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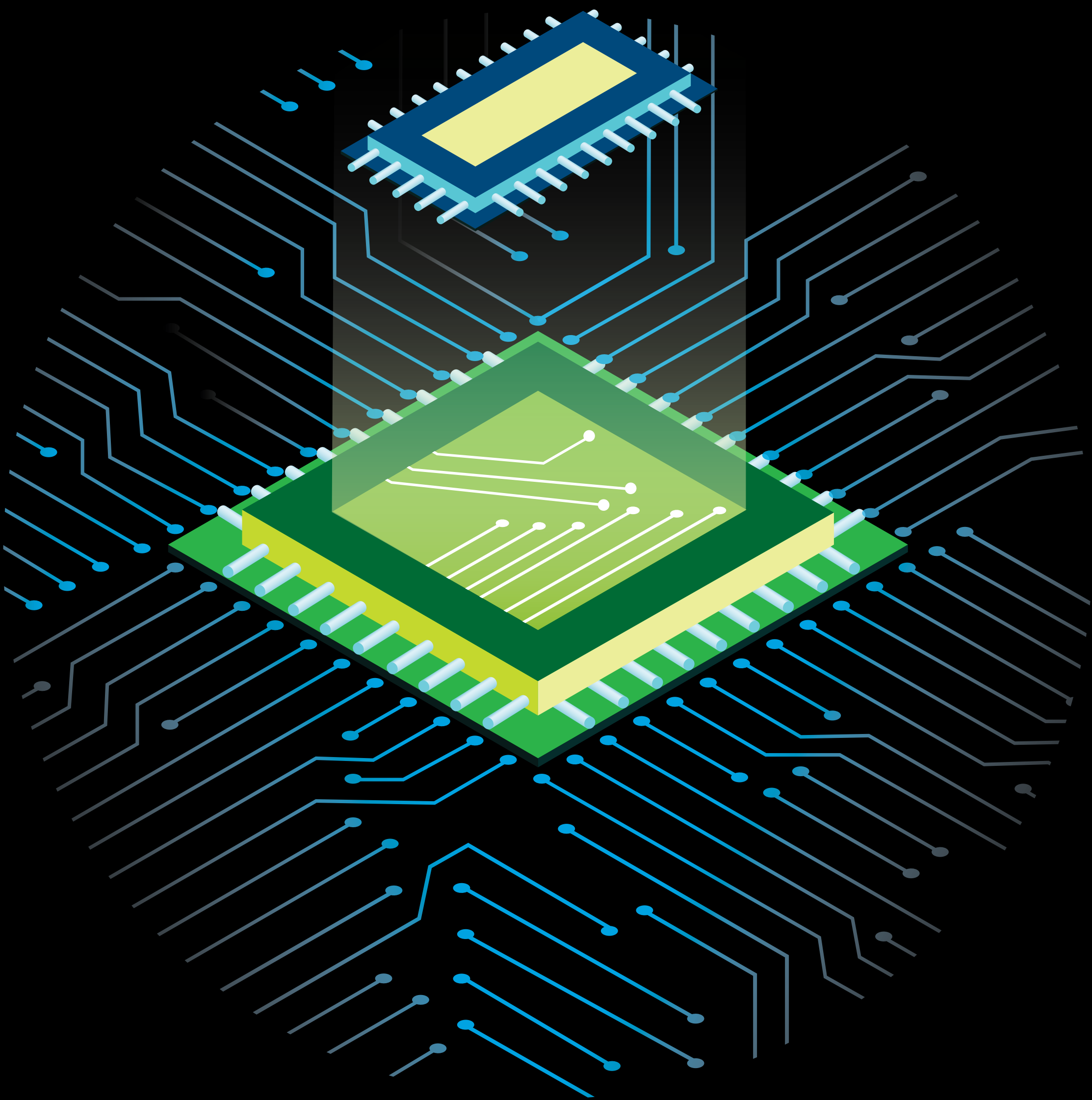


Anchor of global semiconductor
Asia Pacific Takes Off

MAKING AN IMPACT THAT MATTERS since 1845

Contents

Preface

Over the past half century, innovation in computing technologies have rapidly changed society, especially the semiconductor industry which is at the core of technological revolution. The consumer side has always been the most important force, due to the rise of the smart phones and related intelligent hardware. Remote home offices and online schools have become the main forms of working and studying since the outbreak of COVID-19, leading to skyrocketing demand for smartphones, tablet computers and other smart electronic devices, thereby demand for semiconductor chips. In the automotive field, more and more electronic devices are applied to a range of vehicles from manual driving to autonomous driving. For example, voltage control and battery management all require semiconductor chips, driving demand growth for automotive chips. In the global automotive semiconductor market, the value of semiconductors on each vehicle is expected to increase ten-fold by 2035. The upsurge of intelligent hardware and electric vehicles also brings with it substantial demand for storage. Since global data volume is expected to increase to 10 trillion gigabytes by 2030, the demand for integrated chips is also expected to increase.

Figure: The semiconductor industry will be driven by both consumer and business demand in the next decade

In the past 10 years

Drivers:
Smart electronic devices, electronic cars, memory chips, AI, etc.

Driven by Consumer side:
The pandemic brings remote working mode and online school, driving the demand for smart phone and related hardware, which increases the demand for semiconductor elements.

In the next decade

Driven by Consumer + Corporate dual sides
Increased demand for data center and edge hardware, the Internet of Things application has increased significantly, the market' s demand for sensors continues to increase, demand for semiconductor products has soared.

Demand for semiconductors driven by smart devices and automobiles has for the past ten years promoted the development of the semiconductor industry, based on the needs of consumers. However, with the continuous development of technology, we believe that in the next 10 years, the key drivers behind the development of the semiconductor industry will gradually transfer from the consumer side to the "consumer + corporate dual sides", especially for digital technologies such as 5G, AI and the Internet of Things, of which utilization will be more driven by the enterprise side. Some leading industries, such as automobiles, computing and medical care are pushing forward with the wave of AI application, thereby promoting the development of AI semiconductors. Meanwhile, AI also plays an important role in the demand for data centers and edge hardware. In addition to promoting the development of the telecoms industry, the industry-wide use of 5G is also accelerating the development of semiconductors, enriching the design of AI Internet of Things and innovation around automotive technology. On top of that, with the popularity of the Internet of Things, market demand will increase accordingly which will further boost the huge demand for semiconductor products.

As the "Big four" semiconductor regions – South Korea, Japan, Mainland China and Taiwan (China) – have played a leading role in the development of the semiconductor industry at the upstream, midstream and downstream, even on a global level. A series of black swan events have also made the Asia Pacific semiconductor market become increasingly important. We predict that with the increasing demand for the semiconductor market and increasing standards for diversification, Asia Pacific countries will accelerate the pace of R&D and innovation around semiconductors, in order to compete and excel in such a highly competitive environment. In return, this will transform the Asia Pacific into the cornerstone of the world's semiconductor industry.

Asia Pacific becomes an anchor in global semiconductor

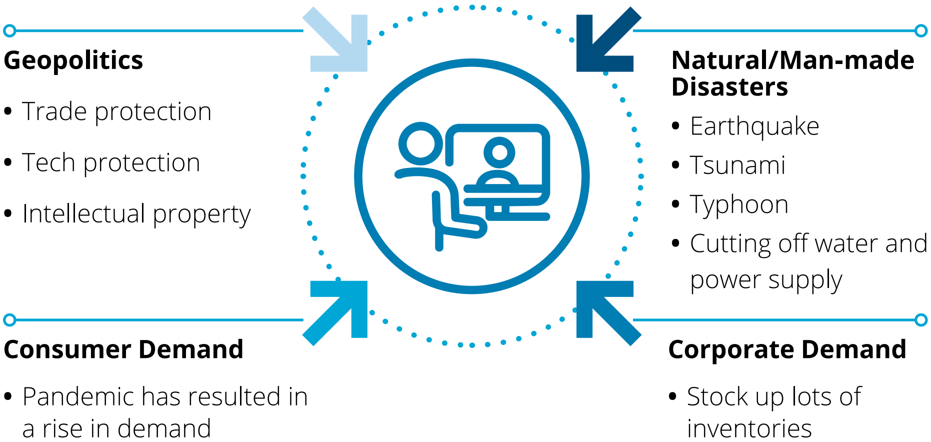
Black Swan events a frequent occasion

From natural disasters such as earthquakes and tsunamis to the global pandemic and geopolitical issues, Black Swan events have become increasingly frequent in recent years. Such incidents have negatively affected the supply and demand of the semiconductor industry on a regular basis. For example, demand for electronic devices has risen significantly since the outbreak of COVID-19, as consumers need to purchase electronic devices such as laptops and monitors to better adapt to online working or studying. Sales of home appliance such as TVs and air purifiers also jumped. With all modern electronic devices being equipped with smart chips, alongside the development of 5G networks and data centres, demand for semiconductor components continues to grow.

Further, the uncertainties surrounding technological competition between China and the US has also interrupted the global supply chain; for example, smart phone and network device manufacturers have stocked up on semiconductor components. Multinational companies have also held inventory volumes above their normal levels so as to offset the potential loss due to the uncertainty of the entire market. These combined factors have been a leading factor behind the supply shortage of semiconductor chips.

These events have resulted in a reduction in vehicle production and an increase in the price of electronics. Game console makers, for example, were unable to deliver flagship consoles to consumers as scheduled, while new smart phone launches could not meet consumer demand.

Figure: Black Swan events impacting the semiconductor industry



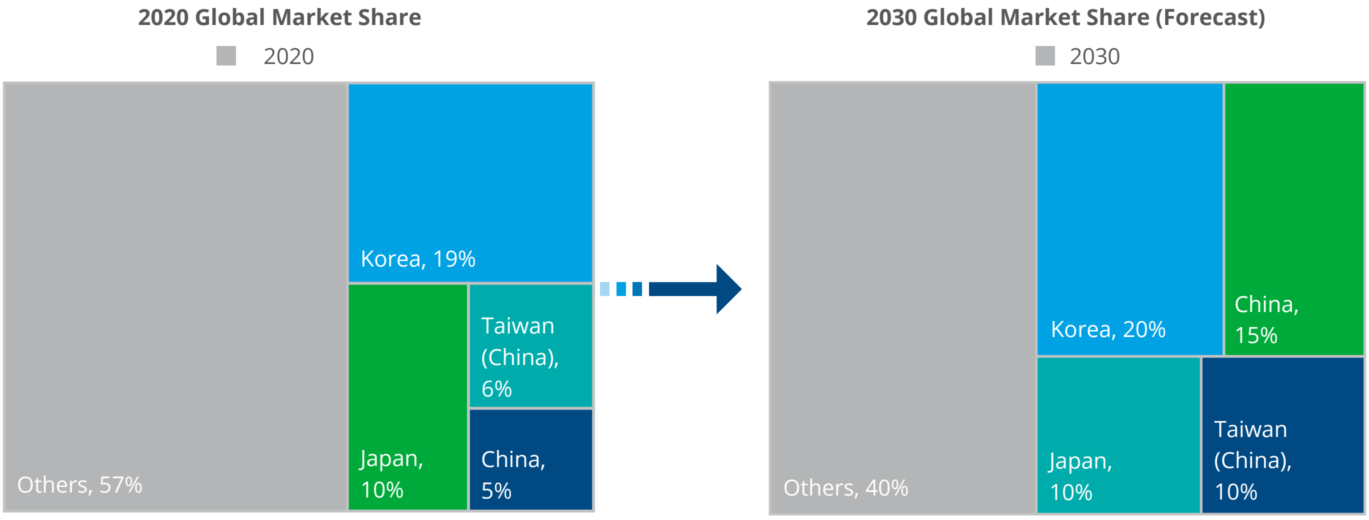
Source: Gartner, Deloitte

Asia Pacific becomes the anchor of global semiconductors

Asia Pacific to become the largest semiconductor market

South Korea, Japan, Mainland China and Taiwan (China) have each played a critical role in the development of the semiconductor industry, from upstream to downstream. A series of black swan events have made the Asia Pacific semiconductor market strategically critical. We expect that the semiconductor industry in the Asia Pacific will grow its global share to 62% by 2030, and the global market of semiconductors will exceed USD 1 trillion.

Figure: Asia Pacific's share in the global semiconductor industry

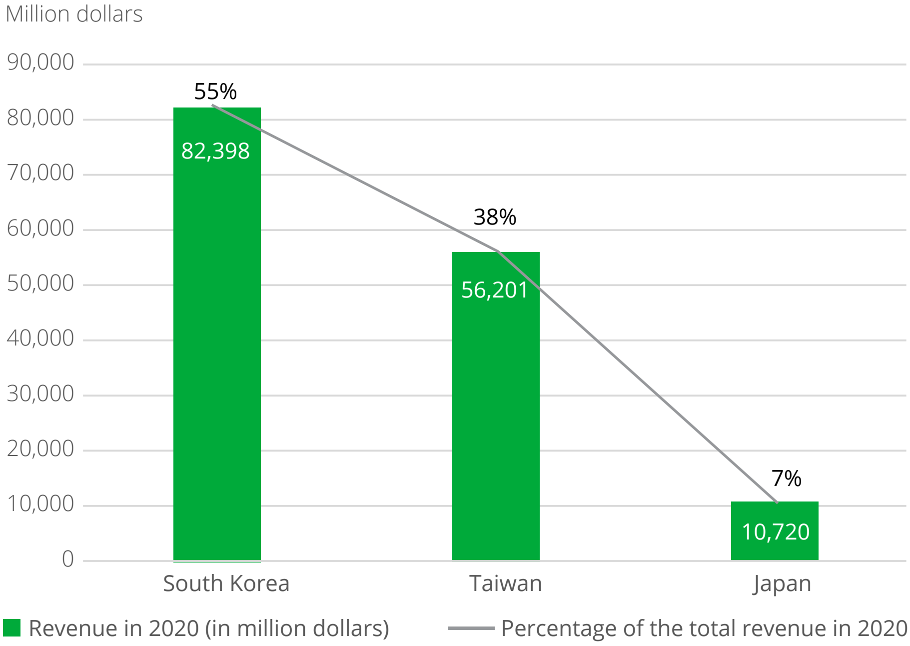


Source: Deloitte

Specifically, South Korea will devote its R&D efforts towards AI and 5G related semiconductor products. Japan's strength lies in semiconductor materials, and is striving for the development of both mid- and downstream, as well as reviving its semiconductor industry. Meanwhile, China is striving towards a development model of self-sufficiency. As for Taiwan (China), although it has already played a leading role in semiconductor manufacturing, the island continues to reinvent itself to achieve a comprehensive tech ecosystem, while devoting itself to the research of sustainable and green semiconductors.

The strength of the Asia Pacific region with regards to semiconductors can also be seen from the location of corporate headquarters. In 2020, there were five Asia Pacific enterprises listed in the global top 15 semiconductor companies by revenue, while three of them were listed as the top three. The total revenue of these five Asia Pacific companies accounted for nearly half of all global revenue, and their annual growth rates ranked among the top 15.

