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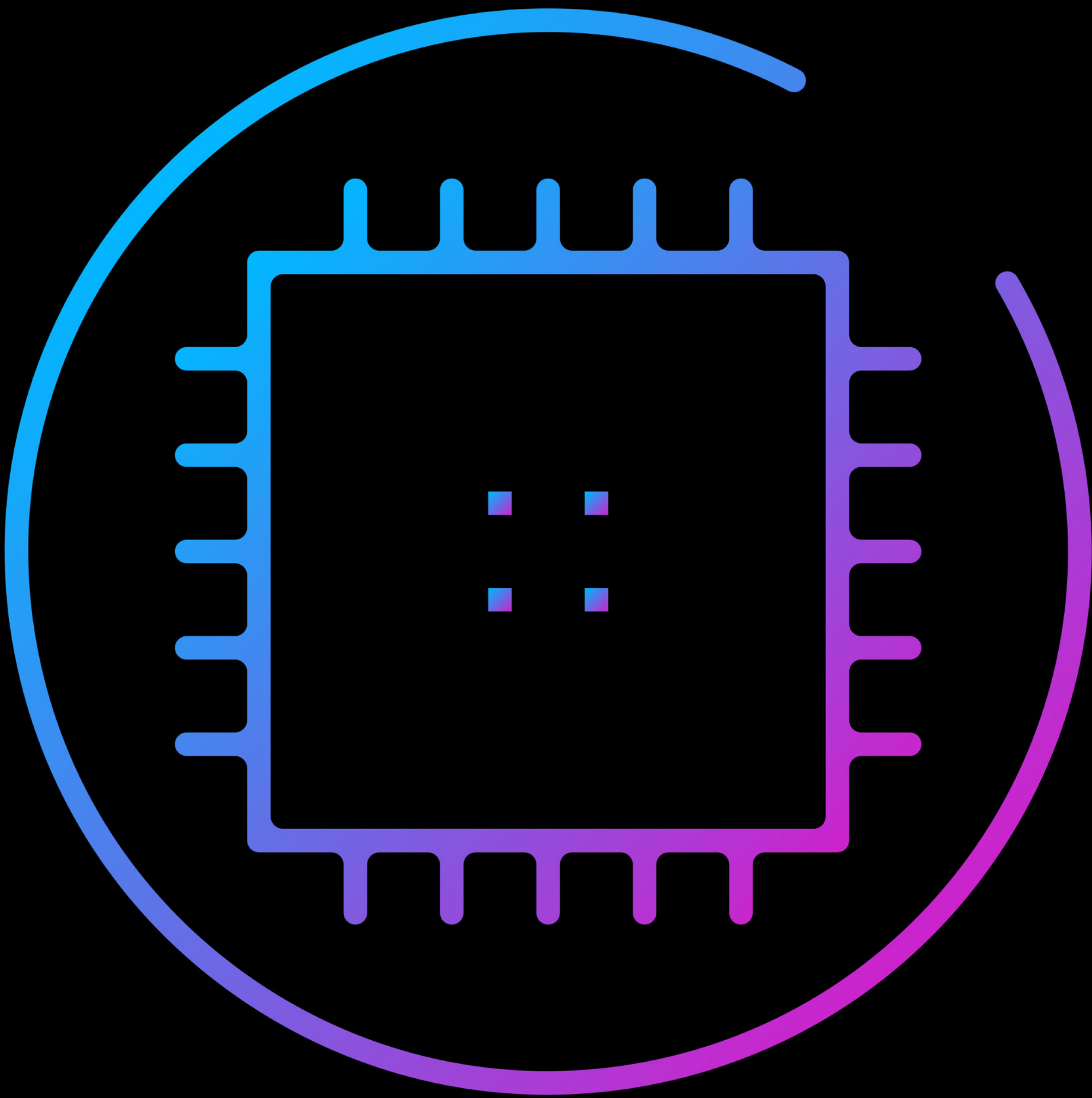


Semiconductors – the Next Wave

Opportunities and winning strategies for semiconductor companies

April 2019

Foreword

Semiconductors are essential technology enablers that power many of the cutting-edge digital devices we use today. The global semiconductor industry is set to continue its robust growth well into the next decade due to emerging technologies such as autonomous driving, artificial intelligence (AI), 5G and Internet of Things, coupled with consistent spending on R&D and competition among key players.

East Asia (Mainland China, Japan, South Korea and Taiwan) is where some of the world's most important semiconductor players are located. The region has become a hotspot for the semiconductor industry due to its burgeoning economy, the rise of mobile communications and growth in cloud computing. China, in particular, commands almost half of overall market value, split roughly 50-50 between domestic demand and Taiwan-based, world-leading ODMs (e.g. Foxconn and Quanta) or foundries (e.g. Taiwan Semiconductor Manufacturing Company [TSMC]) serving global clients. China also aspires to a self-sufficient semiconductor industry and ascension to become a global powerhouse at the same time. Japan, on the other hand, is an important supplier of semiconductor materials, high-end equipment and special semiconductors. Meanwhile, South Korea has a commanding lead in the global HBM (high bandwidth memory) DRAM (dynamic random-access memory) market.

