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Defense Industrial Base Division, Office of Technology Evaluation
Bureau of Industry and Security
U.S. Department of Commerce

Re: SEMI Comments to Risks in the Semiconductor Manufacturing and Advanced Packaging Supply Chain Notice of Request for Public Comments; 86 FR 14308; RIN 0694–XC073; Docket Number BIS-2021-0011

Introduction

Established in 1970, SEMI is the leading industry association working to advance the technology and business of the global electronics manufacturing supply chain. SEMI has more than 2,400 members worldwide, including over 400 members in the United States, and represents the full range of U.S. semiconductor companies, including design automation and semiconductor IP suppliers, device manufacturers, equipment makers, materials producers, software designers and subcomponent suppliers. While SEMI's membership includes many large companies, more than 85 percent of SEMI members are considered small businesses, and half of U.S. members earn revenues of $25 million or less. SEMI member companies are the foundation of the $2 trillion electronics industry and this vital supply chain supports 350,000 high-skill and high-wage jobs across the United States. Semiconductors are a significant U.S. export, the United States consistently enjoys a surplus in semiconductor trade, and roughly 90 percent of semiconductor equipment and materials sales are made to facilities outside the United States.

SEMI is pleased to provide comments to the Department of Commerce's Bureau of Industry and Security (BIS) regarding the March 15 request for public comments on the Risks in the Semiconductor Manufacturing and Advanced Packaging Supply Chain and the February 24 White House Executive Order on America's Supply Chain.

Executive Summary

Semiconductors underpin all electronics and information technology (IT), enabling innovation and growth in countless other industries, including medical devices and the IT solutions that allow for remote working and connectivity. Semiconductor technology and applications also are critical to sustaining America's physical infrastructure, national defense capabilities, and telecommunications and transportation systems. For decades, the United States has led the world in semiconductors, accounting for nearly half of global semiconductor sales and world-leading market share positions in manufacturing equipment, design software, and key materials.

Semiconductor manufacturing is among the most complex production processes in any industry, requiring unparalleled capital investment, sustained and costly research and development, and a supply chain of countless firms providing components and materials. The supply chain is highly integrated and globalized. With little excess capacity available to absorb disruptions and increasing demand, supply disruptions can have broad and cascading effects throughout countless industries. Supply constraints, whether they be in devices, equipment, or materials, can impact the entire supply chain and lead to semiconductor shortages, which can result in line-down situations at electronics factories downstream, and have a ripple effect in our digital economy.

Building a stronger and more resilient semiconductor supply chain in the U.S. will be facilitated by policies that help semiconductor supply chain companies in the U.S. grow and innovate, while avoiding policies weaken or undercut the domestic industry. In these comments, SEMI calls for:

Strong federal manufacturing and research and development incentives for the entire semiconductor supply chain. Putting the U.S. on equal footing with other semiconductor-producing countries will help build capacity, attract new investments, and drive innovation.

Narrowly tailored and multilateral export control policies. The global competitiveness of this complex industry requires access to all global markets to fund research and innovation and preserve competitiveness.

Competitive corporate tax policies. U.S. companies must compete in the global market; competitive corporate tax policies are needed for supply chain strength and resilience.

Trade policies that open markets and eliminate barriers to trade. The semiconductor industry relies on a free and fair rules-based trading system where goods and data can freely cross borders. Global markets are vital to a strong semiconductor industry in the U.S.

Harmonized and pragmatic environment, health, and safety regulations. The manufacturing of semiconductors requires a complex mix of chemicals, clean facilities, and standards that can vary from country to country. Regulations should be harmonized where possible, include adequate transition periods and account for the irreplaceable nature of some articles.

Strong workforce development and immigration policies for high-skilled workers. The semiconductor industry relies on a highly skilled workforce and is currently facing a significant shortage of qualified workers.

SEMI expresses our strong desire to work closely with the administration and Congress to enact the right policies to strengthen the U.S. semiconductor supply chain and semiconductor companies operating in the United States.

I. Critical and essential goods and materials underlying the semiconductor manufacturing and advanced packaging supply chain.

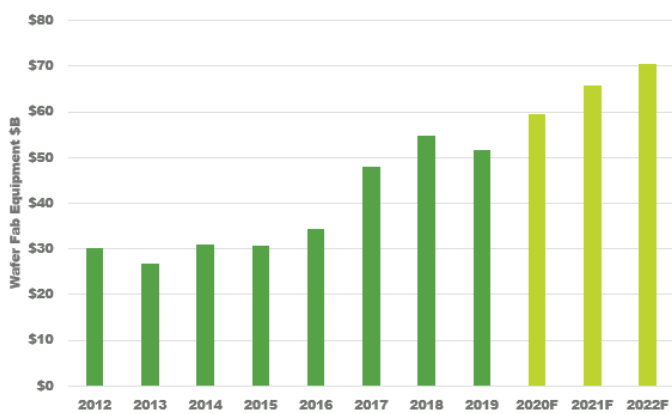
Semiconductors underpin all electronics and information technology (IT), enabling innovation and growth in countless other industries, including medical devices and the IT solutions that allow for remote working and connectivity. Semiconductor manufacturing is among the most complex production processes in any industry, requiring unparalleled capital investment, sustained and costly research and development, and a supply chain of countless firms providing components and materials. In 2020, the global semiconductor equipment market was $69 billion, with a global materials market of $55 billion. These combined markets total $124 billion globally, forecasted to reach $142 billion in 2022.

Wafer Fab Equipment Market

Wafer fab equipment market size has expanded from ~$30B in the first half of 2010s to ~$50B in the past three years.

2020 WFE market surpassed previous high set in 2018 to set a record of $59.4B, driven by advanced logic and China investment.

2021 and 2022 WFE market are projected to grow double digit % and high single digit% respectively, driven by leading-edge foundry and logic investment as well as memory spending recovery.



Source: SEMI Equipment Market Data Subscription, Prelim. January 2021

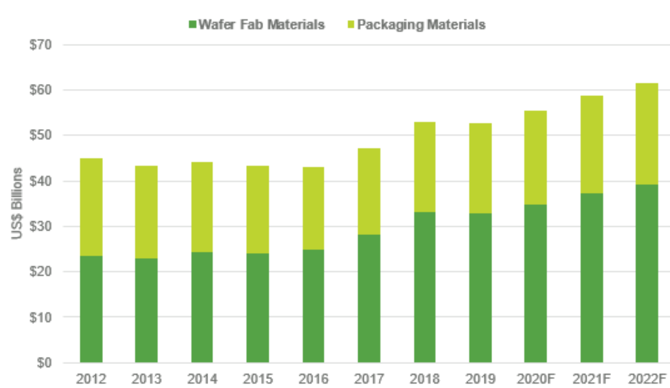
Total Semiconductor Materials Market

Healthy 2020, Record 2021 and 2022

Materials market exceeded $50B since 2018 driven by shipment growth and advanced process requirements in both wafer fab and packaging facilities

Overall Materials market grew 5% in 2020 to reach $55 billion with wafer fab materials outgrow packaging materials

Expect ~6% growth to set a record high in 2021 surpassing $58 billion



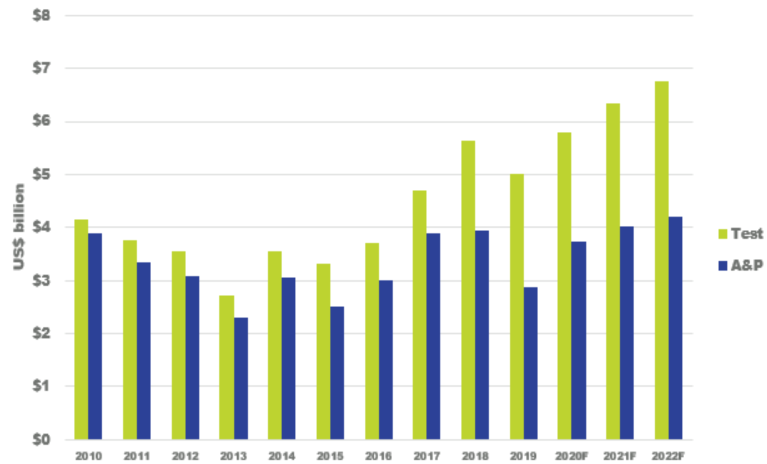
Source: SEMI Materials Market Data Subscription, February 2021

Test and Assembly/Packaging Equipment Market

2020 Test equipment market grew ~16% to reach $5.8B and the momentum is expected to continue into 2021 and 2022

Test equipment growth is primarily driven by 5G and HPC, which are the multi-year drivers of the industry

Assembly & Packaging equipment is forecasted to rebound 30% in 2020 and +8% in 2021 driven by advanced packaging and wire-bonding capacity build



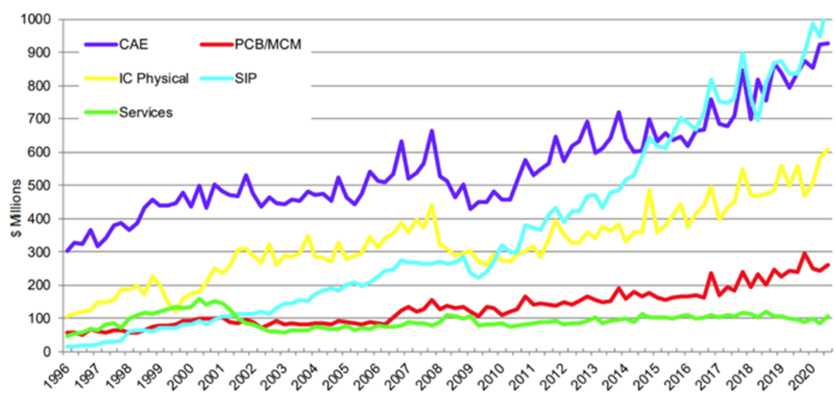
Source: SEMI Equipment Market Data Subscription, Prelim. January 2021

Design Automation and Semiconductor IP Market

The market for semiconductor design software, IP and services surpassed $10B/year in 2020.

Major categories that make up the design market are EDA software (CAE – front end logic and circuit design and IC Physical – design of the chip layout), SIP (semiconductor IP), PCB/MCM (printed circuit board and multi-chip module design), and Services.

The U.S. is the leading global supplier of both EDA tools and technology and semiconductor IP.



Source: SEMI Electronic Design Market Data – Q3-2020

The semiconductor industry is a circular ecosystem – the equipment needed to manufacture semiconductors are also powered by semiconductors, as are production machinery that manufacture semiconductor equipment and materials. Supply chain capacity balance is critical to ensure an adequate supply of semiconductors used in the equipment needed to manufacture them, as shown in section III.

Similarly, when a semiconductor manufacturer develops a new process technology, they partner with EDA and IP companies to develop and provide the technology, tools, and flows needed to allow chip developers to take advantage of the new process.

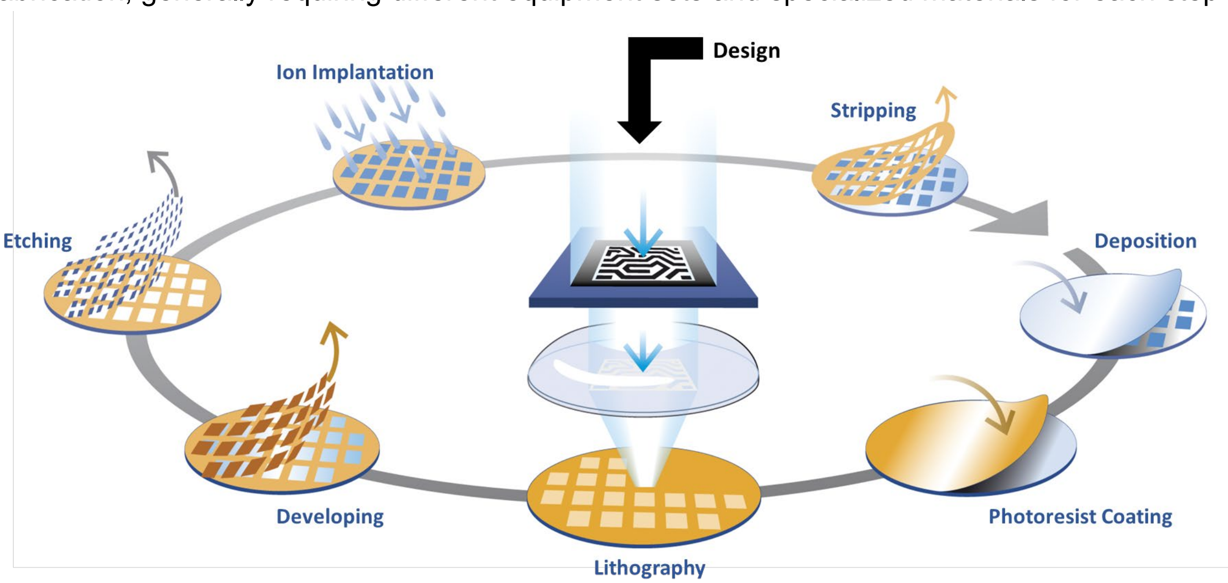
II. Manufacturing and other capabilities necessary to produce semiconductors, including electronic design automation software and advanced integrated circuit packaging techniques and capabilities.