Figure: Annual Revenue of Top 15 semiconductor firms in Asia Pacific (2020)



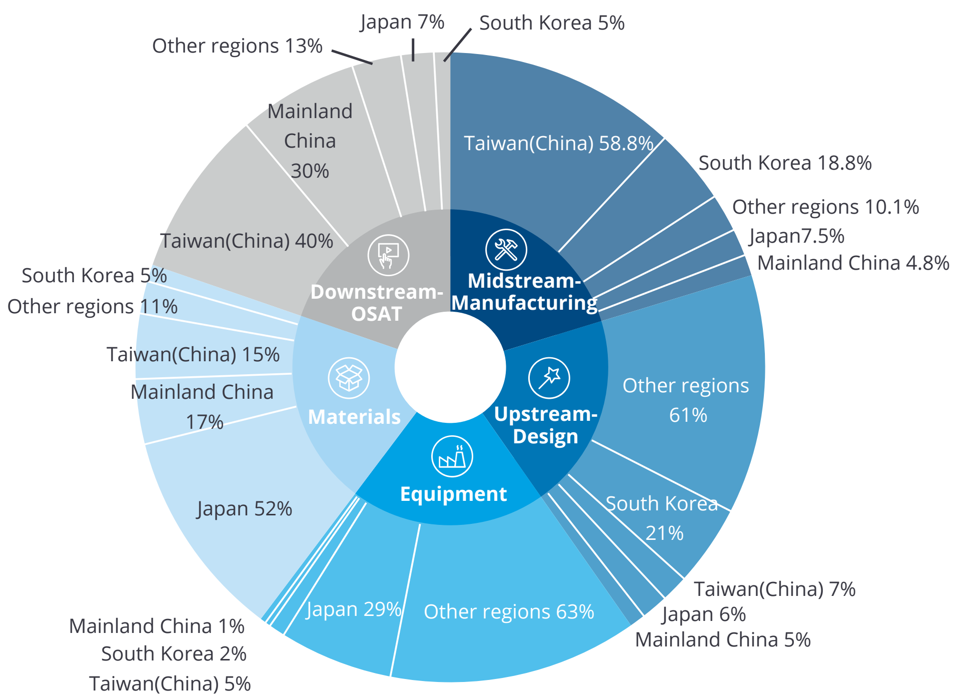
Source: IC Insight, Deloitte

Asia Pacific leads in manufacturing, OSAT and materials

Manufacturing – South Korea and Taiwan (China) play a dominant role

Most of the world's top chip design companies today rely on manufacturers in the Asia Pacific region to manufacture semiconductor chips. The two most influential manufacturers are TSMC and Samsung, which collectively own over 70% of the total manufacturing market, they have in recent years become the only suppliers of cutting-edge chips. In particular, the total volume of semiconductor chips made in Taiwan (China) accounts for over 50% of the global total. The reason being that semiconductor manufacturing is capital (up to tens of billions of dollars) and research intensive. To maintain its dominance in the future, Taiwan (China) is rapidly reinventing its techniques, proposing the most advanced 3nm technology which is planned to be implemented in the second half of 2022.

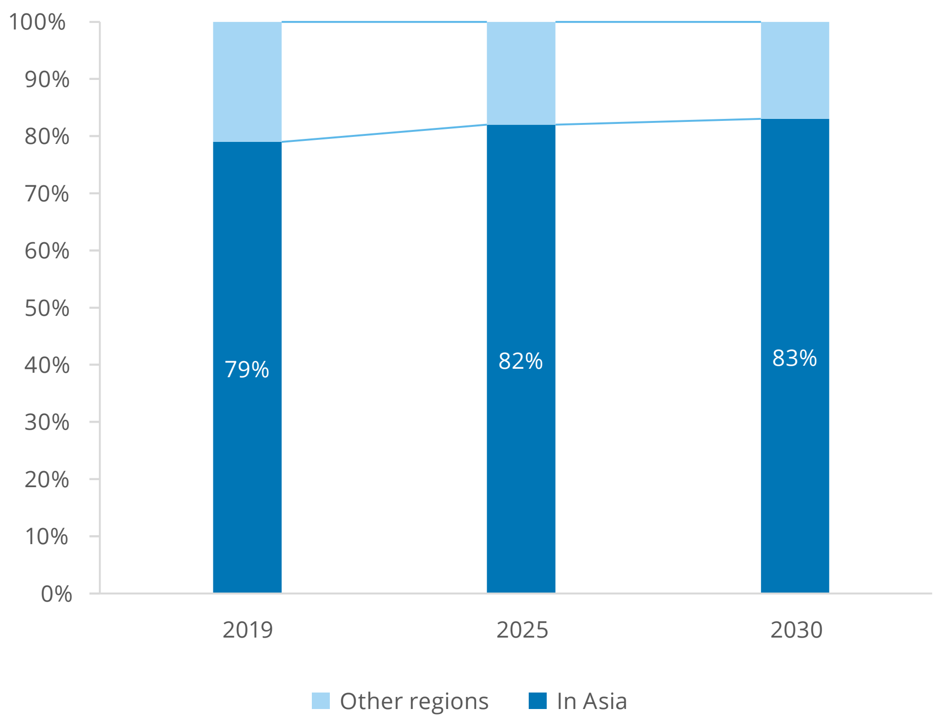
Figure: Proportion of Asia-Pacific semiconductor sector in global value chain (2020)



Meanwhile, South Korea has the similar strengths in wafer manufacturing, including the long-term experience, the constant policy and financial support from government and corporation, which is important to the innovation in manufacturing industry.

China is also playing catch up in semiconductor manufacturing. Both the Chinese government's 14th Five-Year Plan which offers support to the semiconductor industry and policies to attract talent will help the manufacturing industry grow prosperously. In an environment that lacks the sharing of technology information, China should cultivate more manufacturing talent, while simultaneously attracting talent from elsewhere. This is based on the consideration that human capital and manufacturing costs are stringently required by semiconductor manufacturers.

Figure: Global Foundry Share and Wafer Capacity (2019-2030)



Source: SIA

OSAT – Taiwan (China) and Mainland China take the lead

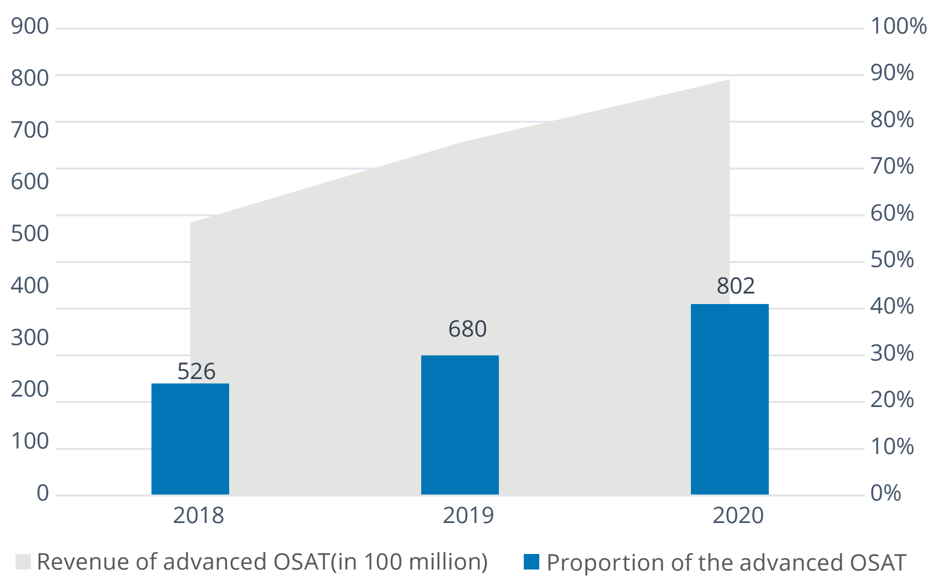
The outsourced semiconductor assembly and test (OSAT) industry sits at the end of the semiconductor value chain, including both assembly and testing. Assembly aims to protect the semiconductor chips from external damage, while enhancing the heat dissipation performance of the chip to ensure the circuits can work smoothly. Testing, on the other hand, aims to identify defects by testing the function and performance of the chips. The transition of the OSAT industry to a more advanced market can be differentiated by wire bonding. Advanced OSAT have outstanding performance which continuously attracts investment from OSAT manufacturers.

The semiconductor industry in Taiwan (China) developed early and has moved downstream to OSAT after achieving success in foundry business. Taiwan (China) is regarded as the top-tier in the global OSAT industry, accounting for 44% of the total market. However, it is facing growing competition from Mainland China, as China has put great efforts into the development of OSAT via cross-border M&A.

Under such a rivalry, OSAT manufacturers in Taiwan (China) are proactively integrating resources, crafting their competitive advantages and re-inventing themselves into advanced OSAT players through highly automated production processes and technical improvements.

By contrast, although Mainland China has acquired advanced OSAT capabilities through mergers and acquisitions, it is still dominated by traditional forms of OSAT and has a long way to go. Since the overall technical level in Mainland China is below the global standard to a certain extent, the revenue derived from the advanced OSAT industry only accounts for 25% of the total revenue, which is lower than the average global level. In the future, the OSAT industry in China faces the challenges of technical improvement, due to the US-China trade and technology war. To further develop the techniques into advanced OSAT and enlarge its market share, the OSAT manufacturers in China need continuous R&D, domestic integration and to proactively cultivate talent in this field.

Figure: Revenue of advanced OSAT in China and according proportion



Source：Founder Securities

Materials – Japan displays absolute advantages

In the field of semiconductor materials, Japanese companies account for more than half of the global market share. For example, Japan occupies a majority market share in area of photoresist, which is the most important consumable in the photolithography and chip manufacturing process. Semiconductor materials have extremely strict requirements for "fineness" and "formulation", requiring a large number of basic scientific instruments and long-term technical experience. Under such conditions, it is hard for other regions and countries to catch up. South Korea previously relied heavily on Japan in the field of semiconductor materials. However, with Japanese restrictions and sanctions on South Korea's materials, South Korea started to enhance its research around "domestic materials" and stepped up the construction of new silicon wafer factories so as to diversify its supply channels.

Mainland China accounts for around 17% of the global market for semiconductor materials, but with a utilization rate of less than 15% for domestic produced materials in the semiconductor manufacturing process, and even lower localization rates in the fields of advanced industrial processes and advanced OSAT, the industry lacks its own autonomy. It is therefore necessary for the Chinese government to promote the development of its semiconductor materials industry, including the reduction or exemption of corporate tax burdens, increasing financial support, and constructing an industrial R&D technology system.

The semiconductor industries in Taiwan (China) and South Korea have strong foundations and occupy a dominant position in their respective areas of strength, while also catching up in the materials market. According to its properties, semiconductor material is hard to be decomposed, whereas Taiwan is committed to sustainable development, helping Taiwan to attract capital investment in what will undoubtedly become one of the dominant development trends in semiconductor materials.

Design – Asia Pacific is rapidly advancing

The semiconductor design sector in the Asia Pacific region ranks as second tier compared to its manufacturing industry. Only Taiwan had three integrated circuit (IC) design companies listed in top 10 for revenue in 2020. The industry's developed started early in Taiwan, benefiting from sufficient policy support, active personnel training and a good momentum of development, especially under the pandemic. Taiwan's semiconductor value chain has been relatively complete for a long time, and has been actively introducing advanced technologies while insisting on originality. Researchers have insisted on their own research and development while obtaining technical support, and have been striving for the development of the design field under the premise of further improving in the mid- and downstream segments. With support from the government, China has gradually made the scale of the mid- and downstream clearer. Based on the solid foundations of its semiconductor industry, it has begun to seek independent research and development in upstream design. A large number of support funds have begun to be invested in the field of design. The government has also come forward to promote joint scientific research between enterprises and universities to create a good environment, train high-tech talent, and initiative greater cooperation with world-leading IC technology research and development and talent acquisition. South Korea continues to adhere to the joint development strategy of the government and consortium, investing in semiconductor companies for design research and development, and taking the lead for companies and universities to conduct talent training programs. South Korea has a relatively complete semiconductor value chain and is a leader in the fields of AI, cloud technology, and electric vehicles. This rich experience in mid- and downstream industries will also help the development of the upstream design field.

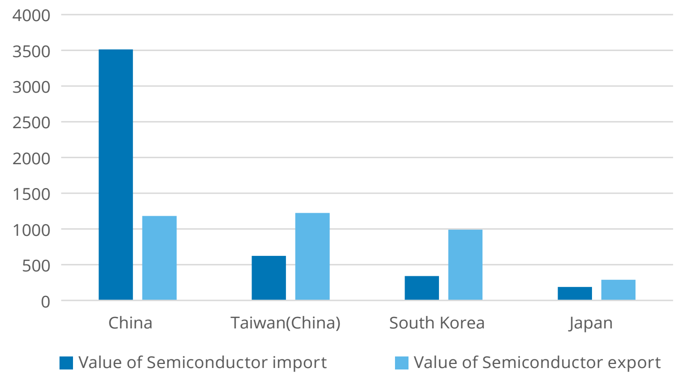
R&D Expenditure – Asia Pacific enhances innovation

R&D expenses on global semiconductor companies continues to grow with a total of USD68.4 billion in 2020, which is expected to reach USD71.4 billion in 2021. Specifically, there is an increasing market share in the semiconductor industry in the Asia Pacific, alongside increasing investment and development. Samsung in South Korea increased its R&D funding by 19% in 2020 in order to accelerate the development of cutting-edge logic processes, while Taiwan's semiconductor manufacturers have also increased their R&D expenditure by 24% to allow their IC manufacturing business to grow steadily. In addition, Tokyo Electron invested JPY135 billion in R&D around EUV high-end equipment, which helps manufacture more advanced high-end chips, thereby enhancing its position in the semiconductor market. Finally, Mainland China is now catching up. Most Chinese companies have increased their R&D budget for chip design research, and in the relatively mature OSAT industry in Mainland China, companies are growing steadily with year-on-year growth of R&D expenses at 20-30%.

Rivalry in the "Big 4" semiconductor regions

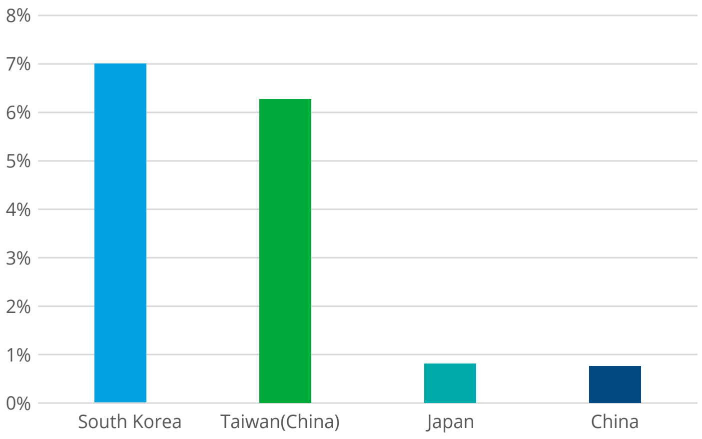
The global semiconductor industry originated from the US in the 1950s and completed the first industrial transfer from the US to Japan during the 1970s and 1980s. During this period, corporates and research institutes worked in collaboration to achieve huge technical success, led by the Japanese government. Aided by cost and technology, the Japanese semiconductor industry expanded rapidly. South Korea then embraced this opportunity and launched a series of semiconductor industry support programs, alongside the introduction of consortiums in South Korea and countercyclical investments. These laid the foundation for South Korea's dominance amid a backdrop of a wider industry downturn. The semiconductor industry has gradually become the lifeblood of the South Korean economy and is one of the pillar industries in the country. In Taiwan, coeval manufacturers proactively introduced technology and independent R&D, starting with OSAT. This enabled the semiconductor industry in Taiwan to grow rapidly and helped gradually establish the entire value chain comprising OSAT, manufacturing and design industries. TSMC has successfully driven the development of the entire industrial chain, especially the Hsinchu industrial base cluster, which has played a crucial role in Taiwan's economic development. Since reform and opening in China, China has realized the importance of semiconductors, thus the semiconductor industry embraced and achieved a period of prosperity, and even a counter-trends growth. The semiconductor industry in Mainland China has since rapidly formed an entire chain consisting of IC design, chip manufacturing and OSAT.

