NY CREATES / SUNY Polytechnic Institute (Albany, NY) comments regarding BIS–2021–0011 RIN 0694–XC073

"Risks in the Semiconductor Manufacturing and Advanced Packaging Supply Chain"

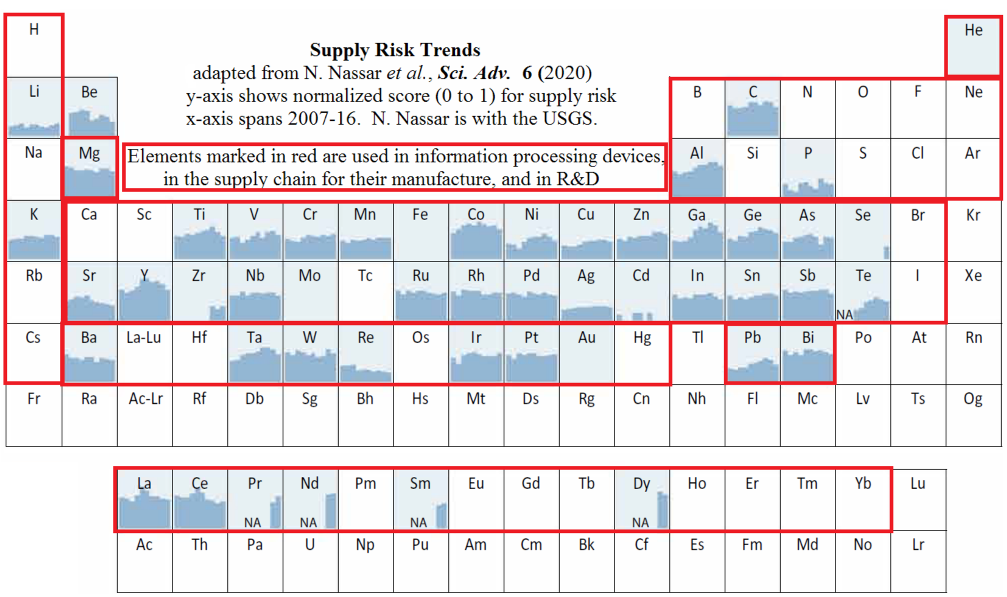
NY CREATES serves as New York's bridge to the global advanced technology industry. As the primary resource for fostering public-private and academic partnerships in the state, NY CREATES attracts and leads industry connected innovation and commercialization projects that secure significant investment, advance R&D in emerging technologies, and generate the jobs of tomorrow. NY CREATES runs some of the most advanced facilities in the world, boasts more than 2,700 industry experts and faculty, and manages public and private investments of more than $15 billion – placing it at the global epicenter of high-tech innovation and commercialization.

NY CREATES' comments below address the breadth and interconnected nature of the semiconductor industry supply chain, and its importance to manufacturing now and in the future, through research and development.

(i) <u>Critical and essential goods and materials underlying the semiconductor manufacturing and advanced packaging supply chain</u>:

Semiconductor manufacturing and advanced packaging leverages resources found across the globe – presenting both the risk of exposure and an opportunity to avoid single-source problems both here and abroad.

Materials that are critical for the Integrated Circuit (IC) industry straddle the entire periodic table, with the understandable exception of the radioactive elements. The chart below builds on a study by authors from the USGS and partners to characterize the supply risk using a 'bottleneck' approach. As can be seen, significant supply risks are pervasive in materials of importance to the entire IC supply chain and in R&D pertaining to information processing devices.



- Advanced ceramic materials (cerium oxide and other engineered nano-abrasives in CMP slurries, yttrium oxide shields inside reactive ion etch process tools, ceramics with controlled coefficients of

thermal expansion in IC packages, lithium niobate and other single-crystal materials for devices operating at gigahertz frequencies, etc)

- Advanced polymers (polymers for ultra-low particle-shedding valves handling harsh chemicals, optically-engineered polymers for matching index of refraction in IC packages, electrically conductive adhesives in IC packages rated for wide temperature fluctuations, and embossed conductive polymers for wafer electrostatic chucks, etc)

- Advanced chemicals, including designer metalorganic molecules for atomic layer deposition, surfactants for chemical mechanical planarization, and for electrochemical deposition processes, chemically amplified photoresists, and metalorganic photoresists newly being introduced for Extreme Ultra-Violet (EUV) lithography

- Advanced stainless steel and aluminum alloys fashioned into pipes and process chamber components, with demanding surface finishes, for handling high purity reactive chemicals.

(ii) <u>manufacturing and other capabilities necessary to produce semiconductors, including EDA software and advanced IC packaging techniques and capabilities</u>:

The reliance of the integrated circuit industry on software, equipment and human resources is both deep and broad. Highly advanced software tools are needed for IC design, for predictive control of the process tools to the required precision and cleanliness, and for characterization of the end product to meet exacting reliability requirements.