The process to create a semiconductor is complex and differentiated – with several primary stages. The semiconductor design process is driven by electronic design automation (EDA) tools and semiconductor intellectual property (IP). At the front-end of the design process, EDA tools are used to plan, prototype, analyze, and verify the functionality and performance of the proposed design. At the back-end, EDA tools convert the high-level descriptions of the design into the physical layout of transistors and interconnects that will be used to create the masks used in the manufacturing process.

Semiconductor IP (building blocks of pre-designed functionality) is used widely in chip design. IP can range from simple interface blocks and logical functions to large processors, memories, and high-speed serial interfaces. Today's complex chip design are often constructed using greater than 80 percent IP.

The physical manufacturing process occurs in several stages, beginning with the manufacture of the raw wafer. Next, microscopic circuitry is created on the wafer. Most wafers are made of silicon. There are also other wafer substrate materials used for certain applications, including applications of critical importance to national security and infrastructure, such as advanced communications and power electronics. The wafer is then cut to create individual semiconductors (die), and these die are then assembled, tested, and packaged (ATP) to create final semiconductor devices, generally at another facility focused on the ATP process.

The most complex part of the process is wafer fabrication. There are many discrete steps in wafer fabrication, generally requiring different equipment sets and specialized materials for each step.



While the equipment and materials are specialized for a specific element of the wafer fabrication process, they are not generally specialized to produce semiconductors for a specific application. Importantly, semiconductor manufacturing equipment (SME) are not specially designed to produce “AI semiconductors”, or “automotive semiconductors”, and the SME used in wafer fabrication is often a negligible factor in whether a semiconductor is particularly suitable for specific applications.

The chip architecture and design and process technology developed by fabs, foundries, and fabless semiconductor companies determine the type of semiconductor device that is produced. The same SME used by a fab or foundry to produce a graphics processing unit (GPU) for an AI application can be used to manufacture a microcontroller used in a consumer smart phone at the same time. More information on the semiconductor manufacturing process can be found on the websites of major producers.[1] [2]

A recent microelectronics supply chain study conducted by SEMI revealed that as outsourced manufacturing trends continue, not only is front-end of line (fab) manufacturing moving away from North America, with 75% of fabs in the Asia-Pacific region, but post-fab assembly has diminished to a miniscule 3% in North America. With the increasing importance of heterogeneous integration, advanced packaging technologies are becoming more integrated into the device manufacturing process flow and more critical to technical leadership and the continuation of Moore’s Law.[3] Historical trends of labor intensive, manual electronics assembly are being replaced by more fab-like processing and robotic assembly, closing the gap in economic factors that led to off-shoring semiconductor packaging. Investment in advanced packaging and heterogeneous integration manufacturing capability within the U.S. can capitalize on the industry dynamics and new Moore’s Law strategies to seize new technology leadership opportunities.

Wafer Production

Silicon wafers are the base of almost all semiconductors, a wafer cannot be fabricated without the manufacturing of silicon crystal (ingot). This means that the entire fabrication process to create an integrated circuit that will ultimately be a component of a larger electronic device rests on this tiny piece of a pure, crystal of silicon wafer. Growing a single silicon ingot can take from less as one week to up to one month. The time taken for the ingot growth is determined by the size, quality, and the specification of the wafer. One of the most common methods used to grow the crystal is the Czochralski Method or the CZ Method, where polycrystalline silicon pieces are put in a trough made of quartz. The crystal is grown using a variety of basic elements, heating, shaping, and stabilization. In addition to bare silicon wafers, there is increasing use of non-silicon substrates and engineered silicon substrates for certain key applications. These engineered substrates, including silicon on insulator (SOI) and silicon carbide (SiC), can provide significant cost/performance benefits relative to bare silicon wafers and have a unique supply chain that should be considered.

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[1] https://news.samsung.com/global/eight-major-steps-to-semiconductor-fabrication-part-1-creating-the-wafer
[2] https://download.intel.com/pressroom/kits/chipmaking/Making_of_a_Chip.pdf
[3] Heterogeneous Integration refers to the integration of separately manufactured components into a higher level assembly (SiP) that, in the aggregate, provides enhanced functionality and improved operating characteristics.

After the wafer is probed and tested, they are thinned, singulated, assembled, packaged, tested, and shipped to the next level to build into electronic systems, whether they be high performance computing & data centers, 5G, smart phones and tablets, medical and health wearables, automobile, or aerospace & defense. Each have their own sets of requirements. Packaging materials includes solder, bonding wire, molding compounds, thermal interface materials, organic substrates, leadframes, and different plating processing chemicals and materials. With new applications and advanced packaging, there is increasing needs for advanced substrates and wafer level packaging materials for today and the future.

Smart Manufacturing

Smart Manufacturing / Industry 4.0 can provide a competitive edge. The industry 4.0 roll out will rely on improved manufacturing tool uptime and predictive maintenance. As semiconductor manufacturing tools become ever more intricate, new approaches for tool maintenance automation and visualization are needed. Smart manufacturing can help enable complete traceability of manufacturing to enhance supply chain security.

Heterogenous Integration and Advanced Packaging

Advanced packaging based upon silicon interposers was introduced seven years ago to bring application-specific integrated circuit (ASIC) processors closely connected to multiple High Bandwidth Memory (HBM) in heterogeneous integration and has become widely adopted since bandwidth has become increasingly crucial for many applications.

While foundries are developing single digit nodes (7 nm, 5nm, 3 nm) their customer architects are innovating to desegregate the monolithic SOC design into smaller dies (Chiplets) heterogeneously integrated into a package. An illustrative case is a fabless CPU/GPU company for 7 nm on the compute die while keeping the I/O die at 14 nm for their CPU processor resulting in high yield, time to market, and high performance. This processor is planned to power two future DOE supercomputers. Similar chiplet concepts are being implemented in the leading U.S. IDM in different applications through advanced packaging.

A recent DARPA presentation “Accelerating Electronics and Photonics Innovation for Revolutionary Microsystems” positioned Heterogeneous Integration to be the 4th Wave extending Moore’s Law and broadening its impact by driving material diversity, functional diversity and technology diversity and bringing DARPA Microelectronics projects along them.[4]

Diffusion Bonding and Wafer Scale Packaging

Three-dimensional integrated circuit (3DIC) and wafer scale packaging, as well as multiple stacked direct bonding interconnect (DBI) wafer bonding can substantially increase the competitiveness of U.S. integrated IC technologies. The ability to produce radically different transistors or sensors using different process flows fine-tuned to the specific needs of the device, and wafer level DBI bonding to create covalently bonded single, integrated circuits is now possible down to bonding pitches in the shallow sub-micron pitch.

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[4] https://ieeetv.ieee.org/video/accelerating-electronics-photonics-innovation-for-revolutionary-microsystems

Sensorization
Sensor systems are essential for all commercial, consumer, and defense applications. The growing sensorization trend will only accelerate across all future industrial and consumer sectors, for example, in electric vehicles and in digital health. The U.S. has an exposed risk with most sensor manufacturing offshore. Building domestic capability to supply leading-edge sensors would mitigate this current risk. These sensor technologies are critical for commercial and defense IoT, AI, edge, and mist applications where data is integrated and pre-processed before being sent to the cloud for AI processing and dissemination.

SEE Testing
Existing U.S. heavy ion radiation test facilities required to test radiation-hardened semiconductor devices cannot meet current or future "single event effects" (SEE) test demand. "There are fewer than half a dozen accelerator laboratories that can produce ion beams with sufficient ion species and energies to meet the needs of SEE testing. These facilities are heavily used because they serve the nuclear physics research community, and the entire U.S. governmental SEE testing community (including NASA, the Department of Defense, the Department of Energy, and other government agencies), and an increasing number of commercial enterprises eager to take advantage of business opportunities offered by access to space. With the many users competing for time, it is usually necessary to book beam time well in advance, with wait times."[5] Current heavy ion accelerators for SEE testing at U.S. universities and Department of Energy labs have limited capacity and capability, and the supply and demand gap is expected to grow more acute over the near-term horizon. Unpredictable funding creates unstable operations at test facilities, which has national security implications.

III. Availability of the key skill sets and personnel necessary to sustain a competitive U.S. semiconductor ecosystem, including the domestic education and manufacturing workforce skills needed for semiconductor manufacturing; the skills gaps therein, and any opportunities to meet future workforce needs.

The semiconductor industry relies on a highly skilled workforce. Companies must attract and retain a wide variety of individuals who can innovate, solve complex problems, and anticipate future challenges and opportunities in this rapidly changing and technologically advanced sector. There are currently tens of thousands of open jobs in the semiconductor industry throughout the entire supply chain, and workforce deficits are projected to continue to grow. In fact, SEMI members alone currently have 23,000 open positions in the U.S. Workforce development is consistently one of the top needs identified by SEMI member companies; approximately 85% of respondents to a SEMI survey cited improving access to, training, and retaining talent as top priorities, impacting sustainability and future growth.

The semiconductor workforce does not currently reflect the diversity of the U.S., which is a significant missed opportunity as more diverse workforces increase innovation, creativity,

[5] Testing at the Speed of Light: The State of U.S. Electronic Parts Space Radiation Testing Infrastructure (2018), National Academies of Sciences, Engineering, and Medicine 2018. https://www.nap.edu/catalog/24993/testing-at-the-speed-of-light-the-state-of-us

retention, and productivity. The U.S. workforce will also become more diverse in the next ten years, so the pipeline must get larger and more inclusive to meet the industry's needs. The U.S. has the workers, the educational institutions, and the U.S.-based companies needed to be competitive in the semiconductor ecosystem, but faces four distinct challenges:

- Decades of studies show that girls and children of color are actively passed over in STEM-based classes in K-12 schools, which dissuades them from pursuing education and careers in STEM-based fields. The industry needs these diverse workers and their talents and perspectives to be competitive in the global microelectronics space, since businesses with a more diverse workforce have been shown to have more customers, higher revenues and profits, greater market share, less absenteeism and turnover, and a higher level of employee, and customer commitment to their organizations. The inequities at the K-12 level must be addressed at schools across the country through educator training and culturally competent curricula to develop the next generation of diverse tech workers that the industry will need as the current cohort of electrical engineers grows older.
- The semiconductor industry does not have the same brand awareness or allure as social media or software companies. Many potential workers - both students and pre-professional individuals willing to up-skill or reskill - who might consider a career in our industry are not aware of its many stable and lucrative jobs.
- There are many colleges and universities with the capabilities and facilities to provide training for the myriad jobs related to semiconductor design, manufacturing, and distribution, but semiconductor-specific career and technical education (CTE) courses are rare and certified CTE instructors even more so. Workforce development organizations and collaboratives need to find ways to make these kinds of trainings more accessible and available to potential workers, to support those workers during training to allow for completion, and to connect those workers to the companies ready to hire them. Identifying current skills gaps based on employer needs, developing trainings that map to those skills, and deploying those trainings via both virtual and in-person platforms is also needed.
- The COVID-19 pandemic has disproportionately affected women and people of color. It is estimated that one in four women are considering leaving the workforce due to the pressures presented by COVID-19. At one university, 20% of female engineers have dropped out of school to take care of their families. Women are leaving or being pushed out of the workforce at alarming rates while their numbers, perspectives, and skills are needed in the industry. Steps must be taken to encourage and support women to rejoin the workforce or stay in school and the workforce if the U.S. is going to be competitive on a global scale.