Figure: Export and Import values of semiconductor in Big 4 semiconductor regions in Asia Pacific.



Source: Deloitte

Figure: Proportion of semiconductor in GDP in Asia-Pacific region



Source: Deloitte

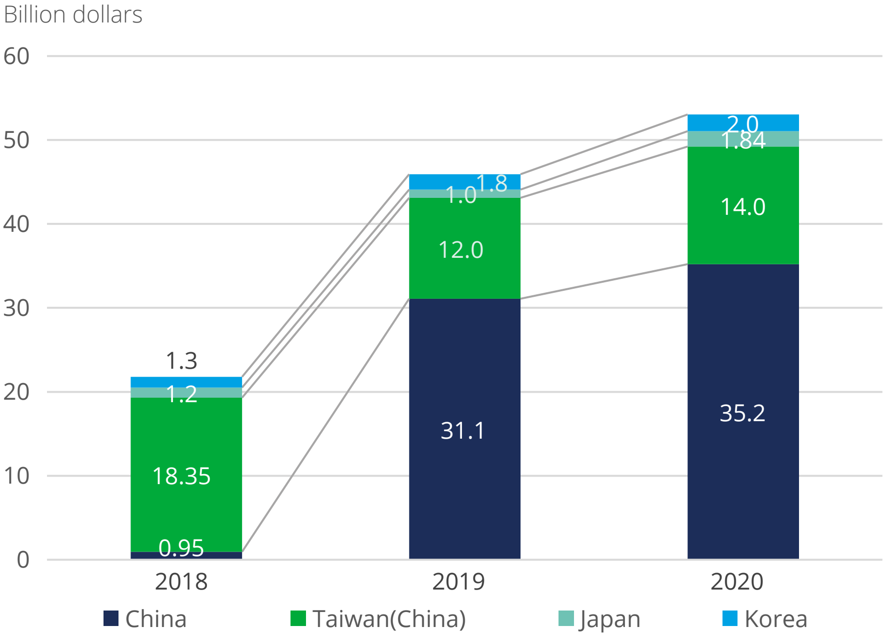
Exports of semiconductors play an important role in the top four Asia Pacific regions. Compared to all three other regions, Taiwan has maintained a relatively high export volume, followed by Mainland China, South Korea and Japan. Semiconductor exports in China have fluctuated significantly over the past decade and grew substantially. Nevertheless, imports of semiconductors into China are higher than that of other regions. According to China Customs data, the total value of China's chip imports reached USD304 billion, far exceeding the second-ranked crude oil imports.

The semiconductor industries in South Korea and Taiwan (China) constitute a large proportion of their respective GDPs. South Korea's semiconductor industry is large in scale. A large-scale and stable semiconductor value chain can be formed and semiconductor city clusters can be formed between cities, based on the competitiveness of its corporate quantities and experience. Taiwan (China) has established a relatively complete semiconductor industry cluster, which is the largest semiconductor foundry region. The semiconductor industries in Japan and China, by contrast, contribute relatively lower proportion of GDP. Japan's economy is mainly concentrated in the industrial and service sectors, and its only competitive advantage lies in upstream semiconductor materials, while it doesn't enjoy any advantages in other industries. The reasons why China's semiconductor sector doesn't contribute a lot to its GDP are that China's GDP has a large base and its semiconductor industry is still in the developing stage. Although the development of China's semiconductor sector continues to accelerate, it still cannot play an influential role in GDP growth in the short term.

From the perspective of the industry's development trajectory, the government plays a crucial role in promoting the semiconductor sector in the Asia Pacific region. Mainland China, Japan, South Korea, Taiwan and other regions have successively released investment plans, established tax reduction and exemption policies, and talent training plans in order to consolidate the semiconductor value chain. In the next decade, the South Korean government will work in collaboration with local companies such as and SK Hynix to invest KRW510 trillion (USD450 billion) on establishment of the world's largest semiconductor industry supply chain, which enables South Korea to consolidate its premier position in the in semiconductor storage industry. Meanwhile, South Korea also plans to attract more advanced technology investment from abroad. Japan has also set up a fund of JPY200 billion and plans to substantially expand support polices. Companies in Taiwan (China) plan to invest over USD107 billion on semiconductors by 2025. At the same time, China's foundry, OSAT and a number of IDM manufacturers are proactively raising funds to expand production. The second phase of the National Fund was also approved in 2018, which means USD30 billion from the second phase of this fund will be invested in the semiconductor industry over the next few years.

Each of the top four semiconductor regions has their own strengths. South Korea's semiconductor industry is highly specialized, including design, manufacturing and processing. From Samsung Electronics' Yongin and Hwaseong wafer production bases located in Gyeonggi Province to SK Hynix's wafer production bases in Chungcheongbuk-do, their factories are surrounded by comprehensive supporting enterprises, forming a

Figure: Government investment in the semiconductor industry in the Asia Pacific



Source：National Bureau of Statistics, SIA

Figure: Distribution of the Big 4 semiconductor regions in the Asia Pacific

Country/ Region	Region	Main areas	Characteristics	Main enterprises
South Korea	Gyeonggi Province	Memory chip	• Owning more than 60% of semiconductor equipment companies • Established four large semiconductor manufacturers and about 50 upstream and downstream suppliers	• Samsung • Hwaseong wafer production base • SK Hynix Icheon Base
	Chungcheongdo area	Semiconductor production equipment	• Factories are surrounded by various supporting enterprises. Semiconductor industry cluster will be built by 2030	• SK Hynix Wafer Production Base
Japan	Kyushu Silicon Island	Wafer manufacturing materials and photoresist filed	• Account for 5% of global semiconductor output. • Focus on production and assembly	• Sony • Toshiba
	Tokyo	Semiconductor manufacturing process	• Coating/imaging equipment, heat treatment	• Tokyo Electronics
Taiwan (China)	Hsinchu Science Park	Foundry and OSAT	• Develop more than 70% of the world's information technology products	• TSMC • Media Tek
	South Science and Technology Industrial Park(Nanke)	Circuits and Optoelectronics	• Machinery and biotechnology determine the position of Taiwan's flat-panel display industry in the world	• Innolux
	Central Science and Technology Industrial Park (Zhongke)	Biotechnology, Integrated Circuit, computer and other industries	• Is the world's largest gathering place for 12-inch wafer fabs	• Ruijing • Winbond
Mainland China	The Yangtze River Delta with Shanghai as its center	Comprehensive development of value chain consisting of basic design, manufacturing, OSAT	• Zhangjiang High-tech Park is the largest semiconductor industry cluster in the mainland China	• SMIC • Hua Hong • Huali Microelectronics
	Pan-Pearl River Delta with Shenzhen as the center	Application fields of integrated circuits	• Improve the shortcomings of the chip value chain and develop independent core technologies	• ZTE Microelectronics • Huawei
	Bohai Rim with Beijing as the center	IC design industry	• Is the region with the most comprehensive scientific research strength	• Wisdom • Vimicro
	The central and western regions represented by Wuhan and Chengdu	Mainly focused on the three major midstream industries, including design, OSAT and manufacturing	• Demand for downstream grows significantly while there is still a lot to be improved	• Yangtze River Storage • Kelei Semiconductor • Optics Valley

Source: Public information, Deloitte

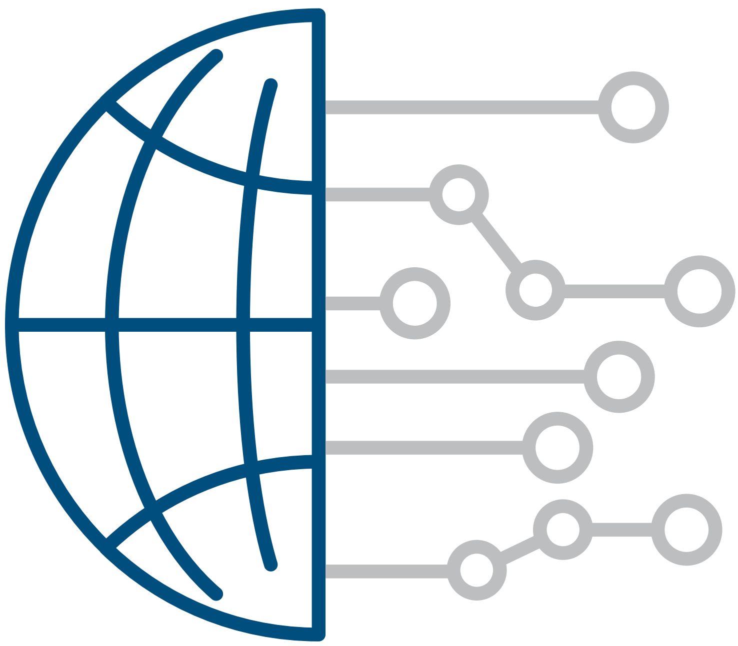
semiconductor industry base. With storage and manufacturing being its area of comparative advantage, nearly 40% of semiconductor finished goods are produced on the island of Kyushu. Japan has a relatively stronger advantage in the field of photoresist and manufacturing materials. Well-known companies such as Toshiba, Hitachi and Mitsubishi all have production bases here. With the development of high value-added electronic component products such as image sensors and automotive semiconductors, the growth of the semiconductor sector on Kyushu Island is evident. Taiwan's semiconductor industry cluster has formed three major science parks including Hsinchu and the Southern and Central areas. Industry clusters give full play to the cluster effect and drive the development of the entire value chain, from upstream IC design, midstream wafer production, downstream OSAT, to equipment and material industries. The distribution of semiconductor industry in China is relatively concentrated, including the Yangtze River Delta with Shanghai at the center, the Bohai Rim with the center being Beijing, the Pan-Pearl River Delta with Shenzhen at the center, and the central and western regions represented by Wuhan and Chengdu. These four industrial clusters have different industrial chain advantages. The Yangtze River Delta and the Pearl River Delta have developed comprehensively in China's IC industry basic design, manufacturing and OSAT value chains. In addition, the Beijing-Tianjin-Hebei region is more specialized on the IC design industry, while central and western regions have developed well in the OSAT area.

South Korea comprehensive transformation

Comprehensive transformation based on manufacturing and production advantages

The semiconductor industry in South Korea has a competitive advantage right across the design, manufacturing, OSAT, equipment and material fields. Such a large-scale industry has also help shape the semiconductor value chain through specialization and outsourcing, which consists of IC manufacturing companies, semiconductor equipment companies and semiconductor material companies. As a result, industrial city clusters have also sprung up, including Yongin, Huacheng and Icheon, which support the semiconductor value chain in South Korea.

South Korea also enjoys a relative monopoly on storage products. The semiconductor industry in South Korea began with the introduction of new technology and has since completed its own technological accumulation after decades of experience. Amid growing trade friction between Japan and the US, as well as cyclical fluctuations in the semiconductor industry, South Korea has accelerated the introduction of new technology (memory)and increased investment into R&D. Therefore, as the semiconductor sector has rebounded, South Korea has acquired more than 90% of mobile DRAM market share, almost dominating the market for global story chips. South Korea has thus caught up to achieve a more stable market position than other countries in terms of manufacturing processes, technology, processes, and yields.



Changes to the global semiconductor environment have led the representative South Korean companies to reduce their dependence on storage products, and instead develop other components used in semiconductors. For instance, South Korean companies have invested more on R&D into advanced manufacturing processes to grow their market share in the wafer sector, while also adjusting and redistributing its subsidiary foundry business to strengthen its competitiveness. On the basis of the stable development of storage products, South Korea has consistently increased its investment, allowing it to successfully transition from a country with a particular focus on storage to one with a comprehensive semiconductor industry.

In May 2021, the South Korean government formulated the "K-Semiconductor Strategy", aiming to establish a highly effective industry cluster which integrates semiconductor production, raw materials, components, equipment, cutting-edge equipment, and design. The goal is for South Korea to become the largest market and manufacturing base for the global semiconductor industry, and to establish a stable and leading global semiconductor supply chain. Therefore, based on their strategic planning, the South Korean government would reduce the tax burden for related semiconductor companies, expand the array of financial means to raise capital, and establish a KRW1 trillion fund to support investment into semiconductor equipment. If implemented smoothly, South Korea's annual semiconductor exports will achieve USD200 billion by 2030.

In the era of 5G and AI, the rapid development and adoption of technologies such as blockchain and big data have driven enormous demand for the high-end chip industry. South Korean semiconductors are undergoing new changes and are embracing these new development opportunities.

Although South Korea is a major player in the global automotive industry, it still relies heavily on the exports of in-vehicle chips. South Korea promoted the localization of automotive chips more than a decade ago, and while it is largely limited to the technology, the actual production still highly relies on foreign manufacturers. According to statistics from the South Korea Automobile Industry Association, most South Korean IC design companies do not have their own factories, and only 2.2% of the automotive chips developed are commissioned by domestic manufacturers. In addition, the lack of connectivity between South Korean IC design companies and the actual manufacturers of automotive chips is also one of the reasons that affect automakers' adoption of domestic automotive chips. Looking at the structure of South Korea's semiconductor industry, automotive chips are mainly customized, thereby car dealers, IC designers and foundries must collaborate cohesively to build a comprehensive semiconductor power. Therefore, South Korea has been committed to the development of new layouts in automotive semiconductors. For example, South Korean companies have been planning to achieve their own technological development through acquisitions. As the market for smart electric vehicles and automotive semiconductors continues to expand, it is projected that the global automotive chip market will achieve USD65.5 billion by 2024. In this context, the South Korean government is willing to provide customs clearance logistics and policy and financial support.

Within the AI field, the ICT segment has been working on transitioning into AI semiconductors, and South Korea is currently increasing the capital it invests in AI. By 2029, it is estimated that KRW1 trillion will be invested in the development of the next generation of AI chips. The South Korean government divides AI-related semiconductors into fiver major areas - automotive, medical, IoT home appliances, robotics and the public - and provides strategic support for the development of IC, targeting each different system. The current plan is to produce AI chips nationwide by 2022 and build a team of 3,000 professionals within ten years in order to achieve the goal of owning a 20% share of the global AI market by the end of this decade.

Japan – on the road to recovery

Materials and equipment are the cornerstones of the semiconductor industry and the engine that promotes innovation in IC technology. Semiconductor materials are at the upstream of the whole semiconductor value chain, featuring large-scale, specialization, high technological threshold and fast update speed. Within the global semiconductor industry, Japanese companies account for as much as 52% of the market. Wafer manufacturing materials include silicon wafers, photomasks, photoresist, photoresist auxiliary materials, process chemicals, electronic special gas, target materials and CMP polishing materials (polishing liquid and polishing pad). Among these areas, Japan has outstanding advantages in terms of circles, target materials and OSAT materials. In terms of materials such as ceramic substrates, resin substrates, gold wire bonding and OSAT materials, Japanese manufacturers all occupy more than a 50% market share with some even as high as 80%,. Japan has reached a level that other competitors cannot exceed, with its high-end purification technology and long-term experience. After years of investment, R&D, technological advancements and talent attraction in the field of semiconductor equipment and materials, Japan has the power of discourse and a competitive advantage in the upstream industry, allowing it to play an indispensable role in the world's semiconductor market.

