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The U.S.-China Battle for Semiconductor Supremacy and Reshaping of Global Supply Chain

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I. Introduction

The realization of digital transformation (DX) and the Fourth Industrial Revolution (4IR) has led to the development of new technologies in areas such as AI, big data, metaverse, autonomous vehicles, digital currency, and blockchain technology. While these sectors are expected to continue to grow, major countries including the United States and China are fiercely competing to secure a global supply chain for the semiconductor industry.

Built on free trade, the global division of production in the semiconductor industry has driven corporate innovation and technology development. However, the trend of technological nationalism and countries' efforts to build a value chain within their territory are expected to hurt the global semiconductor industry. The ever-deepening hegemony competition between the U.S. and China in the semiconductor industry could have a profound im pact not only on the Korean economy but also on a restructuring of the global semiconductor supply chain.

II. U.S. Policies to Foster the Semiconductor Industry

The division of labor by value chains has progressed significantly in the global semiconductor industry. Nowadays, countries are specialized in various manufacturing stages (chipless → fabless → foundry → ATP → delivery) and the GVC has been established according to each country's strength. The United States and Europe specialize in production technology while Korea and Taiwan are strong in process technology and China, Taiwan, Vietnam, and Malaysia have comparative advantages in the assembly, test, and packaging (ATP) sectors. The global value chain has been arranged based on these advantages and driven production efficiency for decades.

Semiconductor manufacturers in the United States take the largest market share and dominate the supply chain in the global market. U.S. companies, however, are comparatively weak in the wafer processing and EUV equipment sectors, while their market shares in other sectors such as IC design, related intellectual property rights (IP), and manufacturing equipment remain high. Recently, as the risk has increased in semiconductor supply chains, countries are actively responding with policies to strengthen their semiconductor production capacity.

The U.S. government has also undergone tremendous changes in its public support system for major industries such as semiconductors. Before 2019, individual project support was centered on various departments of the federal government and each local government, but since 2020, legislation to provide a comprehensive support system with a significant budget has been introduced, promoting cooperation with Congress. In June 2020, the bill for the Creating Helpful Incentives to Produce Semiconductors (CHIPS) for America Act was drafted, aiming to fund R&D and secure technology supply chains to revive the semiconductor manufacturing industry in the United States. This was followed by the American Foundations Act of 2020 (AFA), aimed at providing subsidies to promote the expansion of semiconductor manufacturing facilities. The two bills were included in the United States Innovation and Competition Act of 2021 in June 2021 and passed by the Senate. The new legislation mostly aims at strengthening the U.S. science and technology capabilities, including semiconductors, and responding to potential threats from China. Further emphasis is placed on cooperation with allies in various investigations and sanctions against China, in particular, meaning it will be necessary to closely monitor developments regarding these bills.

III. Chinese Policies to Foster the Semiconductor Industry

China's semiconductor industry has grown rapidly by 12% per annum since 2016, accounting for 60% of global semiconductor consumption and 33% of final demand. The country heavily relies on Korea and Taiwan for semiconductor imports. Demand for semiconductors in China continues to increase, with China's deficit in the sector reaching -233.7 billion dollars in 2020.

China currently serves only as a semiconductor consumption market, and all key technologies related to manufacturing are owned by the United States and its allies or partners. The U.S. sanctions against China in the semiconductor industry are targeted at high technology areas of less than 10nm density, while exports of U.S. products in the area of general-purpose technologies are permitted. China accounts for only 5% of global semiconductor sales, and plays a limited role in the global semiconductor supply chain, mainly involved in the ATP sectors of the supply chain.

The Chinese government is inducing massive investments in the semiconductor sector to lower dependence on semiconductor imports and mitigate supply chain risks. In addition, China selected semiconductors as a strategic development sector within the 14th Five-Year Plan for National Economic and Social Development and Long-Range Objectives for 2035 in March 2021 and is fostering the semiconductor industry through a national semiconductor fund, various tax support measures, and through the STAR Market, the Chinese version of the NASDAQ. However, export control measures, investment sanctions, and financial sanctions currently implemented by the U.S. are major obstacles to increasing China's independence in semiconductors.

IV. Global Semiconductor Industry Supply Chain at the Corporate Level

Using network analysis, the current status of the global semiconductor supply chain was analyzed and schematized, also identifying the location of companies in the supply chain by estimating the centrality and degree of centrality between semiconductor companies. U.S. companies and Samsung Electronics stood out in the network analysis while Chinese companies remained weak. However, China's Huawei, Lenovo, and Xiaomi are gaining presence in the global supply chain. These Chinese companies are not directly involved in semiconductor production but act as consumers of semiconductors as they produce IT devices such as PCs, smartphones, and tablets.