In addition, some semiconductor materials and components, such as quartzware and sputtering targets, require skilled machinists to fabricate the final product. U.S. suppliers of these materials, and makers of SME, report constraints in finding skilled, qualified machinists. Although overseas sources of these materials and components can be relied on to supply additional demand, any appreciable uptick in demand (i.e., a single major fab ramping) will cause supply chain tightness.

Shortages and delays in the supply chain can last 9 months to one year, i.e., the length of time needed to train a skilled glass blower (hot work quartz) or a machinist.

SEMI has made the commitment to leverage its unique position to develop and maintain the talent pipeline for this sector. Launched in February of 2019, SEMI Works® is SEMI's comprehensive approach to develop the industry's talent pipeline. The program is designed to develop the infrastructure to move from the current fragmented approach in training and education to an interconnected one that leverages existing regional assets to create an integrated national talent pipeline. For detailed information on SEMI Works®, please see Appendix 2.

In advanced packaging and heterogeneous integration, the Heterogeneous Integration Roadmap provides a solid set of state-of-art knowledge for college-level teaching, short course, self-study, and importantly to build up the understanding of how the whole electronics ecosystem works together in research, development, and manufacturing. Packaging professionals come from "all walks" of academic discipline from electrical engineering, mechanical engineering, materials science, physics, and chemistry. The field of Advanced Packaging is fast moving. Learning the state-of-art is crucially important. Knowing what and where the roadblocks are is the first step to innovation and creativity.

Immigration policy will play a key role in maintaining a skilled and robust workforce in the near term. Foreign-born, high-skilled workers are important for semiconductor companies in the U.S. due to the long years of education and training that are necessary to work in the industry. The Wall Street Journal estimates that approximately 40% of high-skilled semiconductor workers in the U.S. were born outside of the country.[6] H1-B and Optional Practical Training visas help retain foreign-born students who were educated in highly advanced and technical U.S. programs. Building semiconductor manufacturing capacity in the U.S. will require not only investment in developing domestic talent but must also immigration policies that allow the U.S. to retain and employ highly skilled foreign-born workers, especially in the short-term as we educate younger generations in the field.

IV. Risks or contingencies that may disrupt the semiconductor supply chain (including defense, intelligence, cyber, homeland security, health, climate, environmental, natural, market, economic, geopolitical, human-rights or forced labor risks).

Recent events have shown how disruptions can affect the semiconductor supply chain. Supply chain risks associated with the global pandemic have been exacerbated by market and supply imbalances. Given the vital importance of technologies that rely on semiconductors, the industry requested that governments classify semiconductor industry workers who must be present at the work site during the pandemic as essential workers. In large part, governments around the world classified the industry as an "essential business" to allow continuity in operations. Having global,

[6] https://www.wsj.com/articles/americas-supply-chain-needs-high-skilled-migrants-11590706977

national, and local coordinated policies related to essential travel, vaccinations, and facility safety measures is vital to the sustainability of the supply chain.

Geopolitical tensions in trade and export controls can cause global chain reactions, and actions often have unintended consequences. For example, on January 9, 2021, China's Ministry of Commerce released *Rules on Counteracting Unjustified Extraterritorial Application of Foreign Legislation and Other Measures*, which allow Chinese companies to claim damages against foreign companies that comply with extraterritorial measures by other countries. This was seen as a direct response to U.S. export control measures against Chinese companies such as Huawei and has created strong concerns for non-U.S. companies who must comply with extraterritorial U.S measures. In addition, China's new Export Control Law became effective on December 1, 2020. This law grants the Chinese government jurisdiction over organizations or individuals outside China for activities that endanger the national security and interests of China or obstruct the performance of non-proliferation or other international obligations. Actions to assert extraterritorial jurisdiction and counter the assertions of extraterritorial jurisdictions by other nations create significant risk for semiconductor companies throughout the supply chain that simultaneous compliance with both U.S. and Chinese law may, at times, prove impossible, with the potential for violations and sanctions for compliance with contradictory U.S. and Chinese regulations.

Climate risks include large weather events such as typhoons and hurricanes that may cause short term supply disruptions. However, prolonged droughts and forest fires could cause longer term issues. Availability of clean water is key to semiconductor production. Fires occurring miles away increase air particulates which require more air filtration for clean rooms. Fires, power outages and earthquakes have significantly impacted the semiconductor industry:

- Fires
  - A 1993 fire and explosion at a Sumitomo Chemical facility in Japan impacted semiconductor materials production and caused semiconductor device price increases.
  - 2020 and 2021 fires at a Umimicron substrate plant in Taiwan affected global capacity for semiconductor assembly, test, and packaging.
  - A March 2021 fire at a Renesas fab may cause further supply imbalances, including for automotive applications.
- Earthquakes
  - The 2011 earthquake in Japan had significant effects on production of wafers and other semiconductor materials.
  - A 1999 earthquake in Taiwan caused the temporary closure of Hsinchu Science Park, causing significant industry disruption.
- Power outages
  - The February 2021 winter storm in Texas resulting in production stoppages has worsened shortages of semiconductor devices.

Finally, the high purity wet chemicals supply-chain (H2SO4, HCL, H2O2, H3PO4, NH4OH) runs extremely lean with low margins such that chemical manufacturers within North America have refrained from expanded local production. These materials continue to have supply-chain shortages every other year, if not every year for U.S. chip fabs.

V. The resilience and capacity of the semiconductor supply chain to support national and economic security and emergency preparedness.

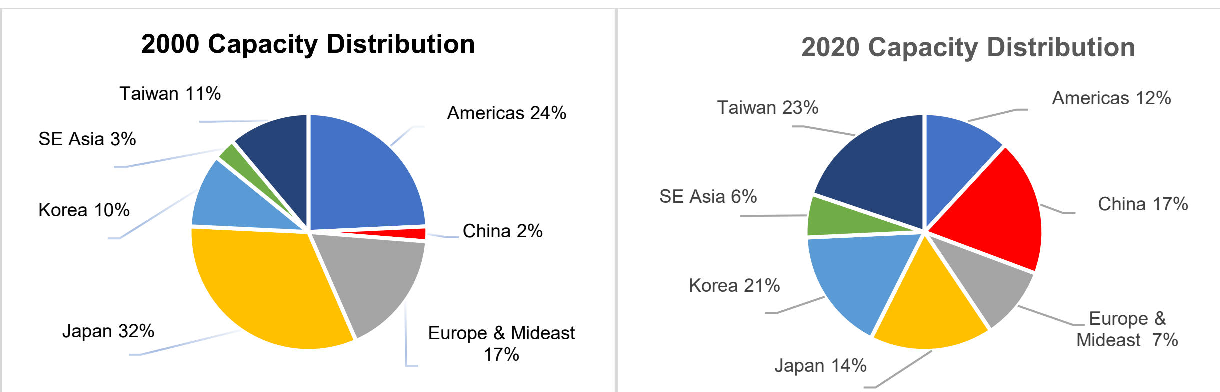
Manufacturing Capacity

U.S. share of global integrated circuit (IC) capacity is 12%, down from 24% in 2000. The most advanced process node capability is currently only available in facilities outside the United States. Loss of access to the production of these facilities would deny access to certain advanced chips needed for many applications, including SME and materials.

U.S. Share of Global Volume IC Manufacturing Capacity

	2013	2014	2015	2016	2017	2018	2019	2020
United States	13.5%	13.8%	13.8%	13.4%	12.9%	12.2%	12.3%	12.0%

Source: World Fab Forecast report, 1Q21 update, published by SEMI



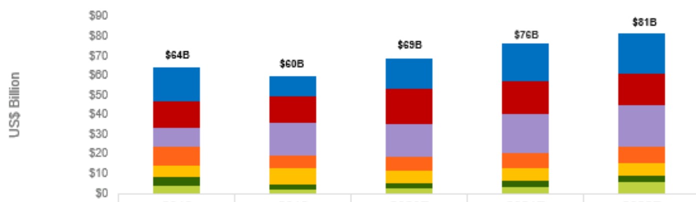
Maximum IC Wafer Capacity by Region

Location of Capacity	% of 2020
Americas	11.9%
China	17.0%
Europe and Mideast	7.0%
Japan	13.9%
Korea	21.4%
SE Asia	5.9%
Taiwan	22.9%
Sum	**100.0%**

Source: World Fab Forecast report, 4Q20 update, published by SEMI

With only 12 percent of global IC manufacturing capacity, the U.S. leads only Europe and Southeast Asia in its share of global IC manufacturing capacity. As shown below, equipment and materials sales forecasts indicate continued expansion in Asia.

SEMI® Total Equipment Forecast *By Market Region*



	2018	2019	2020F	2021F	2022F
Korea	17.7	9.9	15.4	18.9	20.7
China	13.1	13.4	18.4	16.8	15.8
Taiwan	10.2	17.1	16.3	19.9	21.2
Japan	9.4	6.2	7.5	7.9	8.5
North America	5.8	8.1	6.4	6.1	6.0
SEA/ROW	4.0	2.5	2.4	3.0	3.5
Europe	4.2	2.3	2.5	3.5	5.9

* WPE + M/R + Fab Facilities. Total Equipment does NOT include Wafer Manufacturing Equipment

New equipment, includes wafer fab, test, and A&P. Totals may not add due to rounding

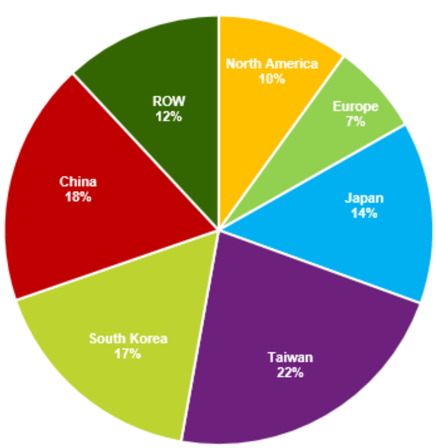
Source: SEMI Equipment Market Data Subscription, Prelim. January 2021

- **2020 equipment market is expected to reach $69 billion, surpassing the previous high set in 2018, representing 15.6% growth**
- **Growth momentum will continue in 2021 and 2022 driven by memory spending and advanced logic and foundry investments**
- **Taiwan is expected to regain the leading position in 2021 and 2022**
- **Korea will see strong growth in the forecast driven by memory**
- **China spending was strong in 2020, though uncertainty looms for 2021/2022**

SEMI® Total Material Forecast by Region

6% Growth in 2021

2021F = $58.7 Billion



US$ Billion	2020F	2021F	2022F
North America	5.59	5.83	6.0
Europe	3.63	4.03	4.25
Japan	7.95	8.08	8.09
Taiwan	12.38	13.08	13.66
Korea	9.23	9.92	10.53
China	9.76	10.79	11.61
ROW	6.76	7.01	7.25
Total	**$55.3**	**$58.7**	**$61.4**

Source: SEMI Materials Market Data Subscription, February 2021

Totals may not add due to rounding

Availability of Substitutes or Alternative Sources

There are few sole source equipment and materials, as shown in the charts below. However, in a situation where there is a short-term disruption, semiconductor device makers cannot easily switch suppliers because devices and materials are qualified on specific processes and machines made by specific suppliers.