The Japanese government will promote R&D and investment to ensure the improvement and development of the semiconductor supply chain at the national level. To deal with the reality that Japan's high-end semiconductor industry was lagging behind, the government established a JPY200 billion technology development fund to support its development and provided a complete research system and environment for semiconductor companies. At the same time, Japan has also launched the advanced process research and development. It invested JPY42 billion to jointly develop 2nm advanced process technology with Japan's three major semiconductor manufacturers aiming to launch semiconductor manufacturing technology at nodes below 2nm. Furthermore, Japan also aims to set up test production lines to develop microcircuit manufacturing technology such as processing and washing. Lastly, the Japanese government will also provide relevant support for its three major semiconductor manufacturers at the national level, and exchange opinions with major semiconductor manufacturers such as TSMC and Intel to conduct research and development, so as to restore Japan's strength in advanced R&D.

Taiwan – ranks top in manufacturing sector

Taiwan's semiconductor industry ranks among the best in the world, and is the strongest in terms of chip foundry. The revenue from Taiwan's semiconductor foundries accounted for over 60% of the industry's total revenue in 2020. Taiwan not only has a strength in foundry area, but also have approached other value chains. Semiconductor companies in Taiwan are comprehensively involved in all areas of IC design, midstream wafer production, downstream OSAT, and equipment and materials.

The OSAT market has been largely dominated by Taiwan. In 2020, the output value of IC professional outsourcing OSAT foundry in Taiwan exceeded USD18.5 billion, with a year-on-year growth rate of more than 15%. OSAT manufacturers in Taiwan continue to consolidate their leading positions through mergers and acquisition, as well as R&D. So far, Taiwan's OSAT has formed a relatively complete value chain development cycle and is reinventing itself on the basis of stable development. The semiconductor design segment has also performed well. The output value of design industry reached 852.9 billion dollars in 2020, achieving a year-on-year increase of 23%. In 2021, the output value of Taiwan's IC design industry is expected to grow by 10.9% by the end of this year.

Taiwan (China) has great potential for the development of the materials industry. In the process of semiconductor development, Taiwan has always focused on cultivating a local supply chain, using materials to increase yield, replacing toxic semiconductor materials, and recycling materials for reuse. In addition, in terms of materials, Taiwanese manufacturers will conduct strict inspections on their own factory materials, since all of the production technology, testing services and delivery are indispensable to the production line. Meanwhile, Taiwan also pays attention to the geographic expansion of material manufacturers, proactively building factories near top semiconductor firms. Such practices enable itself to reduce the distance among various links in the value chain and reduce costs, thereby increasing profitability.

Driven by the era of the Internet of Things, semiconductor manufacturers in Taiwan also attempt to be involved in this area. Considering the extreme importance of Bluetooth and WIFI chips, Taiwan plans to improve the output level of WIFI 6 chips, in order to align with market trends. Furthermore, based on the huge demand for data storage driven by the Internet of Things, Taiwan has cooperated with external research laboratories, consortia and academic partners in terms of emerging storage technologies to try to achieve IA and ML in-memory computing. Taiwan focuses on the rise of 5G communications and the IoT, and focuses on the development of three application areas comprising smart life, high-quality health and sustainable environment, assisting the integration of the 3D integrated circuit industry and creating a new semiconductor industry. With the support of local governments, relevant companies will invest USD100 billion in capital expenditure to cope with the explosive growth of 5G and high-speed computing applications in the next few years.

China — a rising star

The Chinese government has spared no effort in supporting its domestic semiconductor industry. Firstly, in order to consolidate and develop China's cutting-edge technological strength, the Chinese government laid out in the 14th Five-Year Plan a focus on encouraging the development of the semiconductor industry. In this effort, China will focus on accelerating the development speed of advanced processes, such as 14nm, 7nm and even more advanced manufacturing processes to achieve mass production, and will focus on supporting advanced processes of 14nm and below. The outstanding performance advantages of the third-generation semiconductor materials have also received significant attention. From 2021 to 2025, China will commit to supporting and cultivating professionals in education, scientific research, development, financing and application in order to achieve its goal of industrial self-reliance.

China has also previously established a large fund to support the chip semiconductor industry and to promote the development of the domestic semiconductor industry. In September 2014, the state established the first phase of the Big Fund which mainly invests in midstream companies in the industry, including leading companies in manufacturing, design and OSAT.

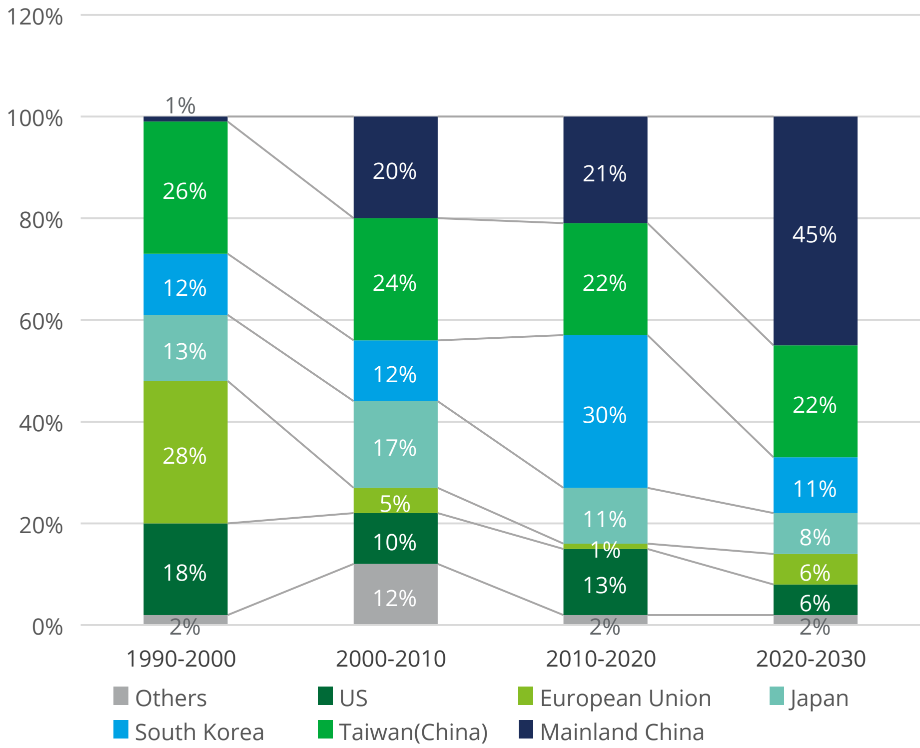
Furthermore, the Chinese government has promulgated a policy to import equipment, materials and elements without tariffs. Companies serving in equipment, materials and OSAT can benefit from "tax exemptions for first two years and half tax reduction for the third year" tax policy. Under a situation where the semiconductor industry in China could not meet the demand with domestic supply, this tax exemption policy has provided financial support for the development of this field. Making it easier for companies to launch their IPO, supporting the capitalization of R&D expenditures, and the combination of"industry + capital" will be some of the most important ways to further develop the semiconductor industry. The many favorable policies offered by Chinese government in capital markets have undoubtedly enhanced the innovation and development of semiconductor companies in China.

China's semiconductor value chain is relatively complete and concentrated, reducing development costs and promoting the rapid expansion of the industry. China's IC industry now has four main industrial clusters, namely, the Yangtze River Delta with Shanghai as the center, the Bohai Sea with Beijing as the center, the Pan-Pearl River Delta with Shenzhen as the center and the central and western regions represented by Wuhan and Chengdu. These four industrial clusters have different value chain advantages. The Yangtze River Delta and the Pearl River Delta have developed comprehensively in China's IC industry basic design, manufacturing and OSAT value chains. The Beijing-Tianjin-Hebei region by contrast is more specialized in the integrated circuit design industry, while the central and western regions have developed well in the OSAT industry. The Yangtze River Delta region has significant advantages, and the central and western regions are also catching up. The Chinese government plans to regard the Shanghai Integrated Circuit R&D Center as the main innovation supporting platform to accelerate the progress and development of various value chains such as chip design and advanced technologies around this center. The Zhejiang region has advanced the strategic planning and development of third-generation semiconductors, is closely connected with Shanghai, and has coordinated the development of the value chain and supply chain. The Jiangsu region will make breakthroughs in core technologies in terms of high-end equipment manufacturing, integrated circuits, and AI. As a result, the semiconductor value chain around China's Yangtze River Delta has gradually emerged, and the concentration of resources and technology will also reduce R&D costs, and gradually accelerate the momentum behind China's semiconductor industry development.

China is equally booming in the design industry. In the first three quarters of 2020, the scale of China's IC design market increased by 24.1% year-on-year. Semiconductor design industries are not built overnight, but demand extremely high requirements around industrial foundations and talent training. China's most vigorous development in the semiconductor value chain is IC design. Overall, the product line of China's IC design industry covers a comprehensive range, including mobile phone SoC, baseband, fingerprint recognition, and bank security chips. It can also be seen that China's IC design plants are in the leading position in the specific fields. However, in the area of high-end chips, the global market share of domestic chip manufacturers is relatively low and still a way off from the major international manufacturers. Therefore, China will continue to concentrate resources in the future and strive to achieve breakthroughs in the field of high-end chips.

China has vigorously developed the semiconductor manufacturing industry in recent years, aiming at "self-sufficiency and reducing import dependence". Although it has been effective, as the largest IC consuming country, its output only accounts for 15.9% of the market, more than half of which is from overseas processing plants. Over the past ten years, with the rise of semiconductor terminal applications, wafer manufacturing capacity has shifted to the mainland, and many overseas chip manufacturers have set up factories in mainland China. In 2020, the total number of chip companies registered in China approached 60,000, and by 2030, China's wafer manufacturing is expected to occupy half of the market.

Changes in the proportion of global chip manufacturing capacity



Source：IC Insight

China's OSAT was the first to start in the entire semiconductor industry. Its scale is equal to that of major manufacturers and it has gradually evolved into a quality-driven industry. China's major OSAT (Outsourced Semiconductor Assemble and Testing) firms have leveraged capital markets to form "joint ventures + cooperation" through acquisitions, thereby enhancing their customer base advantages. In technical areas, their subsidiaries have become national high-end processors, and the OSAT base has broken the monopoly of foreign technology. In addition to professional OSAT, China's third-party testing manufacturers, OSAT issue companies, and foundry companies are also seeking development based on their respective strong area.

There are still many challenges in the development of China's semiconductor industry. In terms of talents, the ability to retain technical talent remains a pressing issue. China's current semiconductor performance is outstanding and is matched by a passion for new start-ups, while the entire semiconductor industry is actively optimizing and the semiconductor market continues to boom. However, the market mechanism is the key to the development of semiconductor companies, since it can affect whether the company can attract and retain talent. Which method should be adopted for the development needs of the industry to be further explored? In addition, China's semiconductor system lacks experience, resulting in an extreme shortage of experienced professionals required to manufacture chips. Moreover, in the process of achieving self-sufficiency in semiconductor chips, it is difficult to balance global and local interests. Under the US-China trade war, domestic high-tech companies have faced bans on sales while local semiconductor manufacturing capabilities remain weak, leading to a disconnect in the value chain. The increasingly stringent control over foreign investment on a global scale has further increased the difficulty of cross-border investment.

When Uncertainty Becomes the New Norm - Restructuring and Balancing

The security of supply chain is particularly critical.

The normalization of 'black swan' events is a reminder that the global supply chain for semiconductors is fragile and that the source of a disruptive event can be completely unexpected. This has prompted companies in the semiconductor industry to shift more of their chip design and production in-house, meaning that the current shortage of semiconductor chips could prompt companies to start designing and manufacturing their own chips. But chip manufacturing is not only capital intensive, requiring semiconductor companies to invest a lot of money upfront, but also requires expertise and experience to manufacture. In addition, the chip plant must reach a certain scale and utilization rate to be economically viable. The normalization of black swan events provide today's semiconductor industry with an opportunity to rethink and reshape the existing business model. To create a more flexible semiconductor supply network and a more adaptable future for the industry, we need greater cooperation between semiconductor manufacturers and suppliers. In order to ensure the safety of the semiconductor supply chain, we should consider this from the national and enterprise levels.

The national level

The increasing demand for semiconductors and the increasing importance of semiconductors in the global economy have attracted the attention of decision-makers all over the world and made semiconductor chips an area of national strategic importance. At the national level, global semiconductor shortages and geopolitical tensions have led to increased scrutiny of the semiconductor supply chain and a scramble for leadership in the semiconductor industry. Under the Biden administration, for example, the United States is working to bring semiconductor manufacturing back home in order to reduce its reliance on a few chip makers. Governments across the region are also racing to secure and strengthen supply chains.

China: China aims to manufacture 70% of its semiconductors locally by 2025, as part of the country's plan to take a global lead in high-tech manufacturing industries such as artificial intelligence and information technology. This target is based on US restrictions on shipments to Chinese tech companies from the US and foreign chipmakers, but it will take some time to see if it is feasible. Because China remains heavily dependent on imported chips, it has spent nearly USD300 billion last year. In the national 14th Five-Year Plan policy, the government has emphasized support for the semiconductor industry. In the plan, special emphasis is placed on upgrading the current Chinese IC design and focusing on support and guidance for high-end power devices. The focus of this coming five-year period will be on supporting the development of advanced packaging technologies, including 3D silicon-through-via (STV) and fan-out packaging. In addition, advanced packaging of logic chips and power devices will also be the focus of development during the 14th Five-Year period. The 14th Five-Year Plan will provide special support for key equipment and materials. The support of government policy will be conducive to China achieving breakthroughs in the field of key equipment and materials of semiconductors, accelerating the industrialization process, enhancing the capacity of industry support locally, and providing a solid foundation for China's independent and controllable semiconductor industry chain.

Japan: Japan and South Korea are regarded by the United States as important partners with which to build a new semiconductor industry chain. The United States, Japan, and South Korea have emphasized the importance of ensuring the security of semiconductor supply chains, and have pointed out that they currently hold most of the key factors for success in the future of semiconductor manufacturing technology. The United States expects Japan and South Korea to strengthen communication and cooperation in this regard. At the same time, the US alone hopes that the two countries will strengthen cooperation in 5G communications, semiconductor supply chains, artificial intelligence and other fields in the future. The two parties also plan to jointly invest 4.5 billion US dollars to develop 6G network communication technology, and promote cooperation in the semiconductor industry to complement each other's advantages.

South Korea: During the time of US-Japan semiconductor trade friction, South Korean companies accelerated their efforts to catch up in the computer's memory field, causing Samsung's market share in computer memory to continue rising. Since the US did not impose high anti-dumping duties on Korean products, coupled with Japan's export controls on Korea, Korea has gradually reduced its dependence on the Japanese market and replaced them. Facing an increasingly competitive semiconductor industry, Samsung Electronics and SK Hynix, the two leading South Korean semiconductor companies, are preparing to expand their market to Texas. South Korea's government plans to promote an alliance between the country's semiconductor companies and auto companies to increase the domestic semiconductor chips used in vehicles amid a shortage of semiconductors.

Taiwan: Taiwan's semiconductor industry is still highly reliant on foreign technology and equipment. The main importers are the Netherlands, Japan and the United States. According to Taiwanese import and export statistics, Taiwan's semiconductor and liquid crystal production equipment imports reached USD18.1 billion last year, accounting for 6.3% of Taiwan's total imports, with the majority being used for core manufacturing processes. While Taiwan also remains dependent on imports in the IC design of important software tools, the island's semiconductor industry nonetheless has the world's most complete ecological system, and its upstream and downstream has formed a long-term stable business community. As a result, any disruption to Taiwan's manufacturing activity would have ripple effects across the global electronics supply chain.

Enterprise level - adaptability of supply chain

At the enterprise level, global semiconductor and electronic technology and service providers should consider both short-term and long-term strategies to ensure the stable development of their supply chains and businesses in the future.

