Comments of the
Semiconductor Industry Association (SIA)
On the Notice of Request for Information on
"Critical and Strategic Materials Supply Chains"
79 Fed. Reg. 42560 (July 22, 2014)

Submitted to criticalmaterials@ostp.gov
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The Semiconductor Industry Association (SIA) is pleased to submit the following comments on the request for information on "Critical and Strategic Materials Supply Chains" issued by the Office of Science and Technology Policy. A secure supply of critical materials is essential for the success of the U.S. semiconductor industry. The manufacture of advanced semiconductors depends on the precise and controlled use of specific materials, chemicals, and gases that are selected because they possess unique chemical and physical attributes. In many instances, there are no known alternatives to these materials that satisfy our functional needs, and therefore a secure and continuous supply of critical materials is of critical importance to our industry.

SIA commends the Critical and Strategic Minerals Supply Chain Subcommittee for its efforts to evaluate critical and strategic materials in the U.S. economy and to develop a methodology for assessing and forecasting criticality. We fully agree on the need for an "early warning" system for both policymakers and industry to avoid significant disruptions in the supply of these critical materials. We respond to OSTP's request for information in the order set forth in the notice.

Category 1: Demand

- *OSTP Question: What materials will be particularly important, and of concern (due to availability, price, etc.) to your technologies and/or your industry over the next 5 years?*

The semiconductor industry relies on a number of materials, chemicals, and gases, and several of them are of particular importance and potentially subject to limits on availability over the next several years. These primary materials of concern at this time include:

- Neon
- Xenon
- Krypton
- Fluorspar
- Germanium
- Helium
- Argon
- Liquid Hydrogen
- Enriched Isotopes (D2, B11)

- Sulfuric Acid
- Hydrogen Peroxide
- High Purity Solvents (IPA/PGMEA)
- Tantalum

In addition to the chemicals and materials listed above, we have a general concern with respect to supply chain stability for materials that are extracted and refined for use in our industry. When we assessed the metals and that are either currently in use within our industry or are likely to be used to meet future technology needs, we determined that while the global reserves seemed to be sufficient to meet future demand, the mining/refining to provide our supplies is often concentrated to just a few countries. Based on this finding, we would also consider any metals with concentrated supply chains to fall into the critical minerals category. This is a complex issue and should be addressed holistically.

- *<u>OSTP Question</u>: What is the growth in demand forecast for your technologies? What factors drive this assessment?*

The World Semiconductor Trade Statistics (WSTS) program forecasts that the world semiconductor market will reach $325 billion in 2014, up 6.5 percent from 2013. This is due to primarily to broad and steady improvements in the global macroeconomic environment. Solid growth for all product categories is expected to continue over the next 2 years, under the assumption of macro economy recovery throughout the entire forecast period. The worldwide semiconductor market is forecasted to be up 3.3 percent to $336 billion in 2015. For 2016, the market is forecasted to reach $350 billion, up 4.3 percent. U.S.-based companies have approximately 50 percent of global market share in the semiconductor market.

In addition to the increased global demand for semiconductors, the increasing complexity of devices may result in higher levels of material consumption in some cases. The industry's consumption of key materials may increase due to increase in layer count and the increase in the per layer material use.

- *<u>OSTP Question</u>: At what point(s) in technology or product development or manufacturing do you select raw materials? How do you consider price? How do you consider performance characteristics? How do you consider availability?*

Each material used in the semiconductor manufacturing process is carefully selected to meet our technology needs and must be integrated together with high precision manufacturing equipment ("tools") to achieve high-yield, high-volume manufacturing. As a result, materials are selected early in the development cycle of both the product and in consultation with the supplier of the manufacturing equipment. Because semiconductor manufacturing tools are very high cost pieces of capital equipment, the use of a particular material can be "locked in" once a tool is selected.