EQUIPMENT	U.S. SUPPLIER	MARKET LEADER	OTHER SUPPLIERS
Etch	Lam Applied	Lam	AMEC Mattson Naura Hitachi Hi Tech Tokyo Electron SEMES
Deposition	Applied Lam	Applied	ACM Research Naura Piotec Tokyo Electron Wonik TES Jusung Ulvac ASM
Implant	Applied Axcelis	Applied	Nissin SMIT
Lithography	Onto	ASML	Suss MicroTec Nikon Canon
Track	n/a	Tokyo Electron	Screen SEMI SEMES
Mask Making	Applied	NuFlare	JEOL
CMP	Applied	Applied	Ebara, Tokyo Seimitsu KC Tech
Process Control	KLA Applied	KLA	Hitachi Hi Tech
MOCVD	Veeco	Veeco	AMEC Aixtron
Strip	Lam Applied	PSK	Mattson
Clean	Lam	Screen	ACM Research Tokyo Electron SEMES
Reticle Inspection	KLA Applied	KLA	Lasertec NuFlare
Wafer Inspection	KLA Applied	KLA	Skyverse Hitachi Hi Tech NextIn ASML
Macro Inspection	KLA Onto	KLA	Skyverse Unity Camtek Nikon Lasertec
Defect Review & Classifcation	KLA Applied	KLA	Lasertec NuFlare

MATERIAL	U.S. SUPPLIER	MARKET LEADER	OTHER SUPPLIERS
Silicon Wafer	n/a	Shin-Etsu	Zing Semi, Siltronic, Sumco, SK Siltron, Globalwafers
Photoresist	DuPont	JSR	Kempur, Ruihong, TOK, Shin-Etsu, Sumitomo, Dongjin, Merck
Photoresist Ancillaries	Brewer DuPont	Brewer	Kempur, Ruihong, Merck, Nissan, JSR, Shin-Etsu, Cheil
Photomask	Photronics	Toppan	Newway, DNP
Electronic Grade Gases	Entegris	Merck	718, Huate, Nata, Air Liquide, Linde, Showa Denko, Matheson, Wonik, SK Materials
Wet Chemical	CMC DuPont Entegris	BASF	Jianghuawei, Jingrui, Merck, Kanto, MGC, Dongwoo, Soulbrain
CMP Slurry and Pad	DuPont CMC	DuPont CMC	Anji, Merck, Fujifilm, Hitachi, Fujimi, Fujibo, JSR, Cheil, Dongjin
PVD Targets	Honeywell	JX Nippon	KFMI, Linde, Tosoh
ALD/CVD Precursors	Entegris	Merck	Nata/UpChem, Air Liquide, Adeka, SKTC/TriChem, Hansol
Electroplating Metals	Entegris DuPont	Entegris	Shinyang, BASF
Spin on Dielectrics	n/a	Merck	Samsung SDI

Gaps in Manufacturing Capabilities and Location of Critical or Essential Goods and Materials

Lack of leading edge

The U.S. lacks leading edge logic and memory fabs, as well as assembly, test, and packaging facilities. The ability to build new domestic capacity will depend largely on whether these facilities can be commercially viable, technically sound, and cost-competitive compared to existing fabs outside the U.S. Domestic policies providing increased federal funding need to be sustained over the long-term and include the whole toolbox of incentives, including tax credits, R&D funding, and grant programs. If new leading edge fabs are built in the U.S., assembly, test, and packaging would likely occur elsewhere, under current trends. With respect to packaging, more advanced packaging could be more competitive in the U.S. for more high-end, innovative chips.

Wafers

Silicon wafers are the dominant starting substrate for semiconductor devices, although gallium arsenide, gallium nitride, and silicon carbide are also used for important devices. Silicon wafers are made from very pure silicon and the atomic lattice structure is perfectly single crystal. Small amounts of dopant atoms are added to modify the electrical properties. Advanced small geometry designs use 300mm diameter wafers, but important devices are produced on 200mm and 150mm diameter wafers. In 2020, the number of 300mm diameter wafers sold worldwide was 6.5 million per month, with less than 5% produced in the US. The number of 200mm diameter wafers sold worldwide was 5.5 million per month, with less than 10% produced in the US. The production in the US is less than consumption by U.S. based plants for both diameters. There is no longer 150mm wafer production in the United States.

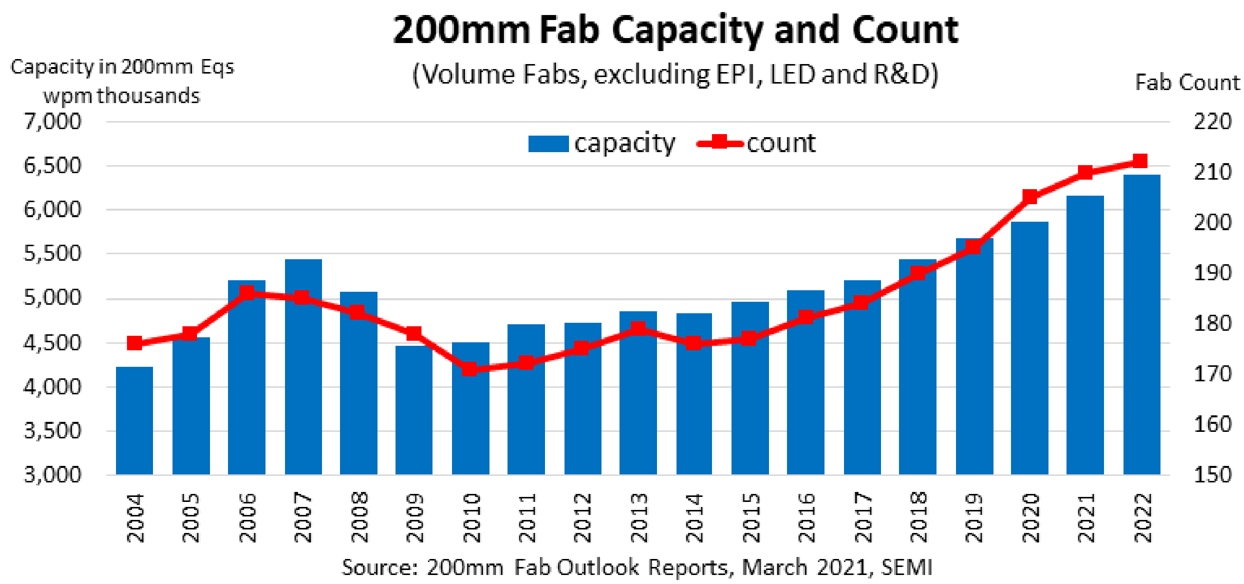
The silicon wafer market is dominated by four companies. Shin Etsu Handotai (SEH) and SUMCO of Japan, GlobalWafers of Taiwan which is currently completing the acquisition of Siltronic AG of Germany, and SK Siltron of South Korea. SEH and SUMCO have full production capability in the US for 200mm wafers and SEH has a full production capability in the US for 300mm wafers. The process of making silicon wafers requires high purity polysilicon, which is of a different grade than that used for silicon photovoltaics or solar cells. Hemlock Semiconductor and Mitsubishi Materials have polysilicon production plants in the US with suitable quality. The polysilicon is melted in special high temperature furnaces referred to as CZ (Czochralski) pullers. The silicon melt is contained in a high purity quartz crucible. A second method of growing silicon is the Floating Zone (FZ) method, which has advantages over CZ silicon for some device applications. After the single-crystal silicon is grown into a long cylinder, the individual wafers are sliced, shaped, etched and polished. The wafer is of a thickness between 0.7 and 0.8 mm and has extreme levels of flatness, surface cleanliness and metal contamination. This equipment, including CZ pullers, slicers and polishers is highly specialized for this industry. Few of these tools are produced in the United States, and few of the specialized materials are produced in the United States. For example, the quartz crucibles, graphite parts, and slicing wire are sole-sourced or not produced in the U.S. any longer.

Many silicon wafers are shipped to the end user as a polished wafer. 300mm polished wafers are used for DRAM and NAND memory chips. Approximately one-third of all silicon wafers are processed further after the polishing step, by growing a thin epitaxial silicon layer by chemical vapor deposition (CVD) on top, or by processing through high temperature argon annealing furnaces, or by bonding two silicon wafers together in a silicon-on-insulator (SOI) wafer. These specialty processes are less commonly found in the United States. Advanced logic devices typically are produced on 300mm epitaxial wafers. Radio Frequency (RF) switches and tuners are produced on 200mm and 300mm SOI wafers. Many types of analog-to-digital conversion devices and sensors are produced on 200mm epitaxial wafers. Such devices are commonly used for automotive, industrial and medical devices.

As electronic systems require many dozens or hundreds of individual semiconductor devices, each of which may be produced on a different diameter wafer or different type of silicon wafer, the full range of silicon products needed are not currently available from US production plants. Most silicon wafers are produced in Japan, South Korea, Taiwan, Germany, France, Singapore and Malaysia. The R&D for such silicon wafers is almost exclusively conducted outside the United States.

200mm and other SME

As global semiconductor manufacturing equipment (SME) spending reaches record highs to meet demand for new fab capacity, and with continued growth forecasted, SME producers may be challenged to meet this growth in demand. The market for mature node, 200mm production tools is currently extremely tight. The chart below shows strong growth in 200mm manufacturing capacity in the last 5 years, reflecting growing demand for mature node semiconductor devices in automotive, IOT, and many other applications. However, growth in 200mm node capacity needed to meet demand is constrained by a limited supply of 200mm SME. With demand for SME rising across all nodes, new SME production has focused on higher-margin, advanced node tools. New mature node capacity has long depended on used tools, and after a significant ramp in the last 5 years, the market for used tools is extremely tight. With continued growth in demand for all SME – see charts on pages 3, 4 and 15 – the availability of SME and spare parts for all production lines are significant concerns that could limit U.S. capacity growth in mature and advanced nodes.



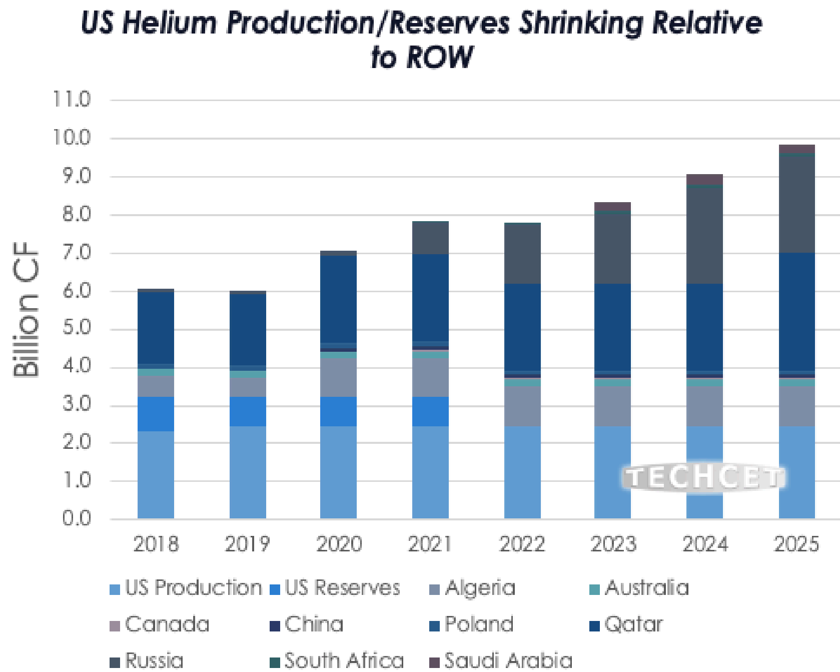
Materials and Rare Earths[7]

Many critical or essential goods and materials used in semiconductor production are not sourced in the U.S., and therefore would leave the supply chain vulnerable if foreign sources become unavailable. Rare earth elements are vital to the production of semiconductors. U.S. optics and magnetics are dependent on rare earths from Australia, China, and Japan. Other materials important for silicon wafer production that are not regularly sourced in the U.S. include germanium and gallium. Materials with a limited number and geographical diversity of suppliers include but are not limited to polysilicon, photomasks, wafers / substrates, photoresists, metal coils, helium, natural gas, SF2 (a glass with lead oxide as an essential component), YAG (used in solid state lasers), and Alpha-BBO (an optical material with a very wide optical transmission window).

- Chemicals
    - U.S. fabs currently source UHP (ultra-high purity) Isopropyl Alcohol (IPA) from Taiwan and Japan as U.S. suppliers have not developed a supply-chain that will support leading edge quality IPA.
    - Sulfuric acid for advanced node production is widely available in the U.S., but not at the extreme purity levels needed for advanced 5nm node production because the reinvestment economics have been low as advanced fabs have been located offshore. “Basic” materials, such as sulfuric acid, may not be readily available from current U.S. infrastructure as reinvestment is not supported by the limited current U.S. market for these materials.
- Electronic Grade Gases

[7] Most of the information in this section was provided by TECHCET CA LLC. TECHCET CA LLC is a SEMI member and advisory service firm focused on process materials supply-chains, electronic materials technology, expert witness work, and materials market analysis for the global semiconductor, display, solar/PV, and LED industries.