Short-term strategy—Assess and analyse supply chain risks: Companies should assess the potential impact of supplier loss of manufacturing capacity on the business and establish alternative supplier options to minimize supply chain disruptions.

Digital supply chain: Supply chain mapping is not only a strategy but the best way for enterprises to reduce supply chain risks. However, due to the time and cost demands associated with mapping out the supply chain, only a few companies have invested in supply chain mapping. Most companies instead refer only to the information provided by their key suppliers and ignore the impact that secondary and tertiary suppliers may have on their supply chains. Mapping can help companies gain better visibility of each link throughout their supply chain, such as more timely identification of which suppliers, sites, parts, and products are at risk in the event of a disruption. This enables companies to develop mitigation strategies to relieve constrained inventories and identify alternatives. For most enterprises therefore, supply chain mapping brings more benefits than costs. For businesses with limited resources, they should initially focus on the key parts that bring in the most revenue, and then lower the hierarchy as much as possible to gain visibility. Companies should also look for ways to digitize their supply chains. For example, clothing manufacturers can choose to create 3D samples online instead of viewing them in person overseas.

Establish backup capabilities and flexible supply chains: Companies should also invest in their backup capabilities, i.e. the ability to "hide" one or more alternative supply networks in the core supply chain. If the core network fails, the backup network will be able to take over immediately. For example, Toyota redistributed its manufacturing network of standard parts after the earthquake so that multiple nodes in the supply network could have the same production capacity. In addition, flexible manufacturing will also improve the elasticity of the supply chain. For example, GM plants in Argentina, Poland, Thailand and Brazil all follow the same design, framework and manufacturing processes. So if one area encounters problems, other plants can provide immediate support.

Long-term strategy – reconfiguring the flexible supply chain model

Many semiconductor companies are now centralizing their manufacturing facilities regionally, hoping to lower their labor costs and maintain a favorable tax structure. In addition, the realization of regional centralized manufacturing is also conducive to the realization of synergies between suppliers and customers. However, this model has also introduced single-point-of-failure into an industry with trillions of dollars in global revenue.

In the long run, semiconductor companies should review their supply chain strategies and operating models to address the risks posed by geographic concentration and a lack of adaptability in manufacturing. Rather than relying on a geographically centralized manufacturing model, semiconductor companies should consider moving to a 'flexible supply node network' model that is flexible and allows for multiple paths, helping eliminate single-points-of-failure.

In this model, companies must strike a balance between manufacturing costs, continuity and sustainability levels. The 'Flexible Supply Node Network' model enables the regional scaling of manufacturing, distributes the company's concentrated manufacturing capacity to adjacent areas (e.g., manufacturing, A/T, tool manufacturing, and support), and identifies alternative sources of supply.

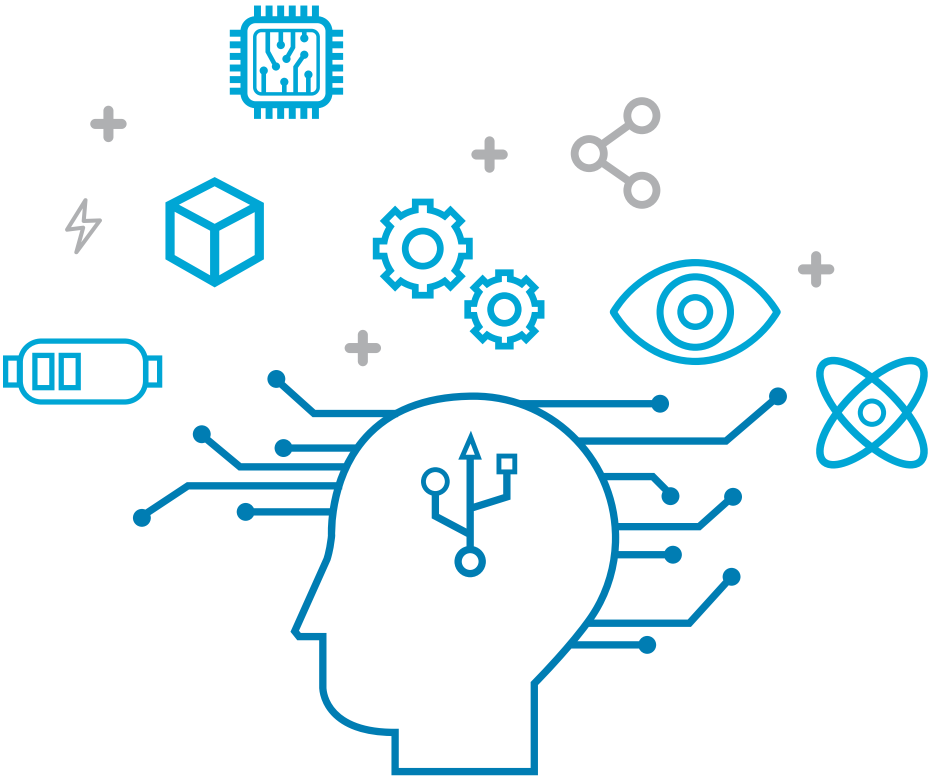
Enterprises should consider not only to have enough storage domestically, but also consider to establish regional nodes which connect with each other. To measure and monitor the level of performance, semiconductor companies should consider using more regional and global network-based indicators to monitor risk across countries and ensure continuity, flexibility and sustainability across the supply network.

Enterprises should consider shifting from country-based centers to more regional and global supply networks, while also developing and investing in talent and infrastructure to rapidly scale up new manufacturing and supply nodes as needed. For example, more mature semiconductor manufacturing, assembly and testing facilities could be built in countries such as Singapore, Malaysia or Vietnam that have already established semiconductor manufacturing ecosystems, but it is critical to provide alternative research & development and manufacturing locations for leading-edge processes.

AI Driving the Transformation of Semiconductor Manufacturing

In recent years artificial intelligence has seen much greater adoption globally. Not only have mobile phones introduced AI functions into smart phones, but industries such as financial healthcare are also accelerating the introduction of AI technologies. AI has become a catalyst for the industry's next growth cycle.

AI's impact on the semiconductor industry is two-folds. The first is by fostering demand for emerging AI technologies to create new market opportunities. The second is to use AI to improve the design and manufacturing of semiconductors. AI can be applied throughout the semiconductor manufacturing process, such as machine learning and neural networks to wafer defect detection and classification, optical measurement, chip manufacturing and modeling, photoresist profile prediction, semiconductor production result prediction and wafer process control. In this chapter we will focus on the application of AI in the design and manufacturing of semiconductors.



The value of AI in semiconductor applications

The application and transformation of AI has brought new growth opportunities to the semiconductor industry, triggered a new wave of innovation, encouraged semiconductor companies to break through new technological nodes, and exerted a huge impact on the production technology of chips. Aided by the application of artificial intelligence in the semiconductor industry, the sector will realize new profit growth by saving costs, shortening the time to market, improving operational efficiency and product quality.

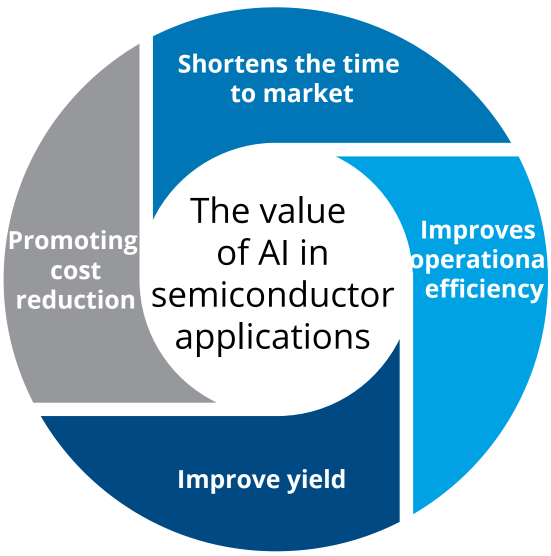
AI simplifies semiconductor process while promoting cost reduction

Semiconductor companies need to actively pursue innovation so as to maintain their competitiveness. As a result, the performance of semiconductor chips is constantly improving, but this also increases production costs. Companies could achieve enhanced automated production by applying artificial intelligence throughout the entire process of chip manufacturing. AI could simplify the test procedures, reduce onerous tasks, and help to improve the manufacturing accuracy of wafer, master the optimal processing time of wafer, and thereby improve manufacturing efficiency and eventually the company's profitability.

AI shortens the time to market and improves operational efficiency

The design and manufacturing of semiconductors is a complicated process and a large amount of data is generated at every step. The traditional data analysis method is unable to meet the requirements of analyzing these complex data. However, by using machine learning method based on AI can assist semiconductor companies to quickly analyze swathes of complex manufacturing and design data to find connections. At the same time, artificial intelligence can be embedded in the production cycle while it shortens the processing time of chip production. For example, semiconductor companies can use machine learning models to capture non-linear relationships between processing time and results (e.g. lithography intensity). This results in an optimal processing time per chip/batch, thereby increasing the productivity in chip design and manufacturing, reducing overall processing time, accelerating existing product production and operation processes, and reducing the time to market for semiconductor enterprises. At the same time, with the help of AI, companies can increase their chip production without adding equipment. For example, in different production procedures, AI can determine the best production steps through machine learning. Artificial intelligence effectively combines different professional knowledge and skills to deal with complex manufacturing procedures, maintain continuous and efficient operations and thus improves the overall operational efficiency without the need for manual operation.

Figure: Core benefits of utilizing AI in semiconductor



Source: Deloitte

Optimize semiconductor production and improve yield

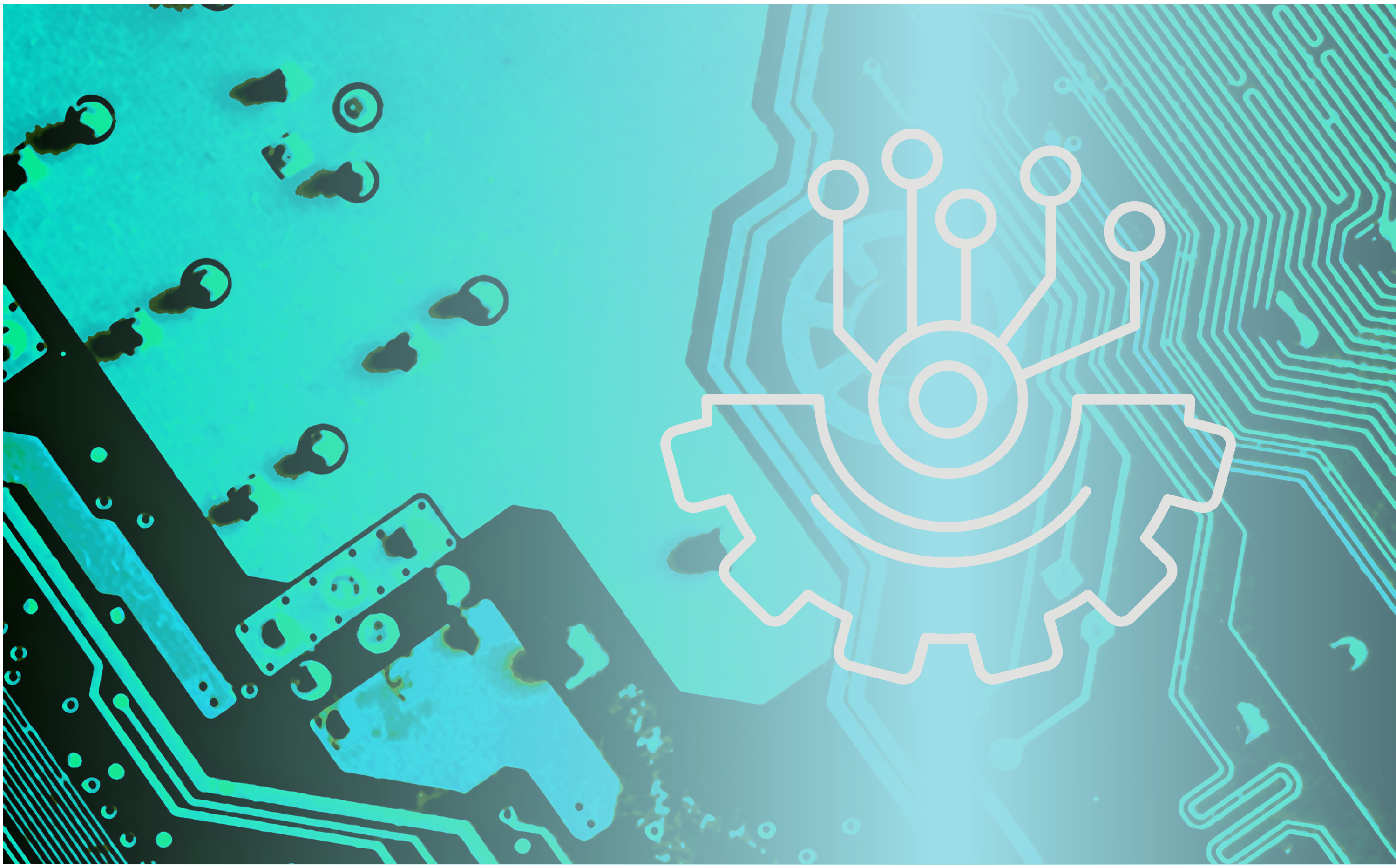
AI can provide optimization systems for defective product detection and traceability. Currently, there are only relatively mature products such as photovoltaic cell defect detection systems, traceability systems and wafer slicing process yield optimization systems. In the past, the semiconductor industry has set up enough sensors in the production process to transmit pictures, videos and other information to the computer, and then manually read the pictures and screen out unqualified products. But AI-based image recognition technology can screen out unqualified products at the end of the production process to replace manual screening and improve the efficiency and accuracy of defect detection. The defect traceability function goes even further. It manages various parameters on the semiconductor production line, establishes a model according to historical production data, establishes the key parameters related to the yield, forms a relationship model, and provides the optimal parameters for each product to improve the yield from the source. AI algorithms can not only identify product defects in the production process and provide solutions, but can also build models to predict defects in future production and improve the yield.

As semiconductor companies gradually improve their chip development and manufacturing skills, as well as time to market, artificial intelligence could potentially contribute over USD1 billion to the annual profits of the global semiconductor companies over the next five years. Accordingly, in the next five years, artificial intelligence will become the new driving force behind the semiconductor industry. Artificial intelligence can bring great business value to the semiconductor industry, from the initial research and development to final sales. Among them, the biggest business value lies in the research and manufacturing procedures, especially manufacturing.

Application scenarios of AI in semiconductor design and manufacturing

In chip research and design, the application of artificial intelligence can help semiconductor companies optimize their portfolios, automate time-consuming tasks, and improve efficiency in chip design and manufacturing. By automating chip verification and optimizing chip design, semiconductor companies can save time in the design and development process, accelerate production generation in the manufacturing process, and reduce the cost required to maintain production. Although AI technology cannot penetrate every phase of chip design and manufacturing, some of the current applications are already showing the advantages of machine learning and AI through significant research and development cost savings.

Core value chain	**AI Application**	
Research & Design	Chip automation	Complete the whole design process automatically
	Chip verification	Ensure projections while reducing resource and time
	Chip optimization	Optimize chip design for improved PPA
Manufacturing	Automatic defect classification	Detect and classify on wafers automatically
	Predictive maintenance	Use ML and find key patterns to predict machine failure
	Fab material analysis	Speed up qualifying and interaction among materials
	Computational lithography	Optimize lithography and etch operations accurately
	Chamber/too matching	Reduce variation on product wafers
	Thermal imagery	Detect tool issue with higher frequency
	Optical metrology	Use metrology device to examine wafer structure
	Production result prediction	Use auto-key method to predict production
	Virtual metrology	Predict wafer properties without actual measurements
	emulation	Create virtual equivalents for process tuning



Design Process

The efficient fault prediction is realized through chip automatic verification.