The materials selection cycle in the semiconductor industry typically is 2-15 years prior to initial production, with continuing use for up to 25 years. This schedule consists of fundamental research, hazard and risk evaluation, demonstration and integration with manufacturing equipment (and sometimes the development of new manufacturing equipment), and production. Semiconductor manufacturers work closely with the equipment and material suppliers to ensure coordination in the development of new technology and the materials to be used for these advancements. Every two years the industry convenes a formal technology roadmapping process, the International Technology Roadmap for Semiconductors (ITRS) (see http://www.itrs.net/) to align the product development plans of the industry and the supply chain.

Price is one consideration in materials selection, but cost tends to be less relevant than performance and meeting technical requirements in the manufacturing process. For example, the use of enriched isotopes were selected and adopted for their performance benefits (particularly reliability and reduction of soft error) during product development for integration into 32nm and 22nm processes approximately 2 to 3 years before production.

- *OSTP Question: What investments, if any, are you making to identify raw material input alternatives?*

The semiconductor industry makes ongoing investments and collaborates closely with material and equipment suppliers to improve upon existing process technology, including the use of alternative materials. Because our industry selects materials due to their unique functional attributes, however, there may not be suitable alternatives for many applications. For example, rare earth gases (Ne, Kr, Xe) are essential to laser function and there are no known substitutes. Typically there are no “drop-in” replacements to key materials, and any material change could result in modifications to other materials, processes, or tools. In some cases, replacement is not economically feasible and might entail shuttering entire wafer fabrication facilities. Thus, finding and qualifying substitutes is extremely complex, requires partnership among semiconductor companies and suppliers, and is process-, technology-, and company-specific.

In some instances, the industry is investigating alternatives, especially when future supply is uncertain. For example, helium plays a key role in many processes, including cooling uses for which there are no substitutes, and the industry is investigating the use of argon or nitrogen for carrier gas and other uses. Similarly, the industry is evaluating more costly alternatives to formulated stripping chemistries using sulfuric acid.

- *OSTP Question: Are there any emerging disruptive technologies or technology transitions (e.g., new applications or substitutes) that would dramatically change demand in the near term (5 years) or long term (15 years)?*

The semiconductor industry is constantly innovating, and there is always the potential for new technologies to change the demand for critical materials. Innovations in material science may contribute to the use of new materials or new processes that require different materials. In addition, over time as the semiconductor industry phases out older technologies and moves to 450mm wafers and EUV lithography, this could result in a reduction of the amount of material consumption per unit due to more efficient material use and reduction in layer counts.

The existing manufacturing technology based on Complementary Metal Oxide Semiconductor (CMOS) is approaching its physical scaling limits for performance. Accordingly, new breakthroughs are needed to maintain the pace of innovation and rapid advancements in our industry, as characterized by "Moore's Law." Many experts believe that these new advancements will leverage nanotechnology, and the impacts on demand for new materials that may result from these future innovations are not yet known.

Category 2: Exploration, Mining, and Smelting/Refining

The semiconductor industry is typically several steps removed from the exploration, mining, and smelting/refining of critical materials used in our processes. The industry utilizes a complex supply chain to supply the materials we need in a refined or purified form, and therefore we often lack direct knowledge, expertise, or involvement on the issues surrounding the extraction of these materials. Nonetheless, we offer our observation that a stable supply of key materials begins with reliable sources of mineral materials and is therefore dependent on an efficient process for the exploration, mining, and refining of these materials, and we believe it is important to adopt a holistic approach and look at the entire supply chain when assessing potential vulnerabilities in supply of these critical materials.

Where we find that the supply of a given material is concentrated due to market conditions or other external factors (e.g., rare earth production in China), then we would want the U.S. to take additional steps to understand how additional resources could be brought on line, including potentially increased support for safe, cost efficient alternative extraction and refining techniques that could be utilized in new countries or regions.

- *OSTP Question: What barriers exist to exploration for additional resources of raw materials in the United States and globally?*

For some materials, such as rare earth gases, there are few barriers since recovery is from the air. Other materials, such as helium, high purity solvents, liquid hydrogen, are byproducts of the natural gas and petrochemical processes and the supply is related to broader demand and pricing considerations.

Other materials are found in high concentrations in regions with a high degree of geopolitical instability. For example, high concentrations of helium are found in locations such as Algeria, Siberia, and Qatar, and several metals are generally located in remote and potentially unstable locations.