- Ukraine and China are the sources of 80% or more of rare gases (krypton and xenon) to the semiconductor industry. Much of the Ukraine's rare gases are sourced from Russia. The only other major source of rare gases is China. Production of these gases is heavily dependent on steel manufacturing, which require very large Air Separation Units (ASUs). There are no ASUs that are solely dedicated to producing these rare gases.
- Russia is a major source of chlorofluorocarbons (CF) gases for at least two gas suppliers in the U.S.
- Various types of valves, containers, and components needed for the storage and delivery of gases and materials have recently emerged as bottlenecks in the supply chain. Back-order times for these types of hardware are now reaching 40 weeks in duration. A major reason for these backlogs is hording across the supply chain (fabs, equipment, sub-suppliers, gas, and materials suppliers) because of concerns about availability due to shipping and production delays.
- Helium is a byproduct of other processes and its supply is largely dependent on the natural gas industry. Without helium derived as a secondary product from oil and gas production, modern semiconductor manufacturing would not be possible. Helium supply has been a concern in recent years. New capacity is coming on-line, primarily in Russia and Qatar. Though the U.S. has large quantities of natural gas reserves, the gas contains very little extractable helium. In 2013, Congress passed the Helium Stewardship Act which allowed the Department of the Interior to continue to sell crude helium from the Federal Helium Reserve in Texas. However, the Act required the Secretary of the Interior to dispose of all helium assets by September 30, 2021, with the intent that private industry oversee the helium reserve and increase production once the reserve was closed. The reserve currently satisfies more than 40 percent of domestic demand.



- Rare Earths, Minerals, and Metals
    - Rare earths of concern include lanthanum, cerium, and scandium. Lanthanum is used in the fabrication of logic devices of 14nm and below technology. Cerium is consumed to produced ceria slurry critical for advanced semiconductor production. Scandium is used in an aluminum-scandium alloy piezoelectric film critical for RF filters and other sensors.
    - China is the source of 60% or more of the fluorspar used in the semiconductor industry to make fluorine-containing products, including CF gases, NF3, HF, WF6, SF6. U.S. operations generally source from Mexico, but Asian semiconductor manufacturers are dependent on sources in China.
    - 80% of the world's tungsten mineral (APT, ammonium paratungstate) comes from China. APT is used to make WF6 and W sputter targets. WF6 is used for the majority of all semiconductor devices. China represents about 80% of the mining production, with 95% of supply controlled by one company. New mining sources may exist in Vietnam and possibly in South Korea.
    - 45% to 50% of global palladium supply is sourced from Russa; it is used to form electrodes, and plating/coating for lead frames and bonding wire. 70% or more of platinum sourced from South Africa; it is used for electrodes and silicide contacts. Ruthenium has applications in metal interconnect and electrode (for sensors, MRAM) applications with over 90% mined from South African sources.
    - Yttrium-oxide and yttrium metal in nearly raw material form (from the mines or one step away from the mining companies for distribution) go from China to post

processing suppliers in Europe, U.S., and Japan to make more refined materials. They then are sold to primary suppliers, predominantly in the U.S., Korea, Japan.

- Sole Source Concerns: For some material segments there may be only one qualified source, and in a few instances, there is only one supplier of a particular type of material:
    - Hydrochloric acid (HCl) for North America has been sourced from one supplier, Olin in Freeport (TX), for the past several years. Despite a second source coming online, Niacet in Niagara Falls (NY), has announced they will exit the business by the end of 2021. HCl is not easily sourced nor shipped overseas, making local supply critical.
    - The CMP (chemical mechanical planarization) market segment is highly dependent on DuPont for CMP pads (polishing). Despite multiple U.S. manufacturing facilities, capacity constraints may result from significant U.S. fab expansions in coming years. CMP slurries are also subject to sole source concerns.
    - Extreme Ultraviolet (EUV) is a specialized lithography area where certain photoresist materials are unique and sole sourced.

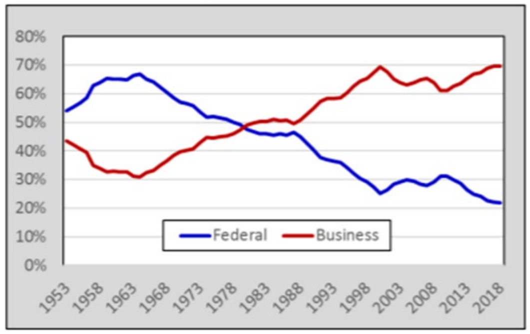
Need for Research and Development Capacity to Sustain Leadership

Research and development are vitally important to innovation and maintaining U.S. leadership in the semiconductor industry. Investing in semiconductor research will make manufacturing in the U.S. globally competitive and strengthen the industry, which requires significant, sustained R&D to push forward the leading edge. A significant percentage of semiconductor industry revenue and profits are reinvested into R&D to keep pace with technology innovation. The next generation of products are being funded by the ability to sell products all over the world.

While total R&D spending in the U.S. continues to grow, the federal government's share of contribution has declined significantly. According to the National Science Foundation, in 1953 businesses funded 43.5 percent of total R&D spending and the federal government funded 53.9 percent. In 2018, businesses funded 69.7 percent of total R&D spending whereas the federal government funded 21.9 percent.[8]

[8] https://fas.org/sgp/crs/misc/R44307.pdf

Federal and Business Shares of U.S. R&D Expenditures, 1953-2018



Source: CRS analysis of National Science Foundation, *National Patterns of R&D Resources: 2017–18 Data Update*, NSF 20-307, Table 6, January 8, 2020.

U.S. tax support for R&D is low by international standards and needs adjustment to be more competitive with incentives in other countries. For example, China, South Korea, Ireland, Singapore, and the U.K. all offer either a preferential tax rate for semiconductor companies, a “super deduction” or tax credit for all current R&D expenses, or a more generous R&D tax. China’s R&D tax subsidy is 2.7 times more generous than the United States’. From 2003-2017, the Information Technology and Innovation Foundation noted that the Chinese government has increased their R&D funding by 330 percent from $23 billion to $98 billion, while U.S. government R&D grew by just 2 percent from $121 billion to $124 billion.[9]

Gaps, Opportunities, and Best Practices for Domestic Education and Manufacturing Workforce Skills

Developing domestic education and manufacturing workforce skills is critical to building domestic capacity for the supply chain. The industry has a wide range of skills needed for current and future positions. As of March 2021, Burning Glass data shows tens of thousands of open engineering, research, and product/project management needs within the semiconductor industry. Workforce development is consistently one of the top needs identified by SEMI member companies. The number and breadth of job openings and needed skill sets further illustrates this need and the gaps within the industry – particularly for technicians and engineers, and even more so for those from underrepresented groups such as women and people of color. Tremendous opportunity, however, lies in identifying, engaging, supporting, training, and welcoming individuals from these groups into the semiconductor industry. There are significant pools of potential workers across the U.S., in communities near educational facilities and semiconductor company clusters. These individuals include returning service members, those entering the workforce, currently underserved populations, and those looking to change careers because they lost jobs due to the Covid pandemic and they need connections, support, training, and infrastructure to become the workforce we need.

[9] http://www2.itif.org/2020-enhanced-tax-incentives-rd.pdf

Role of Transportation Systems
Given the global nature of the supply chain, disruptions to transportation systems can have significant effects on the industry. The industry is currently impacted by a lack of shipping containers, particularly temperature-controlled containers, delaying the arrival of key materials. Over the past year a significant imbalance has emerged between the shipments of materials coming from Asia, in particular China, and shipments going back to Asia from the U.S. There is now about a 30% difference between shipments of materials to the U.S. and shipments back to China. Because of this imbalance, there is an abundance of empty containers in the U.S. and EU and a lack of containers in Asia. To remedy the situation, some shipping companies have instituted a program to ship empty containers back to China for rapid refilling at Chinese ports for shipment back to the U.S. to reduce costs and cycle times. In addition, the container imbalance is also impacting the ability to ship raw materials from Japan to the U.S. for manufacturing products for use in the semiconductor industry. As a result, many products are now on allocation both in the U.S. and in Asian countries that produce semiconductors.

Additionally, air and road transportation disruptions impact the industry. Most semiconductor devices and equipment are shipped via air freight. These costs have increased substantially as the amount of passenger jet traffic was reduced during the COVID-19 pandemic, raising costs for the remaining air freight capacity – another area where the semiconductor supply chain is impacted by second-order effects in another industry. Road transportation of hazardous chemicals is also a challenge as fewer drivers are trained to transport hazardous chemicals, possibly constraining the supply chain as demand increases. Warehousing of materials in close proximity to production can be impacted by local regulations that either prevent or tightly control the volumes of stored hazardous materials.

VI. Potential impact of the failure to sustain or develop elements of the semiconductor supply chain in the United States on other key downstream capabilities, including but not limited to food resources, energy grids, public utilities, information communications technology (ICT), aerospace applications, artificial intelligence applications, 5G infrastructure, quantum computing, supercomputer development, and election security. Also, the potential impact of purchases of semi-conductor finished products by downstream customers, including volume and price, product generation and alternate inputs.

Disruptions in the semiconductor supply chain can lead to serious consequences on downstream industries that rely on chips, including food resources, energy grids, public utilities, information communications technology (ICT), aerospace applications, artificial intelligence applications, 5G infrastructure, quantum computing, supercomputer development, and election security. Nearly all items that run on electricity incorporate semiconductors and news stories today are replete with potential disruptions to downstream industries from lack of an adequate supply of semiconductors. If, for example, medical electronics supply is cut off, critical, life-saving equipment such as ventilators or patient monitoring equipment may not be available, resulting in patient deaths. The supply chain risk is amplified during a worldwide crisis, such as a pandemic, when demand increases and supply decreases due to factory shut downs and shipping difficulties.

Semiconductor supply imbalances impacting the automobile industry have illustrated the key role of semiconductors making smarter vehicles with electronic functions, such as blind spot detectors, rear view cameras, and automatic emergency braking systems. These functions are now essential to the vehicle and this trend will increase significantly as the industry moves further toward electric vehicles and autonomous driving. Additionally, these chips are unique to the function and are not interchangeable with one another. The loss of any number of semiconductor devices can have unforeseen downstream economic, health, safety, and national security impacts.

VII. Policy recommendations or suggested executive, legislative, regulatory changes, or actions to ensure a resilient supply chain for semiconductors (*e.g.*, reshoring, nearshoring, or developing domestic suppliers, cooperation with allies to identify or develop alternative supply chains, building redundancy into supply chains, ways to address risks due to vulnerabilities in digital products or climate change).

Manufacturing Incentives
Federal incentives are crucial to restore U.S. competitiveness in semiconductor manufacturing and reverse the decline in the U.S. share of global manufacturing capacity. The U.S. Department of Commerce financial incentive program passed in the FY 2021 NDAA would make a substantial contribution to make building new fabrication plants in the U.S. competitive. At least $15 billion in funding for this program is needed to incentivize U.S. production and strengthen the U.S. semiconductor supply chain.

The federal investment tax credit (ITC) for semiconductor manufacturing facilities and equipment included in the CHIPS for America Act would help quickly close the cost gap and provide certainty for investments in new and expanded fabs, creating thousands of jobs and reversing the decline in America's share of global semiconductor manufacturing. The ITC is transparent, reliable, and available to all companies to invest in U.S. semiconductor manufacturing facilities. With the U.S. projected to continue to lose ground and years required for new facilities to come online, a tax credit will impact investment decisions most quickly and is a reliable method used in countless other industries to incentivize U.S. manufacturing. An ITC would be the single most impactful federal policy to help build new U.S. semiconductor manufacturing capacity and would provide a strong foundation for the Commerce Department incentive program authorized in the FY 2021 NDAA.

SEMI strongly supports the significant federal investments in the semiconductor industry included in the President's American Jobs Plan. His call to invest $50 billion in semiconductor manufacturing and research, as called for in the bipartisan CHIPS Act, $50 billion in the National Science Foundation (NSF) creating a technology directorate focused on fields like semiconductors, and to provide $30 billion in additional funding for R&D are bold proposals that will strengthen the semiconductor industry and supply chains in the United States. SEMI looks forward to working with the administration and bipartisan leaders in Congress to enact this funding into law, along with the investment tax credit, to reverse the 50 percent decline in the U.S. share of global semiconductor manufacturing capacity in the last 20 years.

These comments lay out a series of key items that are used in and necessary to the efficient functioning of the semiconductor supply chain. Most relate to items that are “upstream” of semiconductor facilities (fabs) themselves, illustrating the importance of the long and diverse supply chain that sustains them. Ensuring policymakers have the flexibility to target incentives to upstream facilities and components, in addition to chip fabs, therefore should be a central element of efforts intended to strengthen the semiconductor supply chain. The proposed investment tax credit and Commerce incentive program must cover facilities producing semiconductor equipment, materials, and design software to ensure that bottlenecks and weak points in the upstream supply chain do not undermine the legislation’s goal to reverse the decline in the U.S. share of global semiconductor manufacturing capacity.