Semiconductors are prone to failure during the process of manufacturing components. Artificial intelligence can identify the fault patterns of semiconductor components by deploying machine learning algorithms, predicting the possible faults in the semiconductor design stage, and analyzing the optimal component layout. With the support of AI analysis, the integrated circuit design is broken down into different components. Based on the existing integrated circuit design, AI compares the structure of different integrated circuit components to find the fault location of individual microchips in the layout.

Optimize integrated circuit design to meet design complexity requirements

Modern requirements for the complexity of integrated circuit design are constantly increasing, and the rules are always changing. Under the traditional method, in the design stage of semiconductors, a large number of engineers and software resources are needed to continuously debug and optimize various problems in the design process, so the design time and cost remain high. Applying AI technology before the production stage avoids a long period of maintenance time. The AI system can automatically identify the factors in the circuit design phase which will influence circuit yield rate. As a result, it can determine the production loss factors and can thus save the investment of engineering resources and costs in the design stage. Computer vision can also identify the integrated circuit design system yield reduction factors, and optimize design to improve power, performance, and area (PPA) metrics to improve throughput for the chip design team.

Manufacturing

Manufacturing is the most promising area in the AI application scenario, and manufacturing costs are also the largest area of spending for semiconductor companies. Artificial intelligent manufacturing technology is built upon the basis of modern sensor technology, network technology, automation technology, anthropomorphic technology, and other advanced technologies, through the intelligent perception, human computer interaction, machine learning, decision and implementation technology, to realize intelligent manufacturing processes and manufacturing equipment. It is a deep fusion of information technology, intelligent technology and equipment manufacturing process technology. Through collecting all kinds of production data and relying on the models of deep learning algorithms, production efficiency and quality can be greatly improved, and the cost for semiconductor manufacturers can be reduced.

Automatic defect detection of semiconductor chips

In the complex and expensive manufacturing process of semiconductor chips, the inspection and classification of chip defects is crucial. Traditional semiconductor manufacturers inspected chip defects manually which is generally expensive and inaccurate. In addition, manual inspection cannot detect some of the hidden chip defects. Through the application of artificial intelligence, by contrast, machine learning and computer vision can classify defects and effectively prevent manufacturing deviations and possible chip quality issues, while also being able to send immediate alerts. By using the microscope high-resolution images to train the automatic defect classification algorithm, as well as continuously collecting relevant data and optimizing the model through machine learning to promote the improvement of the automatic defect classification algorithm, the consistency and accuracy of the results will be improved.

Equipment forecast maintenance

In the manufacturing process of semiconductors, hundreds of extremely complex and expensive machinery and equipment are used to operate and ensure the quality and quantity of semiconductor manufacturing. If there is an unknown and an unpredictable fault in the machine operation, it will interrupt the semiconductor production line, resulting in production losses and increased maintenance costs. Therefore, for the semiconductor manufacturing process, the daily maintenance of equipment is critical. Traditionally, equipment failure prevention and routine maintenance work at predetermined intervals. Through the introduction of AI, and the use of large amounts of data from the semiconductor chip manufacturing process, such as equipment maintenance logs, sensors, and manufacturing related data, as well as the maintenance of algorithms based on the predictions of machine learning, models can be built and any issues that might arise from the machine can be predicted. These machines are equipped with many mechanical elements such as mechanical arms. The auditory sensors of the artificial intelligence system can detect worn parts and mechanical faults by listening for abnormal sounds of the equipment. For example, AI records the sound frequency of machines' daily activities and converts the sound frequency into signals through deep learning records. AI sensors will sound an alarm when the device experiences an unusual pitch or frequency. AI sensors can also predict mechanical failures and detect their causes more accurately and in a timelier manner. In this way, the overall condition of the equipment can be monitored in real time, the maintenance cost of the machine can be reduced, and the service life of the machine can be extended.

Keys to adoption of AI in semiconductor

With the increasing development demands of semiconductor manufacturers, companies need to allocate sufficient resources to carry out the research and development of AI and ML technology. The application of artificial intelligence technology in semiconductor production lines needs more time to run in. The penetration rate of artificial intelligence in semiconductor industry is also still relatively low, and the application of AI in semiconductor industry is challenging. The current application of AI in semiconductor R&D and manufacturing needs to help companies solve practical problems more extensively. There are three aspects that semiconductor companies can consider:

Enterprises need to adjust their AI strategies

With increasingly fierce competition in the semiconductor industry, demand is constantly increasing, and semiconductor companies need to develop new strategies to maintain their competitiveness. In other words, semiconductor companies need to map out specific areas of AI and create new AI roadmaps. To determine the scale and priority level of AI-related business, companies need to evaluate the amount of AI resources applied in each step of the strategy roadmap and the feasibility, value of each step. After determining the business plan based on these indicators, semiconductor companies need to adopt a new value-creation strategy and allocate different resources to AI according to different plans.

In terms of external resources, semiconductor companies should actively seek help from other industries to develop new technologies for artificial intelligence training. At the same time, semiconductor companies can accelerate their own research and development to seek cooperation with other companies. Businesses can achieve this through sharing resources, such as algorithms or data platforms, in order to form a comprehensive ecosystem that supports R&D and manufacturing. Through the sharing of costs and logistics networks, companies will also be able to reduce costs. Therefore, semiconductor companies should find potential partners to strengthen the foundation of artificial intelligence and promote collaboration.

In terms of internal resources, businesses can use the internal operating platform to promote artificial intelligence in multiple perspectives to achieve high-level innovation. Combined with the original resource base, reasonable allocation, and in-depth analysis, companies should emphasize their advantages so as to maximize resources, all the while striving to increase their own market share at the same time. Companies are therefore cognizant on the need to further develop artificial intelligence.

AI is developing rapidly despite a shortage of AI experts

Artificial intelligence is making way into semiconductor companies, from design to manufacturing. Talent within the artificial intelligence field are becoming the core of artificial intelligence development. The development of the semiconductor company affects the demand of AI talents to grow rapidly, but right now the semiconductor industry is facing a shortage of AI talent. Both the government and semiconductor enterprises need to adjust their strategies in time to deal with this shortfall in skilled AI workers.

Enterprises need to attract emerging technology experts to promote the industrialization of artificial intelligence. Semiconductor companies particularly need to continue attracting emerging talent in artificial intelligence and machine learning in order to aid their technical research and experimentation in related fields. At the same time, according to the different application purposes of artificial intelligence in semiconductors, it is necessary to clarify and refine the division of labor to ensure that the functions of each technician are best utilized. Because AI applications require coordination across various departments, semiconductor companies can therefore help technicians to utilize the core resources of the internal projects. Some training strategies include forming a cross functional and multitasking team, and also bringing in talent from other departments. This will reduce the AI team's dependence on external personnel and assist the application of different AI technologies to the development of the company, and hence linking AI with the strategic development of the semiconductor industry and driving the application of AI in all functional departments. In addition, semiconductor companies can cultivate talent by establishing research institutions and jointly establishing laboratories with leading universities. Some other effective strategies include strengthening the flow of artificial intelligence or semiconductor research collaboration between universities and enterprises, encouraging entrepreneurship and innovation, and promoting the transformation and industrialization of artificial intelligence achievements.

AI needs more technical support in the process

The semiconductor manufacturing industry is highly professional, and the complexity and customization of integrated circuits are required in semiconductor production. Therefore, each step in the production and manufacturing of semiconductors needs to establish an independent artificial intelligence system to complete its operation. As previously mentioned, AI is mainly applied in areas that are easy to duplicate and promote, such as automated verification and predictive maintenance, and therefore the development of program design in each phase of the corresponding system requires certain technical support.

At the same time, AI often needs to rely on high-quality training data, in order to improve the work efficiency and product quality in all aspects of semiconductor production. Semiconductor companies need to obtain a large amount of experimental data to support training and improve the efficiency and accuracy of AI models. However, in the process of data collection, the original data of semiconductor equipment cannot be directly used, and there will be a large amount of missing values, wrong values and unusual samples. In addition, there are multiple data sources, which may have issues such as inconsistent format, excessive redundant information and high connection overhead. At the same time, due to different data requirements by different links, there is an inconsistency in the data at each step which cannot be operated in a unified way. So far, a large amount of data generated by semiconductor production equipment cannot be directly and fully utilized by AI machine learning.

The existing data problems can be solved by developing an intelligent database. Data catalog technology is used for data discovery, management, and simplification. In testing, manufacturing and other stages, the chip will continue to produce a large amount of data. While data processing is highly time consuming, using intelligent databases during production will efficiently store production data sets, remove redundant information, and improve the training efficiency of machine learning algorithms. At the same time, intelligent databases can help enterprises to realize data searches in all kinds of intelligent manufacturing operations, including better filtering, detection and treatment of different production data, and the fusion of different data to help in the training of large-scale machine learning algorithms. By applying a data integration layer, semiconductor companies can combine data and cases from different application vendors to simplify information and provide high-quality data sources for large-scale machine learning.

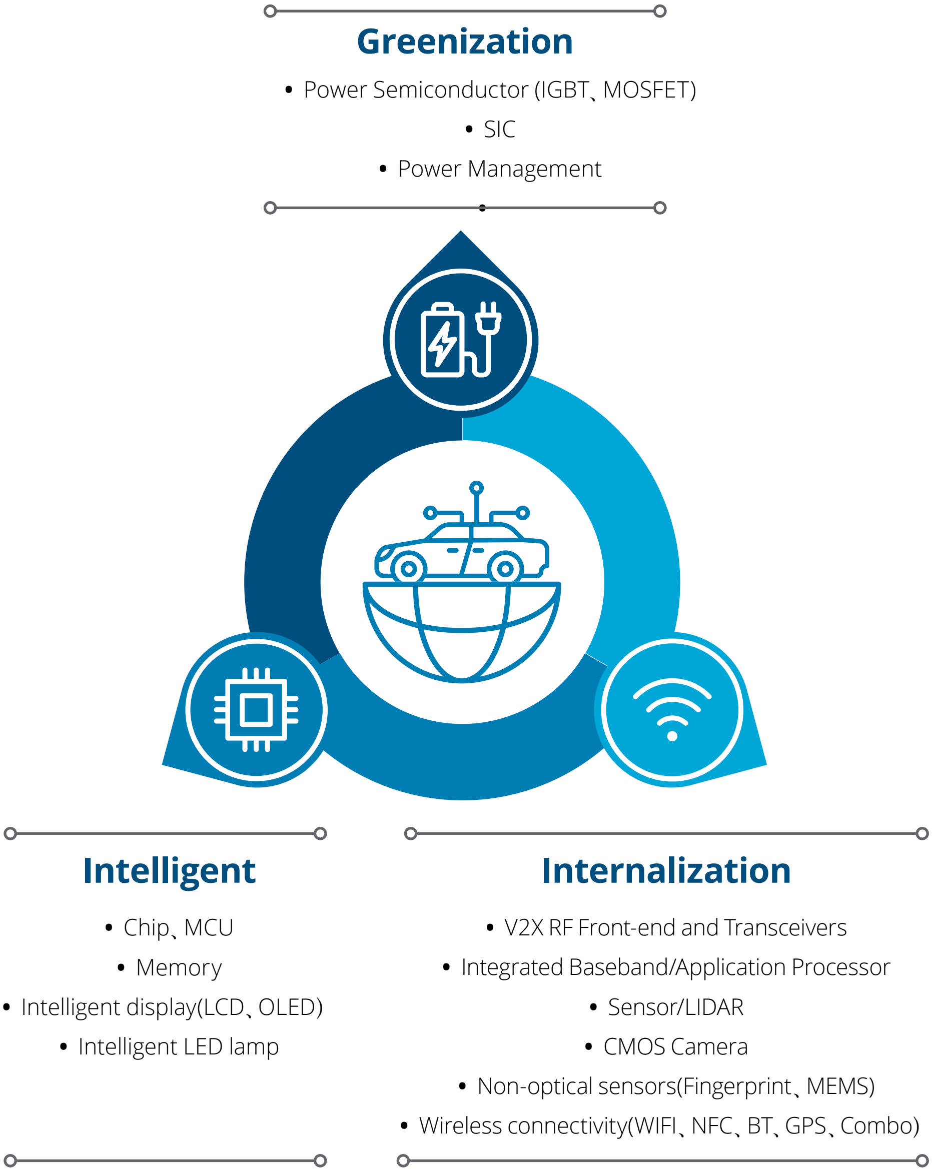
Automotive semiconductors

Within the broader movement towards a low carbon economy, the global automobile industry is constantly catalyzing new changes around decarbonization, intellectualization and the Internet-based revolution.

Greenization

Greenization refers to pure electric vehicles that in time will replace a large number of traditional fuel vehicles under the global low carbon economic movement, resulting in a significant increase in demand for power semiconductors and third-generation semiconductors, and thereby giving rise to an incremental market for automotive semiconductors. In electric vehicles, the inverter and motor replace the role of the traditional combustion engine, so the design and efficiency of inverters is very important as its quality directly affects the motor's power output performance and the cruising power of electric vehicle. At present, most electric vehicles still apply IGBT in high power inverters (DC-AC Traction Inverter) and on-board charging systems. In the future, SiC MOSFET will further improve the power density of automotive inverters and reduce the weight and cost of motor drive systems. SiC is the third generation of compound semiconductor materials, and has excellent physical properties such as energy consumption reduction, a five times smaller power system module, low material cost, shortened charging time, and a stable crystal structure even at high temperatures. SiC will become the next area of strategic emphasis for car brands in the future.