- *<u>OSTP Question</u>: Once discovered, what barriers exist to the timely development of raw materials in the United States and globally?*

SIA has no comment.

- *<u>OSTP Question</u>: Is current North American separation, smelting, and/or refining capacity adequate to ensure reliable material supplies?*

SIA has no comment.

- *<u>OSTP Question</u>: What innovations in separation, smelting/refining technology or processes might affect U.S. or global resource supplies? What are the environmental impacts of these innovations?*

SIA has no comment.

- *<u>OSTP Question</u>: Are the mining, separation, smelting, and/or refining sites of the minerals required for your technologies adequately diversified to account for potential market failures or political risks?*

The adequacy of the supply chain depends on the material in question. For many materials, there is adequate supply from domestic sources or a diverse range of stable foreign suppliers. For other materials, such as rare earth gases, the U.S. supplies are inadequate and we are dependent upon foreign sources of supply which could become unstable. Similarly, shifts in the steel or petrochemical markets can cause shutdowns which can create imbalance in supply and require the operation of air separation plants for Argon, which results in an increase in pricing. As mentioned above, the supply chain for many minerals is generally diverse globally, but the primary production (and in some cases reserves) may be concentrated in a few countries, often China and/or Russia. This creates vulnerability for US manufacturers should those countries decide to limit exports of those materials.

- *<u>OSTP Question</u>: How do market size, market price, capital availability and other economic factors affect production decisions?*

Our industry's recent experience with helium demonstrates the role of economic factors in production decisions and supply. Our industry faced significant shortages in the supply of helium, as well as substantial price increases, as a result of several factors, including the pending closure of the Federal Helium Reserve. Our suppliers were shipping a reduced allocation at dramatically increased cost to semiconductor fabs, and despite efforts to conserve and recycle this gas or find alternatives in some processes, our industry was facing the risk of having insufficient quantities to operate. Fortunately, Congress enacted into law of the Helium Stewardship Act (PL 113-40), which called for the auctioning of helium from the Reserve. The first auction was held in July, and global supplies have stabilized, partly as a result of the introduction of market forces into the helium market.

Category 3: Supply and Supply Chain

- *OSTP Question: What are the supply chains for the technologies identified as being important to your manufacturing processes and industry? How would you describe the significant stages of the supply chain?*

As stated above, the semiconductor utilizes a complex global supply chain to provide the critical materials used in our manufacturing process. The supply chain consists of Tier 1 suppliers that deliver the final product, typically in a refined or purified form, often many steps removed from the original extraction of the material from the earth or the atmosphere.

- *OSTP Question: Are there vulnerabilities in the supply chain (domestic, foreign, sole source, import reliance, etc.) that lead to concerns regarding the supply of any of these materials and/or the ability to manufacture these technologies?*

Our industry is concerned about several vulnerabilities in the supply chain that could lead to disruptions in the supply of critical materials. These vulnerabilities include (1) country specific restrictions or market manipulation, such as governmental measures in China with regard to rare earth materials and fluorspar; and (2) political unrest and military activities in countries such as Ukraine, which could impact the availability of noble gases.

- *OSTP Question: How do you assess supply chain vulnerabilities and their impact?*

Our assessment will consider of a broad range of factors, including the following:

- The nature, type, and amount of usage in the semiconductor industry
- The availability of alternatives to the material to satisfy the industry's functional requirements
- The degree of reliance on imports of the material
- The geographic concentration and location of sources of the material
- The nature of the supply chain and potential vulnerabilities in supply
- Known worldwide reserves and anticipated future supplies
- Current consumption and expected future demand
- Percentage of U.S. consumption of the material, and the usage in the semiconductor industry as compared with other uses
- Price and price trends
- Past incidents of supply disruptions or price spikes
- Environmental or geopolitical factors that may limit the ability to obtain refined metals in particular geographies

A risk assessment is done for each material and a risk index is generated. High risk materials typically have a risk mitigation plan.

