operating cost gaps for US production. Chemicals suppliers could consider joining global partnerships and joint ventures for access to critical technologies, assessing alternative options in upstream supply chain steps with a high risk of disruption, and emphasizing resilience risks more prominently in investment decisions for future supply. Fabs can take a fact-based view on their resilience risk and actively develop a broader and more resilient base of supply options with long-term sustainable economics both for fabs and suppliers. And players across the chain can partner with technology owners to secure important IP while building and expanding capacity.

As the United States and other regions seek increased self-sufficiency, the value of investments in semiconductor materials could have a far-reaching impact in the United States and globally. Establishing a resilient supply of semiconductor materials is a vital part of efforts to establish an at-scale domestic semiconductor industry and secure access to one of the most critical technologies of the 21st century.

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[13] “Mineral Commodity Summaries: Rare earths,” US Geological Survey, January 2024.

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