Figure: Changes in global automotive industry and related semiconductor field



Source: Deloitte Research

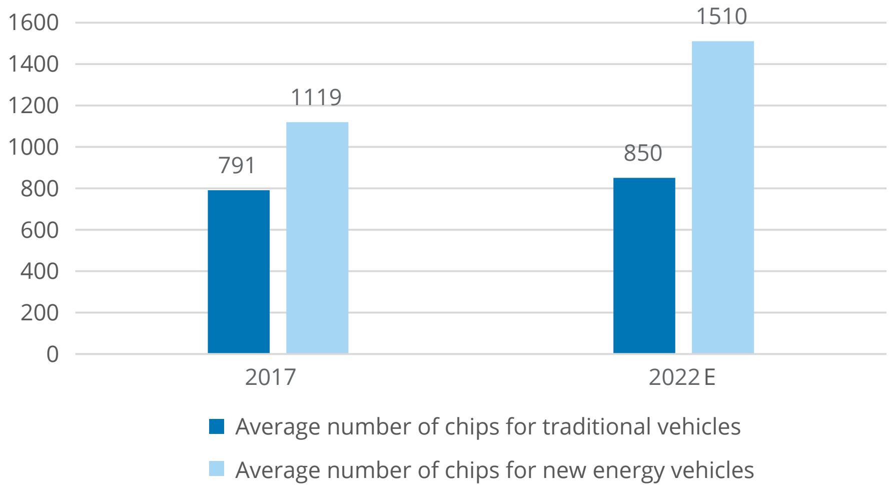
Intelligent

The higher the degree of intelligent autonomy, the greater the number of control chips and capacity of storage required. Correspondingly, demand for semiconductors will increase dramatically. As market-penetration levels in the intelligent vehicle become greater, the incremental cost of semiconductors increases with the level of autonomous driving. In terms of computing and control chips, the average number of chips for new energy vehicles will increase from 800 in 2017 to around 1,500 in 2022. The improvement in computing power will drive substantial demand for master control chip semiconductors.[1]

Increasing demand for memory chips is mainly being driven by rising demand for data storage for intelligent vehicles. At present, the significant improvement in the number and performance of storage units of in-vehicle chips is an important guarantee for driverless vehicles from L2 to higher stage L4 or L5. Different levels of autopilot require different DRAM and NAND. A standard L3 level smart car will require at least 16GB of DRAM and 256GB of NAND memory, while industry estimates for a fully autonomous L4 or L5 level car will require 74GB of DRAM and up to 1TB of NAND. According to Counterpoint Research, single vehicle storage will reach 2 TB to 11 TB over the next decade in order to meet the in-vehicle storage demand of different levels of autonomous driving. Overall, the cost of upgrading from L2 to L3 level automotive semiconductors increases by 286.7%, while the cost of upgrading from L3 to L4/L5 semiconductors increases 48.3%. [2]

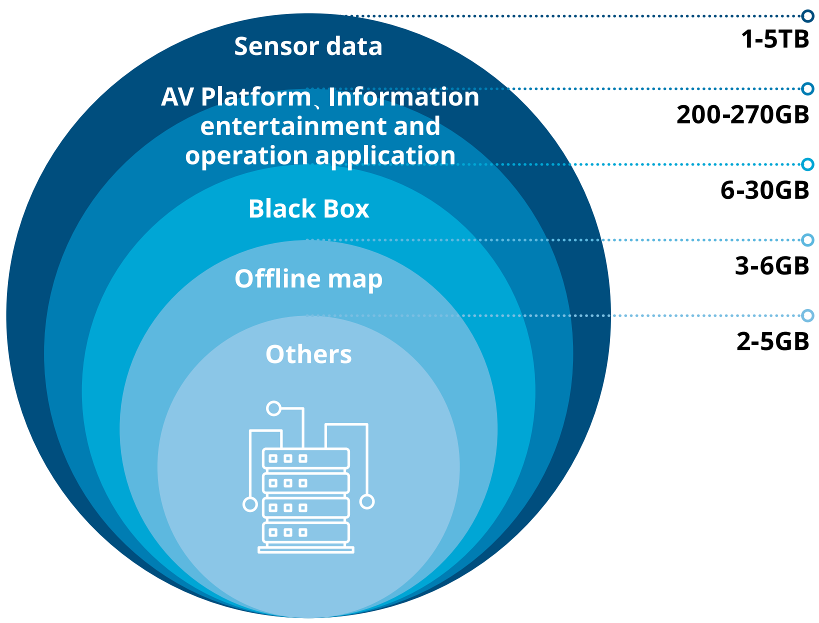
[1]中国汽车工业协会
[2]英飞凌

Figure: Global average number of chips for traditional and new energy vehicles (forecast 2017/2022)



Source: China Association of Automobile Manufacturers, Deloitte Research

Figure: Data storage requirements of L4 level driverless vehicles in 2025



Source: Counterpoint

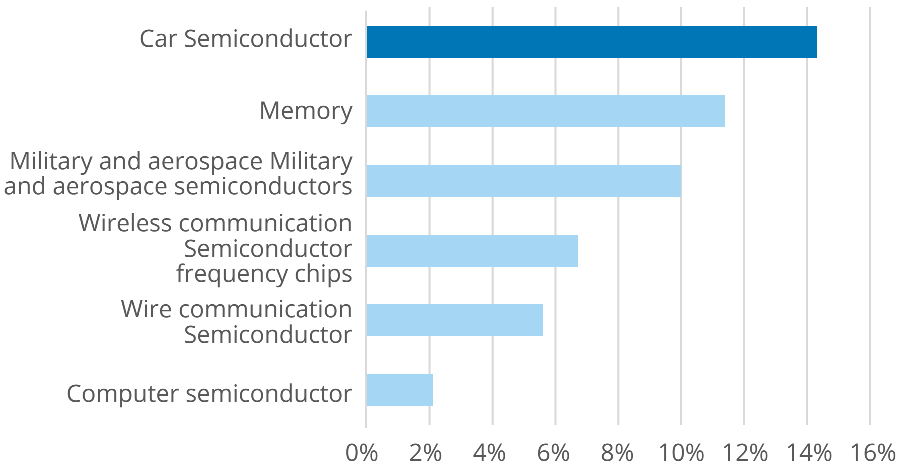
Internalization

The number of radio frequency chips, baseband chips, sensor radars, cameras and many other non-optical sensors will be greatly increased as the internet enables greater interconnection between real-time information from other carriers and vehicles.

The internet will allocate the semiconductor technology and cost in the side of the vehicle and road test, through the V2V (vehicle to vehicle communication), V2I (vehicle to infrastructure), V2N (vehicle to internet communication) and V2P (vehicle to pedestrians communication), to obtain BVR (beyond-visual range) or NLOS (non line-of-sight range) on the pedestrian's state and intentions. Therefore, in the future, all kinds of communication chips, visual chips and sensing chips will provide further room for growth in automotive semiconductors.

Benefiting from the above-mentioned automotive industry trends, automotive semiconductors will play an increasingly important role in the auto industry. Among all semiconductor subsectors globally, automotive semiconductors will grow the fastest at 14.3%, with annual revenues expected to grow from USD38.7 billion in 2020 to USD75.5 billion in 2025.

Figure: Global Growth Rate by Type of Semiconductor (CAGR) 2020-2025



Source: Gartner

Figure: Automotive Semiconductor Applications and Equipment Growth Forecast (2020-2025)

	Sector	Growth Rate (2020-2025)	Market Size $B(2025)	Sub-Sector
By Application (Gartner)	ADAS	31.90%	25	Blind spot detection/Collision warning/Park assistance/V2X/Front view camera
	EV/HEV	23.10%	10.8	Hybrid vehicle
	Body	7.00%	8.9	Power door/Power window/Climate control/Mirror wiper control
	Infotainment	9.30%	7.9	Connectivity/Telematics/Car navigation/Car audio
	Powertrain	3.00%	5	Engine Control/Transmission
	Instrument Cluster	14.60%	4.9	Instrument panel, instrument wiring harness
	Chassis	1.00%	4.7	Suspension/Differential/drive shaft
	Safety	6.30%	4.7	EPS/ABS/Airbags/Traction control/ Tire pressire monitor
	Aftermarket	6.10%	2.9	Vehicle parts/Equipment/Service repair/ Collision repair
By Device (Gartner)	Memory	8.90%	190	DRAM, Flash, NAND, Emerging Menory
	Micro components	1.10%	86	Digital Signal Processor, MCU
	Optoelectronics	8.60%	56	CMOS, CCD, LED, Photo Sensor, Laser Diode, Coupler
	Multimedia Processor	6.10%	39	Discrete Application/Multimedia Processor
	Other Application Specific	5.70%	35	Other
	Discrete	8.20%	33	Transistors, Diodes
	Wired Connectivity	7.40%	33	Interface and function control
	Analog	5.60%	32	Data Converter/Switch/Multiplexer Voltage Regulator/Reference
	Integrated Baseband	14.10%	30	Integrated Baseband
	RF Transceivers	11.70%	23	RF Front-end and Transceivers
	Wireless Connectivity	6.00%	17.8	NFC, WIFI, BT, GPS
	Non optical sensor	9.30%	15	Fingerprint, Inertial, Magnetic, Environmental Sensors
	GPU	8.20%	15	GPU
	Power Management	3.80%	14	Power Management
	General-Purpose Logic	18.00%	7	FPGA, PLD, Display Driver
	Discrete Cellular Baseband	-4.60%	5	Discrete Cellular Baseband

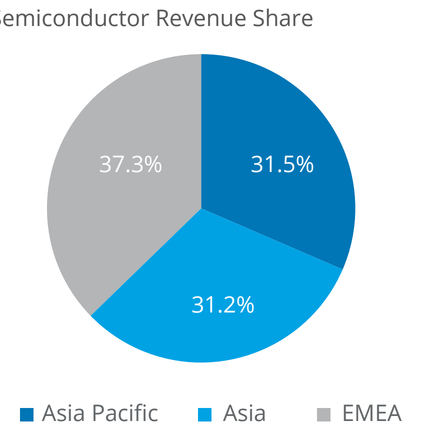
Source: Gartner

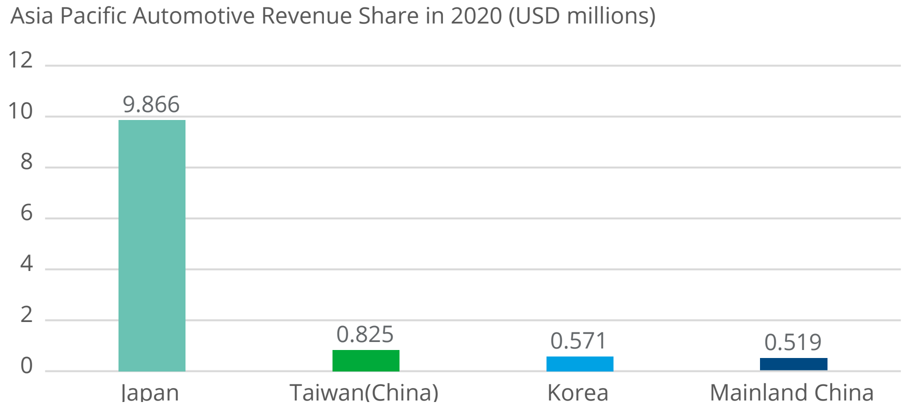
The Asia Pacific automotive semiconductor market accounts for one third of the world's total, and Japan is the clear leader in the market.

In 2020, the revenue of automotive semiconductor companies in the Asia Pacific region will be USD12.19 billion, accounting for 31.5% of the global automotive semiconductor market. The Americas accounted for 31.2%, and Europe, the Middle East and Africa together accounted for 37.3% of the global market.

In 2020, Japan led the rest of the Asia Pacific region in the automotive semiconductor sector with revenues of USD9.86 billion. Taiwan ranked second in the region with USD820 million revenues, while South Korea was third with USD570 million revenues and China fourth with USD510 million revenues.

Figure: Asia Pacific Automotive Semiconductor Revenue Share and Asia Pacific Automotive Revenue Share in 2020 (USD millions)





Source: Gartner

Japan enjoys well-rounded advantages in the automotive semiconductor industrial chain and in its self-sufficiency. From power semiconductors, microprocessors, to sensors and LEDs, Japan firmly occupies a leading position in all areas. By virtue of MediaTec, Taiwan Automotive Semiconductor occupies the highest market share in the Asia Pacific region in the field of integrated baseband and wireless communication, and it ranks second only to Japan in the field of wire communications. In South Korea, Samsung holds the number one market share in the field of memory. Although China currently has a low overall market share in automotive semiconductors, it is catching up in memory and CMOS. In addition, the China-led C-V2X Internet of Vehicles (IoV) standard has been recognized by the international industry association 5GAA. In the future, with the world's leading 5G technology, there will be great development in the field of Internet of Vehicles.

Table: Asia Pacific four automotive semiconductor strategic advantages

Country	Strategic Advantages	Representing Company	V2X Policy
Japan	• Power Semiconductor • CMOS • Microcontroller • LED • Analog • ASIC、RF Front-end and Transceivers、Non optical Sensors • Power Management • Photo Sensor • Flash Memory • Coupler	• DENSO、Rohm、Hitachi • SONY • Renesas、DENSO • Nichia • Sanken、Nisshinbo • DENSO • Rohm • Hamamatsu • KIOXIA • Toshiba • MediaTek	• Japan's "road transportation and vehicle law"paves the way for the commercial use of autonomous driving.
Taiwan (China)	• Integrated Baseband、Wireless Connectivity • Wired Connectivity • Display Driver	• MediaTek • Realtek、Silicon Motion • Himax	• The smart road side standard is drafted and V2I construction will be arranged in the demonstration area to test the feasibility and application of autonomous driving.
Korea	• Memory、Display Driver	• Samsung、SK Hynix	• The Korean government first focused on car side intelligence , and then began to promote road side autonomous driving infrastructure. • The test site Kcity achieved full 5G network coverage and plans to establish the world's first 5G network-based autonomous driving test site in Seoul.
Mainland China	• 5G technology is leading in the world and strong in communication chip • Catching up in memory • CMOS	• Hisilicon、Unisoc • Ingenic 、Nanya • Will Semicondcutor	• Promote C-V2X to become the international standard of autonomous driving. • The goal is to gradually carry out the application of 5G-V2X in some cities and highways by 2025, and to achieve full coverage of the high-precision service network.

Source: Deloitte

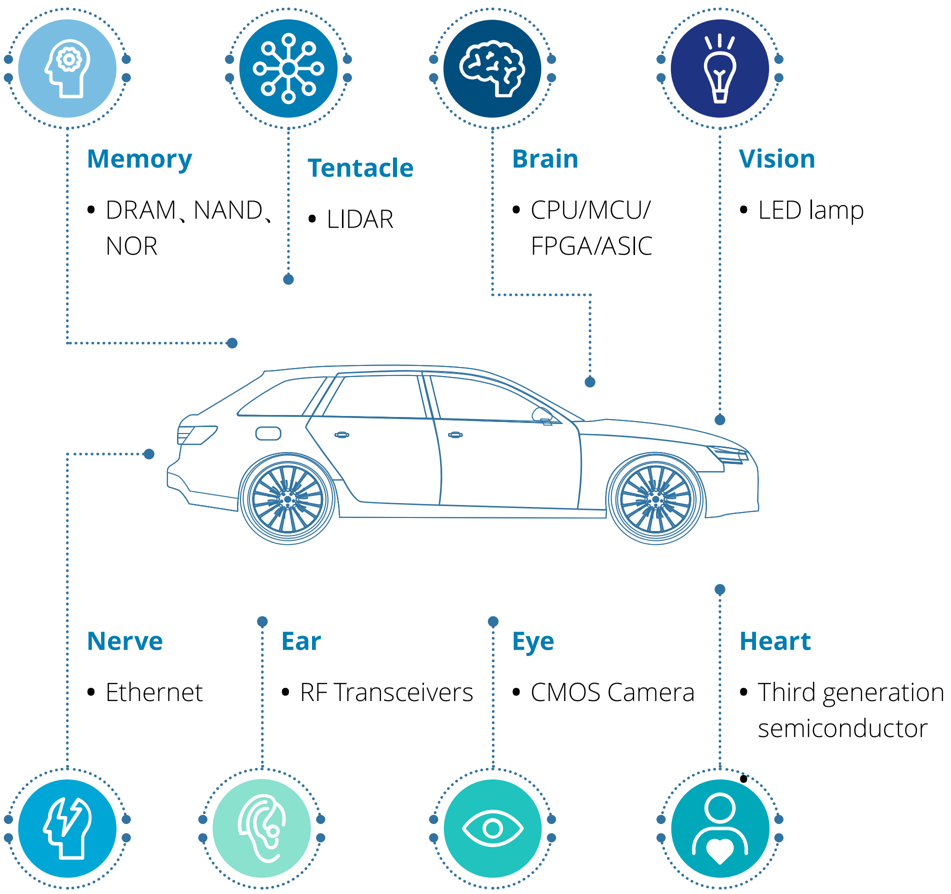
Fully Intelligent Vehicles

At the perception level, intelligent vehicles could utilize multiple integrated sensors on the vehicle that allow for data collection from the surrounding environment through the radar system (Lidar, millimeter-wave radar and ultrasonic radar) and the vision system (camera).