Category 4: Market Dynamics
Most minerals and mineral materials are globally traded commodities and any analysis of supply chains must take account of the global context for each commodity.

- *OSTP Question: How would you describe the market dynamics of your supply chains, including the overall supply of materials of interest?*

Market efficiency is typically high for the materials where multiple sources are available. For more specialized materials, the market dynamics are less efficient. Our industry has faced instances of significant price increases and/or shortages with regard to rare earth gases, helium, argon, and liquid hydrogen. Supplies also appear to be tight for high purity grade supplies of sulfuric acid and hydrogen peroxide.

- *OSTP Question: Are there any market distortions in the supply chain, such as opacity, lack of information, or trade-related distortions?*

The market place is fairly efficient and competitive. Opacity exits to the extent that key participants such as suppliers, OEM, and end material consumers try to limit the sharing of information and to lock IP to gain advantage. However, distortion from governments such as China's control over fluorspar is one major risk factor.

- *OSTP Question: Is there price volatility? If so, what factors drive this volatility?*

Prices are typically stable for most materials. Volatility is seen for materials that are highly correlated with an index such as natural gas, oil, fertilizers. For example, the costs of high purity solvents are correlated to petrochemical costs, and the cost of liquid hydrogen is linked to the costs of natural gas, electricity, and transportation.

Prices have fluctuated for some materials where there has been a significant supply shortage. In some cases, semiconductor companies have been placed on “allocation” – the delivery of a fixed percentage of expected amounts of supply – due to supply shortages, which are typically accompanied by price increases. For example, in recent years semiconductor companies have been placed on allocation for helium and xenon, which has also resulted in significant price increases. The industry has also experienced a large price increase in tantalum.

Category 5: Mitigation

- *OSTP Question: What are some strategies you employ to mitigate supply chain concerns? (e.g., stockpiles, hedging, etc.)*

Semiconductor companies typically enter into long-term contracts and agreements and qualify multiple suppliers and production sources to mitigate the risk of supply disruptions and price fluctuations. For some rare earth gases (e.g., Ne, KR, Xe), companies mitigate supply disruptions from off-shore suppliers by qualifying suppliers who recover these gases in the U.S. In addition, companies stockpile certain materials as part of their mitigation strategy where it is practical to do so. For example, companies may construct larger storage tanks to stockpile materials such as argon, liquid hydrogen, and high purity solvents, or build on-site purification capacity for these materials. It should be noted that some materials, such as helium, cannot be readily stockpiled in large volumes and may require specialized storage containers that are in short supply. Semiconductor companies also implement conservation, recycling, and recovery measures for materials such as enriched isotopes and tantalum.

- *OSTP Question: How do you cope with price volatility?*

Companies employ a range of strategies to address price volatility. For some materials, companies enter into long term contracts as a means of achieving price stability. For example, companies set pricing agreements for a 2-year term for materials such as enriched isotopes, sulfuric acid, and hydrogen peroxide. Companies also identify secondary source suppliers to help manage price increases. For example, for some rare earth gases (e.g., Ne, KR, Xe), some companies avoid price increases from off-shore suppliers by qualifying suppliers who recover these gases in the U.S. Where storage of materials is practical, companies sometimes stockpile supplies as a hedge against price increases.

- *OSTP Question: Do you consider using technologies available with slightly reduced performance to avoid price and availability concerns?*

No. Advanced semiconductors are designed and manufactured to achieve specific performance levels and with a high degree of reliability. To achieve these exacting standards, semiconductor manufacturing is a highly complex process, and materials are selected for use in this process because of their unique physical and chemical properties. As a result, there may not be suitable alternatives to these materials that can achieve the performance and reliability needs in our industry.

Category 6: Other

- *OSTP Question: Is there additional information, not requested above, that you believe the CSMSC Subcommittee should consider in identifying emerging critical materials? If so, please provide here.*

The U.S. government should develop the capability to forecast future demand and supply scenarios for known critical and strategic commodities, and in order to identify potentially critical and strategic commodities, as well as have policy instruments in place that can expedite cycle-time to bring new production online to alleviate critical supply issues.