Tax policy

In addition to providing tax incentives to build a stronger U.S. semiconductor industry and supply chain, avoiding tax policy changes that would weaken the competitiveness of the industry in the U.S. is also very important. The requirement in 2022 to amortize research expenses over five years will significantly increase the cost to perform essential research and development in the U.S. Reversing this policy is critical for companies to continue to support innovation via U.S. investment in R&D. Bipartisan, bicameral legislation to repeal the requirement to amortize research expenses has been introduced in Congress and should be enacted promptly.

Raising the U.S. corporate tax rate or reducing the benefit of the foreign-derived intangible income (FDII) deduction would harm the competitiveness of the export-oriented semiconductor supply chain. With the majority of semiconductor device, equipment, materials, and software sales made to foreign sources, the FDII deduction’s preferential tax treatment for foreign income based on IP held in the U.S. is a strong incentive to keep IP in the U.S. and service foreign customers via exports, rather than offshore production facilities. These domestic facilities exporting from the U.S. are strengths for the U.S. semiconductor supply chain that should be preserved, not weakened. Competitive corporate tax policies are important foundations for U.S. supply chain strength and resilience. SEMI urges the administration and Congress to avoid eroding the benefit of proposals to improve the competitiveness and strength of the semiconductor manufacturing supply chain by implementing other provisions that will make the industry less competitive, weakening the supply chain in the process.

Export Control

Export controls are powerful national security tools that are best used strategically, in a manner that is integrated in a unified strategy with other tools of national policy, narrowly tailored to address specific national security concerns, and implemented multilaterally with other semiconductor-producing countries. When used instead as a unilateral tool of U.S. industrial policy, any potential short-term benefit to national security is likely to erode over time as the global competitiveness of the controlled industry is ultimately weakened.

The semiconductor industry operates global supply chains, with leading technology for semiconductor devices, equipment, and materials present in many nations. There is significant foreign availability of semiconductor device technology, with a strong majority of manufacturing processes and technology available and occurring outside the U.S. For SME, there is substantial foreign availability of similar technologies. SEMI has consistently maintained that multilateral controls – where items of concern are controlled by all major producing nations – create a level playing field, maximize effectiveness, and minimize harm to U.S. national security and economic competitiveness. Unilateral U.S. controls over items for which there are comparable non-U.S.-origin items are generally ineffective in supporting national security goals and are likely to erode any technological advantages enjoyed by U.S.-origin items. Global customers who are unable to procure U.S.-controlled items will be incentivized to purchase comparable foreign-origin substitutes that are not similarly restricted or simply design out U.S.-origin technology altogether. Increasingly, foreign competitors are marketing their non-U.S. origin substitutes as “free from U.S. export controls” which has become a key differentiator. History has shown that such unilateral controls are detrimental to U.S. competitiveness, exemplified by the adverse impact on the commercial satellite industry from the International Traffic in Arms Regulations (ITAR). Over time, unilateral controls will stifle innovation in the U.S. by reducing the financial resources U.S. exporters need to perform R&D and maintain technological competitiveness and/or by forcing companies to shift production and R&D outside the United States. In addition, as U.S.-origin items are removed from the global supply chain, the U.S. Government’s visibility into the technological prowess and roadmaps of global producers is reduced.

With over 89 percent of semiconductor equipment and 90 percent of semiconductor materials shipped to facilities outside the United States, access to export markets is essential to these segments of the semiconductor industry and is the foundation of U.S.-headquartered companies’ market share positions. Unilateral U.S. export controls may contribute to a perception that the supply of U.S.-origin items is unreliable and contribute to customer efforts to avoid or “design out” U.S.-origin products and technology. The loss of essential foreign revenue needed to maintain research expenditures and compete at the leading edge of technology will make U.S. exporters even less competitive and further shift market share away from U.S. exports. The semiconductor industry allocates roughly 20 percent of revenue to R&D. Segments within the industry allocate even more: over 30 percent of revenue for design software providers is directed to research. With 90 percent of sales outside the U.S., unilateral controls that place U.S.-origin items at a disadvantage in the global competition for market share will contribute to the demise of U.S. leadership in this technology, harming exporters in the U.S. and U.S. national security.

Carefully formulated end-use or end-user controls can be more narrowly tailored to specific national security interests and concerns and can provide national security protection without the enormous economic costs of broad export denial policies. However, in practice, such controls are often applied unilaterally since most other nations lack an Entity List or similar broadly applicable sanctions. This limits their effectiveness to address the proliferation of technology while creating unique disincentives to the purchase and use of U.S.-origin technology.

The May and August 2020 expansions of General Prohibition Three as regards transfers to Huawei were unprecedented expansions of U.S. jurisdiction – well beyond conventional controls on U.S. exports – to control items that are foreign-made products of U.S.-origin technology, equipment, or software, regardless of their national security sensitivity or their ubiquity. This dramatic expansion of U.S. controls to cover products developed by the customers of firms providing U.S.-origin equipment, materials, and design software creates strong and unique disincentives to purchase U.S.-origin items and technology. Purchasers of U.S.-origin items reasonably fear losing access to other customers for items with no conventional nexus to national security. Furthermore, these types of controls, because they often extend jurisdiction beyond common practice or usual legal standards, lend themselves to being targets of blocking statutes and counter-regulations further complicating the compliance and competitiveness of companies operating in the U.S. These actions have created significant uncertainty and doubt about the reliability of U.S.-origin items. This, over time, has the potential to undermine market acceptance and confidence in these items, with potentially disastrous consequences for firms developing items and technology in the U.S.

Ongoing efforts to control foundational and emerging technology must be implemented via proposed rules consistent with statutory requirements and best practices. Absent urgent national security considerations, emerging and foundational technology controls should be proposed to the relevant multilateral regime with adequate time reserved for regime partners to agree to any U.S.-proposed changes before a unilateral U.S. control is implemented.

In addition to the underlying policy of what is controlled to where, a transparent and predictable regulatory process, including robust consultation with industry before and after new or expanded controls are implemented, is essential to avoid unintended, harmful, and unforeseen consequences of policy changes. Proposed rules with adequate comment periods, whereby industry has an opportunity to share its views and expertise with government, and the avoidance overly prescriptive legislation that ties the hands of regulators to adapt to changing technological developments are key process considerations to avoid weakening the U.S. semiconductor supply chain. Commerce should work to reduce the backlog of licenses and classification requests pending review. Long delays operate as de facto license denials and create uncertainty that contributes further to the design-out of U.S. technology, weakening the U.S. semiconductor supply chain. Additionally, greater alignment among the interagency departments at the start of the licensing process regarding supplemental information requests and their nexus to license standards of review would reduce the regulatory churn that delays licenses, fosters uncertainty, and weakens the competitive position of U.S.-origin items.

A transparent and deliberative process for the consideration and implementation of new export control measures is even more important in a time of supply constraints and imbalances. While it usually takes years to bring new capacity online, restrictions on the supply of items needed for continued production impact capacity much more quickly and there is little available excess global capacity to meet production needs. Policymakers therefore should proceed cautiously and seek to fully understand the potential impacts on semiconductor-consuming industries of new measures that could impair or reduce the production capacity available to meet increasing demands from the many semiconductor consuming industries. Measures that would have the effect of reducing capacity in the near term, before policies intended to support new capacity investments are implemented and take effect, would likely further strain the supply of semiconductors and exacerbate imbalances currently roiling the semiconductor market.

Federal Research Funding

Semiconductor manufacturing is among the most complex production processes in any industry and requires significant, sustained research and development to push forward the leading edge. The research provisions in the NDAA are critical for industry to maintain its global leadership and SEMI supports fully funding those program authorizations:

- $9.05 billion for Fiscal Year 2021 through 2030, to establish a National Semiconductor Technology Center (NSTC) at the Department of Commerce to conduct research and prototyping of advanced semiconductor technology to strengthen the economic competitiveness and security of the domestic supply chain. Of which, includes:
  - $5 billion to establish a National Advanced Packaging Manufacturing Program at the National Institute of Standards and Technology to establish U.S. leadership in advanced microelectronic packaging.
  - $3 billion for a National Strategy on Semiconductor Research.
- $7.5 billion over five years, for semiconductor research at the National Science Foundation to maintain U.S. leadership in semiconductor technology.
- $2 billion for semiconductor research aligned with the National Strategy on Semiconductor Research at the National Laboratories at the Department of Energy.

Additionally, the U.S. should increase and stabilize funding for maintaining and upgrading proton and heavy-ion accelerator facilities to restore resilience in national testing capabilities for radiation-hardened semiconductor chips.

Trade Policies

The semiconductor industry supply chain relies on the interconnectedness of global economies and the free flow of goods and data across borders. As noted earlier, with over 89 percent of semiconductor equipment and 90 percent of semiconductor materials shipped to facilities outside the United States, access to export markets is essential to these segments of the semiconductor industry and is the foundation of U.S.-headquartered companies' market share positions. SEMI supports updated trade policies that include the protection of intellectual property rights, the reduction and elimination of tariffs, the harmonization of global technology standards, and a transparent, rules-based global trading system that fosters fair competition and market access for all companies in the semiconductor supply chain. International trade rules and enforcement mechanisms should be strengthened, while continuing to open global markets needed to sustain U.S. innovation.

Pursuing new export markets through trade agreements should be a priority for the administration and Congress. SEMI supports continuing the ongoing negotiations with the United Kingdom and the European Union and encourages a comprehensive free trade agreement with those important trading partners. We also encourage U.S. engagement in additional trade agreements in the Asia-Pacific region, including phase two negotiations with Japan and China.

Recent tariffs actions against several countries, including China and the EU, serve as taxes on U.S. importers, make goods more expensive in the U.S., harm the competitiveness of U.S. manufacturing, and can weaken U.S. supply chains that are reliant on these items. Some tariffs on Chinese goods have disincentivized bringing tools and equipment back to the U.S. from China and raise the cost of U.S. operations that utilize imports from China in their production processes. SEMI supports the removal of these harmful tariff actions. The increased costs associated with these tariffs can also lead companies to scale back production, postpone facility upgrades and investments in product development and R&D, cut investments in technology and infrastructure, and significantly curtail the hiring and recruiting of new employees at the expense of U.S. manufacturing operations, employees, and local economies. Other measures to reduce tariff barriers, such as the renewal of the Miscellaneous Tariff Bill and an expansion of the WTO Information Technology Agreement would serve to increase affordability and accessibility of products critical to the supply chain.

Environment, Health and Safety

Environment, health, and safety (EHS) regulations are significant factors affecting the production of semiconductors. For example, the U.S. Environmental Protection Agency's (EPA) recently issued a final rule under the Toxic Substances Control Act banning Phenol, Isopropylated Phosphate (PIP) from products sold in the United States. This regulation would create significant disruptions across the supply chain since PIP is commonly used in the industry, particularly in wiring for equipment and other items. EPA regulations that prevent the importation of stabilized bromine antimicrobial, and the U.S. Food and Drug Administration's regulations on imports of lasers, all affect processes in the supply chain. One of the key EHS issues that equipment manufacturers face are material restriction regulations that apply broadly (i.e., such that all components that are acquired to make equipment must be surveyed) and with extremely low or no threshold, both in the U.S. and in other regions.

Ensuring a practical and pragmatic threshold for domestic substance restriction regulations would aid compliance and understanding of the regulations. Test methods that are economically viable for the supply chain, and/or the regulations that overtly accept attestation from the supply chain as a means of demonstrating sufficient diligence are needed. Additionally, the U.S. must increase coordination with other regions that also are major semiconductor manufacturing regions to avoid requirements for equipment manufacturers to design equipment specific to a particular region and allow one tool that will be accepted globally. For example, the EU's restriction on perfluorooctanoic acid (PFOA) to a level of 25ppb in articles cannot be achieved or confirmed in any practical way with consideration of all the components that originate in China and it is often difficult to secure reliable information regarding articles used in upstream points of component manufacturing occurring in other countries.