Precision machining, surface finishing and other tools are essential to make the process equipment needed by advanced IC fabs. The list of high technology components that are needed by modern lithography tools is mind-numbingly vast, with each needing its own supply chain – ultra-high reliability lasers, and optical components, as well as wafer stages and motors capable of high speeds and high acceleration/deceleration rates, sensors to measure position to sub-nanometer precision.

It is also important to note that the demands on equipment and software continue to ratchet up. Hence staying abreast of manufacturing implies that this country needs to keep pace with cutting-edge technology research.

(iii) <u>the 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</u>:

The 20th century (and 21st century) semiconductor industry can be compared to the cotton industry of the late 18th century – driving innovation, and efficiency across large swathes of the economy, empowering and toppling entire kingdoms across the globe ("Empire of Cotton: A Global History", Sven Beckert, 2014). The IC industry needs an intricate global web of support to function smoothly – but the products of the IC industry have driven productivity gains over the past 3 decades, and will create whole new industries in the decades ahead. The skill sets needed by the IC industry (including the supply chain) are wide-ranging and critical for its continued growth.

Traditionally, semiconductor fabs experience a long term, consistent construction horizon, extending years and decades. This requires deep capacity in sophisticated construction trades to build the cleanrooms, specialized utility systems and perform tool installations. In addition to *semiconductor technician and engineering programs, successful regions require a strong set of construction trades curricula, which can be deployed by local community colleges, industrial associations and especially trade unions.*

In the operation of fabs and advanced packaging facilities, equipment engineers and maintenance technicians, physicists and chemists, chemical engineers and electrical engineers, semiconductor process technicians and process integration experts create enormous value, and are known for compensation well above the average in other less advanced industries.

Historically, veterans of the US Armed Services have been welcomed by the IC industry – continuing that tradition maintains a pathway for the skills accumulated in the years of service to be harnessed by private industry. Considering the opposite direction, skills honed through years of experience, or developed in the training programs of the IC industry and its supply chain, are portable and advantageous to other areas of the nation's economy. This can fuel a virtuous cycle of entrepreneurship and opportunity creation and supply of skilled human capital that energizes the whole country's economy. Such a networked talent pool can accelerate other industries that are growing in the United States, including the commercialization of space in Earth's orbit and beyond, creating and maintaining the internet of things, machine learning and AI, as well as the defense industrial base.

The revitalization of the semiconductor industry is a golden opportunity to enshrine the value of a diverse workforce that pulls in currently underrepresented minority groups. The resurgent IC industry and its supply chain can seed the proliferation of a diverse workforce throughout the knowledge economy of the century ahead. If the IC industry grows again in the United States – driven by the world-wide need for ICs – it can reignite the need for technical skills, and foster the growth of well-paying jobs. The IC industry and its supply chain are natural take-off points for other growing areas such as quantum technologies, internet of things, and AI. Hence a robust semiconductor industry in the United States bodes well for anchoring newer technologies firmly onshore, with additional high-value job creation.

Regions that focus on workforce training and retention, from K-12 through graduate programs, will have the greatest chance to create and retain leading edge semiconductor manufacturing. As a concrete example, New York is home to more than 170 colleges and universities, with over 1.0 million students gaining post-secondary education. It is the only state in the U.S. with two Ivy League universities (Cornell and Columbia), and is proud to have the nation's largest public university system, the State University of New York (SUNY). SUNY's 64 institutions—with programs and initiatives supporting STEM education—include research universities, liberal arts colleges, community colleges, colleges of technology and several semiconductor-related curricula.

(iv) <u>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):</u>

a. Risks posed by reliance on digital products that may be vulnerable to failures or exploitation;
b. risks resulting from lack of or failure to develop domestic manufacturing capabilities, including emerging capabilities;

The supply chain for the future of the IC industry in the US needs to cater both to classic, Moore's Law-driven CMOS ICs, as well to novel technologies that will drive the next few decades of innovation – machine learning, neuromorphic computing, 6G communications, and quantum *technologies. Manufacturing and R&D are closely linked - countries that have sought to outsource manufacturing have found their R&D leadership slipping away as well, while countries that gained a foothold in manufacturing have found stable, long-term R&D investments flowing in a decade later.*

It is important to highlight the need for a strong supply chain in the US to uphold the vitality of both manufacturing and R&D here. The persistent need (even today) for trust and human relationships in business engagements drives close contact, and even proximity, between all components of the supply chain in the IC industry – between designers and suppliers of process tools, designers and builders of fabs, designers of consumables used in the IC industry, test equipment and the software tools to analyze test data, and so on. Hence, it is preferable to look for strengthening the footprint of the global supply chain in the US by making it 'good business-sense' to do so, rather than seeking to wall off sections of it or forcing transplantation, or duplication.