According to our results, China's Hisilicon, which specializes in design and manufacturing, and SMIC, a foundry company, are not influential in the global semiconductor supply chain and show high foreign dependence. China's Huawei, while not a producer of semiconductors, is regarded as very important in the global supply chain, but remains highly dependent on U.S. suppliers. According to the Eikon database, 1/3 of suppliers which provide products to SMIC are U.S. firms, followed by European companies in the UK or Germany. 43% of the suppliers that provide goods to Huawei are U.S. companies and 20% of sellers are also from the United States. This means that U.S. companies account for the largest portion of the suppliers and sellers dealing with Huawei. On the other hand, it turned out that the proportion of Chinese domestic suppliers was about 15% and that of sellers was about 10%. As we can see, the high foreign dependence of Chinese companies makes it difficult for them to become self-reliant. This indicates that Chinese semiconductor companies will likely face difficulties in the U.S.-led global semiconductor supply chain for a considerable duration.

V. Supply Chain Structure of the Korean Semiconductor Industry

In 2020, Korea's semiconductor imports amounted to about $57.03 billion in total, mainly from China (31.2%), Taiwan (20.4%), and Japan (13.6%). System semiconductors and memory semiconductors accounted for 70.8% of total semiconductor imports, and respectively 39.1% and 31.7%.

Most of Korea's imports in the sector from China and Hong Kong are memory semiconductors (78.3%) and system semiconductors (44.6%), while system semiconductors are imported from Taiwan and semiconductor equipment and materials from Japan and the United States. Twelve items out of semiconductor materials account for 80.9% of total imports, and these items are still highly dependent on Japan. Korea's semiconductor exports in 2020 amounted to about $95.46 billion, mainly to China (43.2%), Hong Kong (18.3%), and Vietnam (9.6%). Memory semiconductors accounted for 62.0% of all semiconductor exports and system semiconductors 28.0%, with these two areas representing 90.0% of all Korean exports of semiconductor chips. 71.3% of Korea's exports of memory semiconductors and 46.6% of system semiconductors were to China and Hong Kong, with China taking up a major portion.

Korea has established a global supply chain base linked to China and the United States and constructed a specialized production system. Due to a large number of packaging companies in China, most exports to China are wafer-processed semi-finished products, while imports from China are mainly in the form of intra-firm trade from investment corporations established in the country by Korean chip producers such as Samsung Electronics and SK Hynix. Particular care should be taken to manage supply chains in areas where Japan possesses an overwhelming advantage. Korea needs to closely monitor and manage supply chains of related items, as its technical vulnerability of depending on Japanese sources in the areas of materials, components, and equipment will persist for the time being.

Another risk is that Korean companies producing semiconductor materials are highly dependent on overseas suppliers as they lack source technologies. Along with basic raw materials for semiconductor manufacturing, items that account for more than 50% of semiconductor process imports are considered to be subject to supply chain risks and require constant management.

VI. Conclusion

The strengthening of U.S. leadership in semiconductors and its ongoing policy of decoupling from China are the biggest variables in the global supply chain structure of the semiconductor industry. The U.S. is expected to thoroughly block China's access by building a "digital fortress" around China to prevent the

Chinese semiconductor industry from accessing new technologies while applying stricter control over core semiconductor technologies.

The U.S. is also expected to leverage its technological superiority to contain China, inducing the "de-Sinicization" of semiconductor companies investing in China in the long term, while reorganizing its supply chains to relocate high-tech semiconductor production out of Chinese territories. Advanced countries with core semiconductor technologies and tech firms with exclusive technologies are expected to further cement their dominant position in the global market, while the supply chain structure between allies will be reinforced.

The global market is involved in a war to gain technological hegemony, and Japan will likely continue efforts to hold in check Korea's semiconductor industry amid this new Cold War. The growing alliance between the U.S., Japan, and Taiwan in semiconductors could pose a challenge to the Korean semiconductor industry. Korean semiconductor companies have grown to meet the semiconductor demand of multinational companies in China and Chinese companies, but will likely be affected by the direction of the U.S.'s semiconductor technology control policy in the future.

The diversification and duplication of supply chains is an important issue, and Korea's semiconductor industry is facing an era of global value chain transformation. In the short term, Korea should actively enter the U.S.-led supply chain and focus on stabilizing its supply chain. It will also be necessary to plan for the reorganization of the current supply chain to mitigate the current dependence on specific countries.

In addition to the government's strategy to foster the semiconductor sector, there is an urgent need to expand R&D manpower, establish a comprehensive semiconductor research institute, support semiconductor factories in the metropolitan area, and improve regulations. The Seoul Metropolitan Area Readjustment Planning Act should be flexibly operated, and we also propose the enactment of a special act to establish a graduate school specializing in semiconductors. Recently, China has established many universities specializing in semiconductor-related fields to actively cultivate the manpower it needs, and Korea could benefit from benchmarking these efforts. KIEP