Workforce and Immigration

As discussed previously, a reliable and skilled workforce will be required to build capacity in the U.S. using both domestic and foreign-born talent. To fully develop workforce capabilities, using potential best practices, the following should be considered:

a. Current and projected employer needs around skill sets, based on direct data from employers and best research on trends around projected skill needs in the next 2-5 years.

b. Mapping of training resources, including virtual and in-person; development of new trainings as needed that map directly to employer needs.

c. Mapping of locations of semiconductor facilities, nearby educational institutions and resources, and communities proximate to both with high numbers of potential workers, to create target regions that will best lend themselves to cohort-based movement into the industry.

d. Coordinated, region-based approaches that connect workforce development agencies, employment agencies, support service providers, educational institutions, employers, and other agencies to work collaboratively to support individuals on their pathways toward joining the industry.

e. Coordinated support for employers to strengthen their diversity, equity, and inclusion practices as well as their mentorship and sponsorship programs so they can attract, retain, and promote a workforce with the diversity of perspectives needed to be competitive in the global market.

The U.S. should raise visa caps for high-skilled workers, reverse the declining approval rates of H-1B visas, and promote increased visa access to foreign graduates of U.S. universities in STEM disciplines. High-skilled immigrants and students educated in the U.S. are critical to the workforce of global industries and positively complement the American workforce. Policies that preclude U.S. technology companies from employing uniquely skilled immigrants, and the elimination of opportunities for foreign-born, U.S.-educated STEM students, are counterproductive to the continued leadership of the U.S. in the semiconductor supply chain.

Standards

Other countries often financially subsidize the participation of individuals and companies in international standards development and reward them for successfully adopted standards. The U.S. government could promote U.S. influence in the evolution of technology by financially supporting smaller companies' participation in international standards bodies, as these companies often cannot afford the costs involved for an engineer to work on standards proposals and attend meetings all over the world. By influencing international standards development, the U.S. will be able to compete with countries that promote standards as a matter of coordinated industrial policy.

FDA Approvals of Medical Electronics

As presented in SEMI's February 2021 report "Medical Microelectronics Industry Capability and Resiliency Assessment (M2ICRA)", medical electronic devices have unique criteria and constraints due to FDA regulations and required approvals. Many equipment suppliers have cited the significant overhead of qualifying alternate electronics parts as a reason for limited second sourcing. Without options for back-up parts and suppliers, supply chain risk is multiplied. A review of FDA approval requirements with a focus on allowing alternate bills of materials with the same form, fit and function can reduce the supply chain risk for medical electronics.

Supply Chain Programs and Initiatives

A. Supply Chain Risk Management: A Public-Private Partnership Network

The U.S. government has structure in place that maintains a military supply for trained personnel at a state of readiness for national defense. In the case of supply chains critical to defend against national threats of a non-military nature (pandemic, energy grid collapse, water source and integrity), there is no parallel structure. Furthermore, these critical supply chains are largely commercial. A public-private partnership could be formed to inform and organize the supply chains critical to the response to national threats outside the military industrial base. Support and planning for crisis events would include, but not be limited to, national safety supply chain teams in key companies, collaborative contingency planning, inventory strategy development, and clear communication supporting a coordinated strategy. A network of private, commercial sector resources could be interfaced with a public, federal management structure. As a neutral organization, this network could align with government but also drive industry and promote competitiveness. In SEMI's February 2021 report "Medical Microelectronics Industry Capability and Resiliency Assessment (M2ICRA)", such a network is proposed in detail – see Appendix 1.

Establishment of a National Supply Chain Registry listing all U.S. companies participating in the microelectronics ecosystem would provide increased visibility for both private industry and government organizations into available materials, components, equipment, and other critical domestic supply chain capabilities for microelectronics manufacturing. The registry can aid in the assessment of infrastructure readiness, including energy sources, transportation, and logistics.

B. Research Commercialization Institute

SEMI administers several public-private partnerships to enable workforce development, technology development and industry standards. This proven method of multi-organization collaboration could also be used to improve semiconductor supply chain resiliency by assessing gaps and deploying risk mitigation measures to strengthen the microelectronics ecosystem.

Although the U.S. government spends billions of dollars each year on research and development programs, the IP created can struggle or fail to reach mass production. This "funding gap" or "Valley of Death" that exists between research and commercialization can leave viable technology abandoned or result in its migration outside the U.S. Much like industry management of product pipelines, a national effort is needed to leverage existing U.S. R&D programs through the complete product path ecosystem and demand side development.

With a goal of easing the transition to manufacturing, a Research Commercialization Institute could review R&D programs from early stages to prototype demonstration and provide guidance and support. Developed devices could be helped to commercialization through combinations of federal, state, and private investment opportunities, infrastructure support and close collaborations with strategic partner companies in the U.S. Metrics such as commercial readiness levels, start-up company spin-outs, and IP licensing could be tracked by the institute to gain data for establishing best practices for the transition to manufacturing.

C. Electronics Manufacturing Infrastructure Task Force

Equipment and facilities are key components of innovation. Microelectronics manufacturing facilities require specific infrastructure for power, water, chemicals, and waste management. A national task force aimed at establishing best policies and supporting economic development zones with streamlined permitting procedures would minimize the difficulties faced when setting up a new fab.

D. Heterogeneous Integrated Systems Institute

Focused on advanced packaging, 3D integration and system-in-package solutions, a Heterogeneous Integrated Systems Institute will enable improved performance via higher functionality devices and systems. This is a non-scaling extension of Moore's Law and critical to future, successful U.S. semiconductor manufacturing. While 97% of the world's current packaging infrastructures exists outside the U.S., next-generation assembly will require very different equipment, facilities, and skills. The Institute can foster research and development of advanced packaging methods as well as promote commercialization and technology deployment to U.S.-based manufacturing. Establishing leadership in this field could lead to re-shoring of assembly and test capability. Many U.S. fabs are looking to extend the utility of their current semiconductor nodes into new, higher value-add products. By bringing these companies together to collaborate on and utilize heterogeneous integration, the Institute could help make the semiconductor industry in the U.S. more competitive in the global market. Including an Advanced Design and Test element in the Institute is needed, as system solutions are becoming ever more complex.

E. Smart and Secure Manufacturing Institute

To better compete in the world market, U.S.-based semiconductor manufacturing facilities will need to employ Smart Manufacturing with higher automation levels and data driven control systems. Focused on Industry 4.0 roll out, a Smart and Secure Manufacturing Institute will promote a fully connected 5G Industrial Internet of Things (IIOT), improved manufacturing tool uptime, predictive maintenance, and flexible/adaptable factories. As semiconductor manufacturing tools become ever more intricate, new approaches for tool maintenance automation and visualization are needed. The Institute can support upgrading U.S. fabs with Smart Manufacturing technology and systems including, but not limited to: sensorized tools and components for monitoring, big data, and machine learning-based predictive maintenance, as well as parts tracking and traceability.

F. Sensor Systems Institute

Sensors are the fastest growing segment of the microelectronics industry. Sensor systems and the data they provide are essential for all commercial, consumer and defense applications. This growing sensorization trend will only accelerate across all future industrial and consumer sectors. For example, a modern car has over 100 sensors and up to 20 communication networks for managing everything from engine operation to passenger comfort. Furthermore, electronics accounted for 40% of a vehicle's cost in 2020 and is expected to grow to 50% of cost by 2030.

The U.S. has an exposed risk with most sensor manufacturing offshore. In a recent example from the COVID-19 pandemic, demand increased for infrared (IR) sensors to monitor people's temperature, and U.S.-based suppliers could not keep up. Shortages of IR cameras and IR thermometers likely allowed the virus to spread more rapidly.

Focused on sensor technology research, development and manufacturing, a Sensors System Institute could bring together a network of sensors designers, manufacturers, and end users to collaborate on next generation devices and commercialization. The Institute can promote public-private partnerships and pre-competitive collaboration among existing and emerging sensor companies in the U.S. Together, best solutions to sensor-critical initiatives, such as sensors to fight pandemics and sensors to support industry 4.0, can be achieved. Assuring domestic capability to supply leading-edge sensors will strengthen U.S. competitiveness and mitigate the current supply chain risks.

G. Supply Chain and Systems Security Commission

Cyber security attacks have been increasing in both frequency and severity. Design integrity to prevent backdoors or trojans allowing malicious intent or data theft, IP security measures to halt part counterfeiting that could lead to compromised performance and part traceability methods would strengthen device and production security. A Supply Chain and Systems Security Commission could be established to facilitate a multi-faceted approach to combat these diverse security vulnerabilities. The commission could monitor and harmonize existing initiatives (including federal, defense, commercial, academia) while fostering collaborative dialogue to ensure secure interoperability among manufacturing stakeholders. The commission could perform additional roles from education (i.e., threat awareness) to pre-competitive solutions development (i.e., leverage blockchain/hyperledger, materials finger printing, etc.) to infrastructure investments (i.e., private-public funding).

H. Balanced Approach to Resource Deployment

With so many needs to strengthen the U.S. semiconductor supply chain, SEMI recommends a balanced, multi-regional approach supporting large, medium and small businesses, to both build capacity and spur technology growth in different areas of the country. Supporting or creating small-to-medium sized facilities (< 100,000 sqft of cleanroom space), which are flexible enough to accommodate semiconductor, MEMS, sensors, and nanotech manufacturing will help ensure that these manufacturing sites generate enough revenue to be self-sustaining. A supply chain is only as strong as its weakest link, so risk analysis and prioritization become an important first step.

VIII. Any additional comments relevant to the assessment of the semiconductor manufacturing and advanced packing supply chains required by E.O. 14017. Commerce encourages commenters, when addressing the elements above, to structure their comments using the same text as identifiers for the areas of inquiry to which their comments respond to assist Commerce in more easily reviewing and summarizing the comments received in response to these specific comment areas. For example, a commenter submitting comments responsive to (i) critical and essential goods and materials underlying the semiconductor supply chain, would use that same text as a heading in the public comment followed by the commenter's specific comments in this area.

Appendix 1: Case study – Medical Microelectronics Industry Capability and Resilience Assessment (M2ICRA)

A recent study by SEMI examining the disruption to the medical microelectronics supply chain caused by the COVID-19 highlighted ten risk categories resulting from the pandemic that could also result from other causes of worldwide supply chain perturbations. Industry best practices related to business continuity planning stresses that supply chain disruption is more effectively managed by preparing for the effects of such disruptions, rather than causes, to develop a robust response and recovery strategy. Experts identify causes including climate, natural disasters, virus outbreaks, cyber-attacks and financial changes among circumstances and events that can cut off a supply of people, locations critical to the supply chain, or availability of resources that are necessary for the supply chain to continue operation. The COVID-19 pandemic caused disruptions of the semiconductor supply chain greater than twice those of 2019, worldwide. The vulnerabilities that came to light in the SEMI study regarding digital medical products included:

- Lack of an organized supply chain management structure at the national level
- Customization and lack of standards that exacerbated the supply bottlenecks
- The need for better visibility into the supply chain real-time
- Some sole source and single source supply situation that were allowed to persist for cost reasons
- Dramatic dependency on foreign manufacturing services particularly in the case of packaging and assembly
- Technical limitations that could be addressed by emerging capabilities at an increased pace

As defined in the SEMI M2ICRA report, resiliency is an interdisciplinary subject that brings into consideration strategies that extend beyond, and complement, supply chain management. Resilience involves predictive and adaptive skills and competencies that result in gaining a competitive advantage. Numerous interviews were conducted during the research in the M2ICRA report and one question was “what were the key strengths that improved your company’s resilience?” Interview participants indicated resilience involves: (a) new technology and materials development; (b) advanced, redundant, agile, and automated manufacturing; (c) R&D skill that includes supply chain development; (d) use of business continuity planning practices; (e) Strong business relationships with partners in their product’s life cycle and supply chain such as the FDA and distributors; and (f) having the best products on the market.

The state of U.S. microelectronics manufacturing capability has changed significantly over the last three decades. Nearly 50% of the world’s chip sales accrue to U.S. headquartered companies but less than 15% of global fabrication capacity is in the U.S. The trend of outsourcing manufacturing during the 1990’s and 2000’s removed a significant capital burden on the microelectronics design companies while increasing the complexity of their supply chains. As a result, greater emphasis was placed on maintaining resiliency and business continuity within a dynamic marketplace without owning or having complete control over each of the steps within a product’s life cycle. Visibility and management of this increasingly complex supply chain created a new set of challenges.