(v) <u>the resilience and capacity of the semiconductor supply chain to support national and economic security and emergency preparedness, including:</u>

a. Manufacturing or other needed capacities (including ability to modernize to meet future needs);
b. gaps in mfg capabilities, incl. absent, threatened, or 1-point-of-failure capabilities, single/dual suppliers;
c. location of key manufacturing and production assets, and risks posed by their physical location;
d. exclusive/dominant supply of critical goods & materials by or thru unfriendly/unstable nations
e. availability of substitutes or alternative sources for critical or essential goods and materials;
f. need for R&D capacity to sustain leadership in the development of goods & materials critical to IC mfg;
g. current domestic education & mfg workforce skills & identified gaps, opportunities & best practices;
h. role of transportation systems in supporting the semicon supply chain and risks associated with them;
i. risks posed by climate change to the availability, production, or transportation of goods and materials

As we seek resilience in the supply chain of the IC industry, it could be useful to heed the alarm-bells that have rung recently.

Disruptions to fabs in the earthquake-prone Pacific rim regions following shocks were only short term - a testament to the superb engineering of such modern fabs, but it could be wise to, in parallel, seek geographical diversification into other parts of the world.

A modern gigafab needs large amounts of reliable power. In a world combating climate change, such power would come from renewable energy sources – hence the semiconductor industry provides another opportunity for the United States to show the world how to 'do it right'. When such renewable energy sources are already available, they represent an opportunity to be capitalized upon, taxing this nation's interconnected electricity distribution grid that much less. The IC industry has been typically careful to discharge water are meets the exacting standards of the United States through treatment – but it does need copious supplies of water.

The disruptions to the global supply chain by COVID-19 related travel restrictions highlighted the problems caused by not having adequate in-country equipment support and availability. The industry innovated again through the use of augmented reality devices – but those present another window of opportunity for a determined hacker or other malevolent entity.

The disruption to semiconductor manufacturing that resulted from the February 2021 ice-storm in Texas was not only an environmental but a public policy disaster, which cost those fabs, especially around the Austin area, hundreds of millions of dollars in lost production, damaged equipment, and further constrained an already tight supply. Strong utility regulation focused on *reliability, safety and redundancy is paramount to a healthy US supply side. New York has shown leadership in terms of disaster preparedness and response, from the statewide Office of Emergency Management and a NYS Disaster Preparedness Commission. The NYS Energy Emergency Plan prevents the sort of disruption that took six weeks to repair in Texas, which is an eternity in this industry.*

(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 semiconductor finished products by downstream customers, including volume and price, product generation and alternate inputs.

The ubiquitous nature of information-processing devices in our daily lives, and in our society will only increase. Integrated circuits (relied upon for security) will be so woven into the fabric of life that it is essential that the US have a vibrant semiconductor industry, including advanced packaging facilities, capable of ramping up to respond to disruptions, whether they are caused by natural or political events somewhere on the globe. Such a 'baseline' capability could serve as the nation's "Semiconductor Manufacturing Guard" – normally engaged in typical business partnerships with companies across the world for mutual benefit, but ready to spring into action when needed for the nation's defense.

This capability will not be sustainable over the long term if equal attention is not paid to maintaining a research and development capability, and judiciously nurturing technology development. The United States has excelled in fostering fundamental research, but has not found it easy to support nascent technologies across the "valley of death". As the next revolution in information (AI, quantum) happens, such an oversight could cause the US not to benefit from the fundamental research it has nurtured – but to see the scaling and commercialization happen abroad.

Programs designed to develop and fund early stage companies commercializing critical technologies can be better coordinated and connected both regionally and nationally to retain talent and technology within the U.S. ecosystem.

(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).

In order to accommodate and support a re-shoring of this industry there must be an adequate supply of "shovel-ready" sites of a scale adequate to support these multi-billion-dollar investments. Having a program that invests in real estate development, including site acquisition, high voltage power, industrial scale water and wastewater supply and treatment systems and transportation assets ahead of any one company's decision to commence building is paramount. These sites will depend on the investment of public resources in an economic development program that understands and responds to the industry, so that the industry has confidence that a region will be there to support its growth over time.

Utilizing technologies applicable for remote and online learning could enable availability beyond traditional boundaries. Rebalancing the dependence of the domestic semiconductor industry on non-domestic talent sources is necessary for sustained growth of U.S. infrastructure and is in the interest of national security.

For the US to maintain a leadership position in the research and development of products which ensure national security, domestic and global health and economic security, it is essential that access to domestic state of the art semiconductor fabrication and advanced Packaging capabilities improve for industry (small and large), academic and government researchers and developers. Improvement of access and affordability of service is particularly challenging when advanced semiconductor fabrication and packaging capabilities exists solely within for profit organizations. Conflicting research objectives, priority access to critical processing tools and the requirement to be profitable often prevents the "for profit organization" from running smaller lot sizes which are typical to researchers and developers. ***We recommend housing advanced semiconductor fabrication and packaging capabilities, which can be focused on product and process research and development, in a not for profit structure****. This structure supported by revenue from users, public-private partnerships and the US government would be positioned to leverage the best technical and process capabilities available in the US.*
We support the language in the National Defense Authorization Act Sec 9906 (g) which requires executive agencies to develop policies requiring domestic production, to the extent possible. Domestic production will provide a source of revenue which will be important to sustainability.

(viii) Any additional comments relevant to the assessment of the semiconductor manufacturing and advanced packing supply chains required by E.O. 14017.