At the decision-making level, data is processed through in-vehicle computing platforms and appropriate algorithms to make an optimal decision, and then the execution module converts the signal of this decision into the behavior of the vehicle.

At the control execution level, this mainly includes vehicle motion control and human-computer interaction to determine the control signals of each actuator, such as motor, accelerator and brakes for example.

Picture: The car is fully intelligent



Source: Deloitte Research

- **The chip is the "brain" of an intelligent vehicle.** GPU, FPGA and ASIC have their own advantages around AI computing in the field of autonomous driving. The CPU, usually the control center on the chip, possesses strong scheduling, management and coordination capabilities, but the CPU's computing capacity is relatively limited however. For AI computing, people usually use GPU/FPGA/ASIC to enhance.
- **Power semiconductors are the "heart" of intelligent vehicles.** Power semiconductors are inseparable to such vehicles, no matter whether they are applied in the engine, driving system, gearbox control, braking or steering control.
- **Camera CMOS is the "eyes" of intelligent vehicle.** CMOS image sensors share a common history with CCDs (Charge Coupled Device), but CMOS is 15%-25% cheaper than CCDs, and CMOS chips can be integrated with other silicon-based components to help reduce the cost of the system. 18 cameras are required for aiding driving above L3 autonomy, such as rear-view, round-looking, forward-looking, and blind spots.

Figure: Comparison of options for autonomous driving chips

	CPU	GPU	FPGA	ASIC
Definition	Central processing unit	Graphics processing unit	Field programmable gate array	Application-specific integrated circuit)
Hash rate and Energy Efficiency Ratio	• Lowest harsh rate • Poor Energy efficiency	• High hash rate • Medium energy efficiency	• Medium harsh rate • Good energy efficiency	• High harsh rate • Good energy efficiency
Functions	Most generally utilized (Control and command + calculations)	Strong general data handling capacity	Semi-strong general data handling capacity, specialized	Strongest AI hashrate, most specialized
Benefits		• Large-scale • Multi task simple operation	• Flexible • Programmable • Parallel operation	• Dedicated, highly customized; • PPA optimized (PPA is short for Performance, Power consumption and Area)
Cost	Highest unit price cost	Higher unit price cost	Lower trail and error cost	• High cost but reproducible; • Effectively lower cost after large-scale mass production
Speed of coming to market	• Fast • Product maturity	• Fast • Product maturity	• Fast	• Slow • long development period
Application	widely used in various fields	widely used in various fields of graphics processing, numerical simulation and machine learning algorithms	applicable to scenarios with low cost requirements, such as military, laboratory, scientific research, etc	mainly meets the high computing power demand fields such as consumer electronics with single scenario

Source: China International Capital Corp

- **Radio frequency receivers are the "ears" of intelligent vehicle.** Radio frequency (RF) devices are an important part of wireless communications. Radio frequency is an electromagnetic frequency that can radiate into space, with a frequency range between 300 kHz and 300GHz. RF chips refer to the chip that can convert RF signals and digital signals, and are composed of a power amplifier PA, filter, low noise amplifier LNA, antenna switch, duplex, and tuner. In the future, the RF chip will be like the ears of the car to help the development of C-V2X technology, linking "people-vehicle-road-cloud" and other traffic participation elements organically together, making up for the lack of single-vehicle intelligence, and promoting the development of collaborative application services.

- **Ultrasonic/millimeter-wave radar is the "walking stick" of intelligent vehicles.** Smart cars get a lot of data from sensors, and L5 cars will carry up to 32 sensors. Vehicle-mounted radar mainly includes ultrasonic radar, millimeter-wave radar and laser radar. Among them, China's ultrasonic radar has become more sophisticated and technical barriers are not high. Millimeter wave radar however does have high technical barriers and is an important sensor for intelligent vehicles, while also being in a stage of rapid development. Lidar has high technical barriers and is an important sensor for high-level automatic driving, but it is currently costly and difficult to gain regulatory approval and implement.

- **Memory chips are the "memory" of intelligent vehicle.** The demand for memory in the intelligent vehicle industry is increasing day by day. In the post-mobile computing era, vehicle memory chips will become an important emerging growth point and a decisive force in the market pattern. DRAM, FLASH and NAND will be widely used in various fields of intelligent vehicles in the future. In addition, the amount of local storage will stabilize or even decline in the future as cloud and edge computing will flourish in smart vehicles, and L4/L5 autonomous vehicles will develop complex networked data and apply advanced data compression technologies.

- Car panels are increasingly becoming multi-screen. At present, on-board display equipment mainly includes central control displays and instrument displays. In addition, intelligent cockpit instrument displays, windshield composite heads-up displays, virtual electronic rearview mirror displays, and rear seat entertainment displays are gradually becoming the new direction of demand for intelligent vehicle development.

LEDs are the main "lights" for intelligent vehicles. In terms of illumination brightness and irradiation distance, LEDs have achieved a new level that halogen lamps could not reach in the past. It can achieve functions such as bend assistance (compliance steering), speed adjustment and vehicle distance warning. With the development of LED volume and technology, its intelligence began to be vigorously developed toward the bright, intelligent and surprising direction.

Connectivity is a Must for Autonomous Driving

Connectivity refers to organically connecting the traffic participation elements with the "human-vehicle-road-cloud" through the Internet of Vehicles on the basis of the existing intelligent driving of a single vehicle. This also involves expanding and facilitating the upgrading of the ability of intelligent autonomous driving of a single vehicle in environmental perception, computing decision making, controlling execution and other aspects, and accelerating the maturity of the application of autonomous driving.

Technology and cost are allocated on the "vehicle-side" and "road-side". The optimal model of L4 and L5 autonomous driving is to achieve collaboration at a "vehicle–road–cloud" level. Intelligent cars collaborate in a smart way with a high amount of synergy between vehicle intelligence and road intelligence. However, the development of the intelligent road and intelligent car is not entirely a synchronous relationship. Self-driving route choice face ability allocation problem of its perception, decision-making abilities and different abilities in the development of intelligent vehicles and intelligent roads, and the corresponding cost of autonomous driving is also different. Due to the high cost of a single intelligent vehicle, if road-side equipment is used to replace part of the technology on the vehicle-side and make the road "smarter", a lot of in-vehicle costs can be reduced. In this way, the two directions of autonomous driving are detached between single intelligence vehicles and vehicle-road cooperation.

In the case of in-vehicle sensors, Lidar is expensive, especially the L4/L5 autonomous radar, which is used for long-range and wide-range detection. But if companies install cameras on the road, millimeter wave radar and laser radar and other sensors such as upgrade the light poles, install various kinds of sensors to detect the 3-D coordinates of the surroundings. The light poles can efficiently fuse information, and due to their high

Figure: semiconductor technology and cost distribution in vehicle side and road test

	Vehicle Side	Road Side
Perception and Decision	• Vehicle side sensor • On Vehicle computing platform	• Road side sensor • Edge computing
Cost per Vehicle	• High	• Low
Marginal cost	• High	• Low

Source: Deloitte

installation height, wide coverage and better visibility conditions, they can dramatically reduce blind spots and improve the accuracy of data acquisition, while also being able to send real-time information to the center of ITS (intelligent transportation system) and the end of the car. This helps to save in-vehicle laser radar costs, thus greatly reducing the cost of the overall car.

The distribution and development of vehicle-side intelligence and road-side intelligence are affected by many factors such as the government's support for the reconstruction of intelligent highways, road conditions in different regions, the characteristics of traffic participants, accuracy of maps and positioning, price changes of in-vehicle semiconductors, consumers' willingness to pay, and changing costs. These common factors determine the adoption of different distribution schemes and evolution routes in different countries and regions.

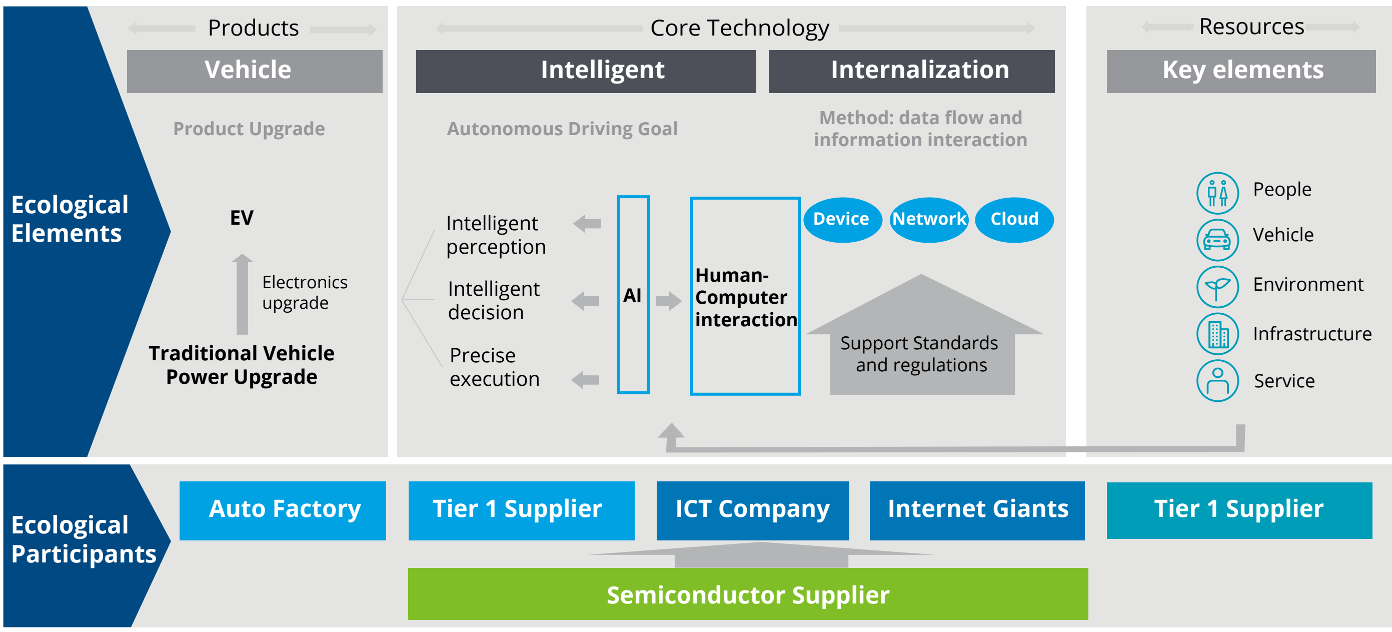
Ecological Cooperation of Intelligent Vehicles Creates Win-Win Situations

The ecosystem of the intelligent connected automobile industry is relatively complex. It is an ecosystem jointly built by multiple parties, including OEMs, Internet companies, ICT enterprises, Tier1 suppliers and the government. In the ecological panorama of the intelligent and connected automobile industry, the vehicle is the carrier, the realization of intelligence is the ultimate goal, and the internet is the core means.

Among the ecological participants, OEMs, as the final integrators, need to centralize the roles of hardware and software, functions and ecological service providers to complete the transition from vehicle manufacturing to long-term mobility services.

The traditional Tier 1 suppliers are partnering with OEMs and IT companies in areas such as artificial intelligence and software to promote IoV development and strengthen their research and development capabilities. ICT enterprises have advanced intelligent network technology, which promotes the intelligence and network of vehicles, transforms human-vehicle interaction into a human-vehicle relationship, and enables vehicles to connect everything online in real time. Internet enterprises need to continuously explore the application scenarios of "people-car-road-cloud-life", improve the initiative and precision of services based on data analysis, and build an internet service ecology. The government is responsible for building a platform, creating an environment conducive to development in terms of supportive legislation, policies and standards, and vigorously promoting the application of new technologies.

Pictured: Ecological panorama of intelligent and connected automobile industry



Source: Deloitte

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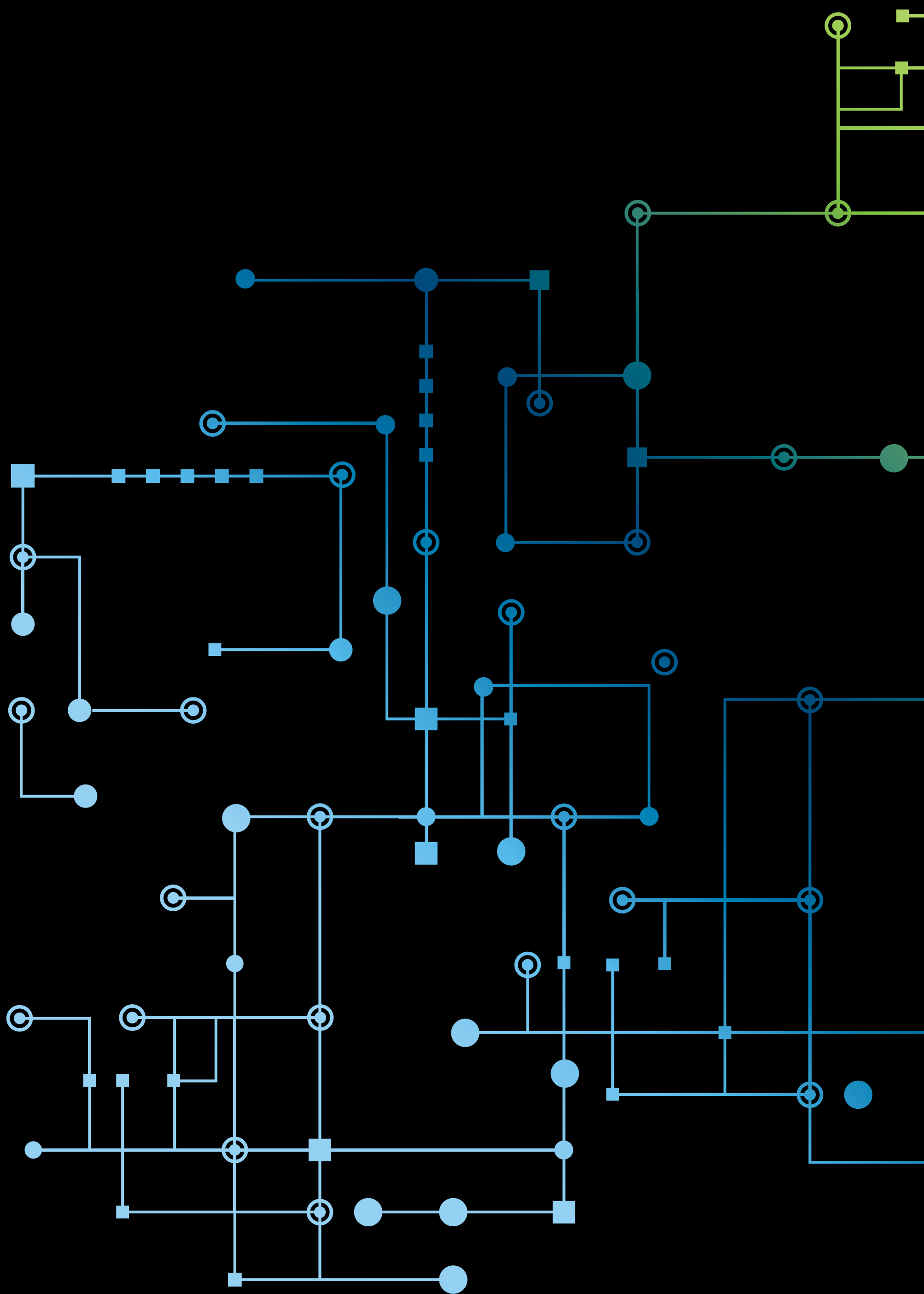

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