New product introduction of a semiconductor product involves various steps including R&D, down-selection of the technology of choice, design, manufacturing, test and qualification, market introduction, and finally, end of life or end of support for that product. Capability to deliver that product and to manage the supply chain for that product depends upon skill and competency at each step and at the hand-off between each step. Manufacturing strategy and capability is critical, as is design, test, and market intelligence. Design creates differentiated products and services. Fabrication and manufacturing own the “know-how” which is key to sustaining differentiation. Product and marketing teams ready the market and hasten adoption. In addition, marketing teams are often the eyes and ears of the industry and, with skill, can alert the product development team to disruptions and threats at the earliest possible stages (tactical and strategic intelligence). Discovery, and more specifically R&D, feed the pipeline and are at the heart of readiness for a paradigm shift, as well as development of the next generation technology for future threats/competition. The quality of that readiness depends not only on the quality of the R&D but the coherence and linkage between R&D, design, and manufacturing.

Capability of the semiconductor supply chain to support national and economic security depends on the comprehensive set of steps, each equally important. With less than 15% of the semiconductor fabrication capacity within the U.S., and that falling further to only 3% of the packaging of semiconductors in the U.S., manufacturing is a weak link. Also compared to the other steps in the product development cycle, manufacturing typically employs the most people, making a key factor in economic security. Taking medical microelectronics during the pandemic in 2020 as an example, various gaps in manufacturing capabilities were found:

- Little to no high-volume semiconductor packaging manufacturing lines in North America
- Little to no domestic supply of displays
- Some outstanding demonstrations of agile manufacturing but not enough examples of this capability
- Sole or single source supply situation that were allowed to persist stating cost reasons for not pursuing additional suppliers
- With travel and transportation restrictions, numerous component and consumables became difficult to source as there were no U.S. suppliers

Appendix 2: SEMI Works®

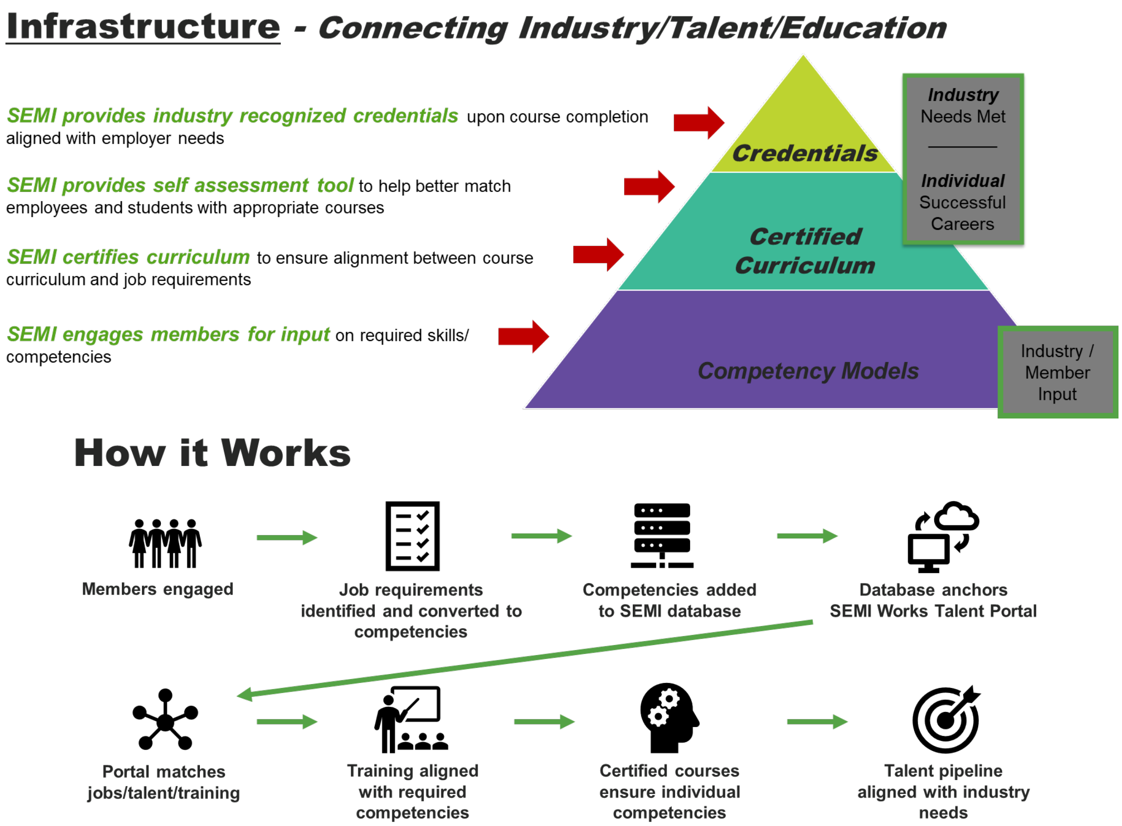
Launched in February 2019, SEMI Works® is SEMI's comprehensive approach to develop the industry's talent pipeline. The program is designed to develop the infrastructure to move from the current fragmented approach in training and education to an interconnected one that leverages existing regional assets to create an integrated national talent pipeline.

SEMI is developing the infrastructure and scalable model with stakeholders from industry, government, and academia within three regional pilot areas; Upstate New York, the greater Research Triangle in North Carolina and Portland, Oregon. In partnership with the Micro-Nano Technology Network, funded by the National Science Foundation, the SEMI Works® program will be expanded nationally through community colleges within the network, aligning their course curricula with the industry competency standards created and maintained through a dynamic industry engagement model facilitated by SEMI. This activity can be expanded through colleges and universities involved with activities aligned with the National Nano Coordinating Infrastructure and Nano Technology Initiative.

Tremendous opportunity lies in identifying, engaging, supporting, training, and welcoming currently underserved groups into the semiconductor industry. There are significant pools of potential workers across the U.S. in communities near educational facilities and semiconductor company clusters. Through the SEMI Works® program, individuals will be able to access connections, support, training, and infrastructure to engage in "learn and learn" opportunities. SEMI's Advanced Manufacturing Rapid Response Partnership – Career Readiness Program is designed to engage regional stakeholders in identifying potential candidates to enter a SEMI certified training program to prepare individuals for entry level production technician apprenticeships in 150 hours or less of training.

Engaging young students in experiential, STEM-based learning opportunities broadens the talent pipeline. SEMI's programs begin early in K-12 and provide elective courses aligned with required competencies throughout the high school years that lay the foundation for applicable careers and continuing education. They also provide adult, veteran and incumbent worker training focused on filling competency gaps through SEMI certified programs and apprenticeships. All of this is made possible in part by SEMI's newly redesigned "Unified Competency Model" ("UCM"), developed in partnership with the U.S. Department of Labor Employment and Training Administration (DOL-ETA) and through SEMI facilitated engagement with industry. Through its extensive membership base consisting of small, medium, and large companies, SEMI has identified the skills and competencies required by the industry, and advanced manufacturing broadly. This catalog of required competencies anchors the SEMI Works® database to match employers, training courses and individual training requirements.

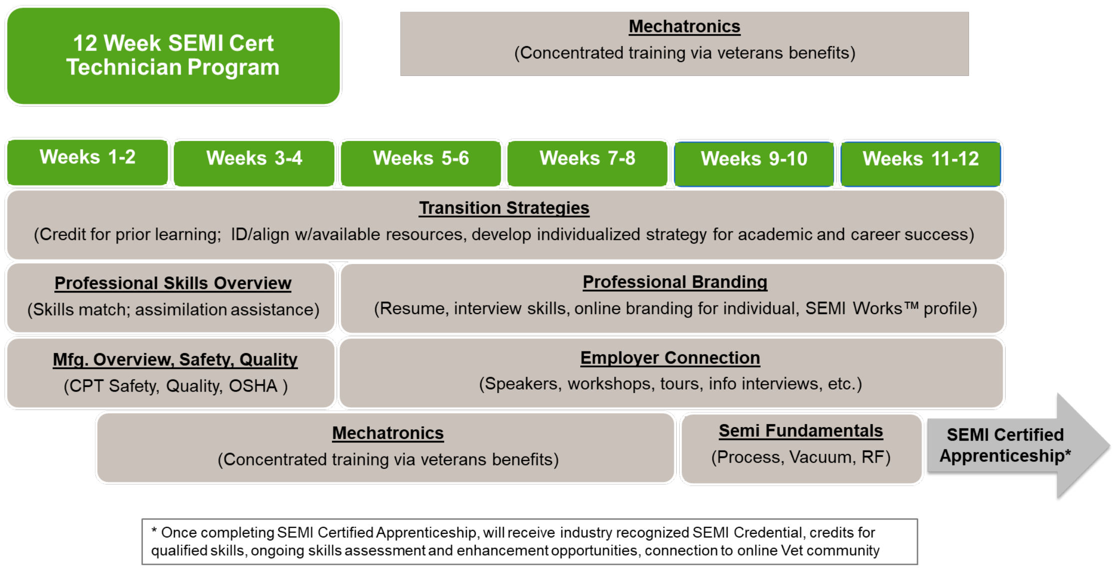
The components of the SEMI Works™ infrastructure are depicted below:



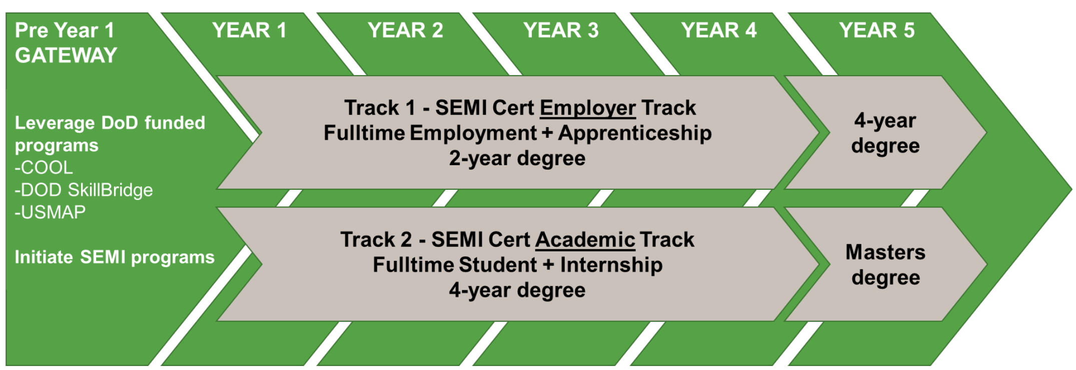
A major opportunity to help meet the needs of the industry is tapping into the very diverse population of returning service members. Of the approximate 250,000 members returning to civilian life each year, many are suited well for tech careers. While a majority have only a high school education, the type of training and experience they have received in the service positions them well for various technician roles. While there are efforts being made to align them with private sector employment opportunities (i.e.: SkillBridge), there has been no comprehensive method of making broad connections with industry. The SEMI Works® veteran training and placement program, or Veteran's Fellowship Program (VFP), is designed to scale and become a pathway that provides all returning service members visibility into career opportunities, determining alignment with required competencies and training to augment existing skills within a fellowship model that leverages SEMI's Industry Approved Apprenticeship Program Infrastructure.

The graphics below depict the SEMI Transitioning Veteran's Technician Program which leverages the SEMI Works™ infrastructure to provide a path to employment or continued education aligned with a related career. Note that the key training partners are employers and Community Colleges.

Transitioning Veterans Technician Program – *The Foundation*



2 Options - Employer vs. Academic Track
(Full time Employer vs. Full time Student)



Through SEMI Works®, SEMI leverages existing structures, work, and partnerships to develop and execute a holistic, programmatic, scalable approach to ensure a robust, interconnected, talent pipeline. It aligns with many current initiatives, including more nimble apprenticeship models, enabling returning service member transition, national credentialing and badging, and the evolution of job descriptions as industry shifts to greater automation. This STEM-based model has a fundamental design principle of enabling access for a more diverse population, engaging students early, providing career and education pathways through one's life and broadening the talent base by increasing career opportunities for currently underserved populations. It leverages SEMI's experience in industry standards through its "SEMI Certs" program, which ensures alignment between needed skills and applicable training and education programs through an industry recognized course certification and individual credentialing effort. In addition, the infrastructure is designed to be expanded to other strategic industry sectors and create an integrated, national talent pipeline which is fundamental in ensuring global competitiveness. Given the current and anticipated future shortfall in required workforce, any support that would expedite the scaling of these activities and help achieve an integrated national talent pipeline should be considered.