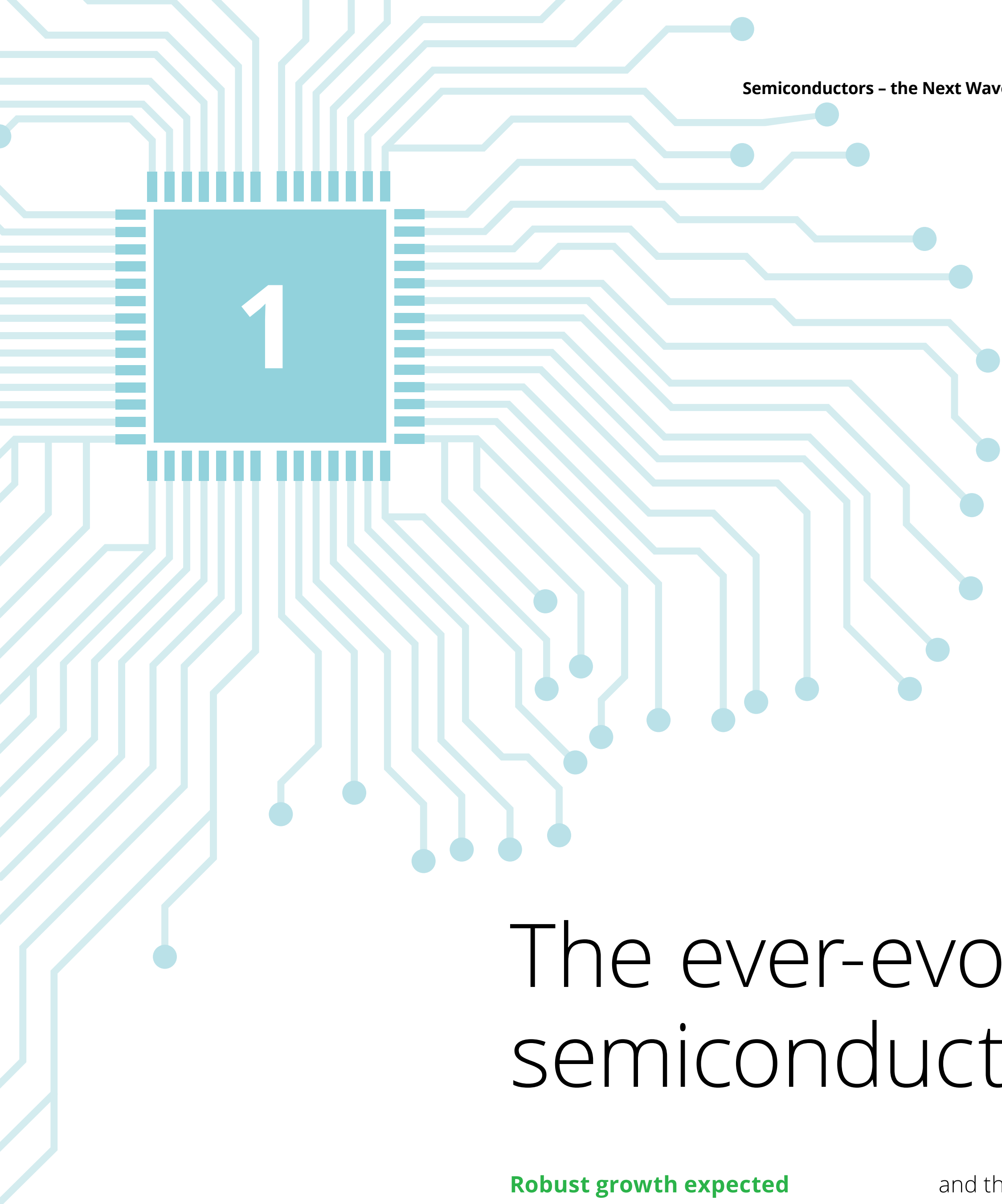
M&A activity in the semiconductor industry has already peaked and specialized verticals are becoming the primary focus. Japan and Korea are seeking to revive their industries through acquisitions, while the continuing trade war and disputes over intellectual property will hamper China's ambition to go on a global spending spree.

The semiconductor sector's growth trajectory will flatten somewhat as demand for consumer electronics saturates. However, many emerging segments will provide semiconductor companies with abundant opportunities, particularly semiconductor use in the automotive sector and AI.

In the automotive sector, the adoption of safety-related electronics systems has grown explosively. Semiconductor components that make up these electronic systems will cost USD600 per car by 2022. Automotive semiconductor vendors will benefit from a surge in demand for various semiconductor devices in cars, including microcontrollers (MCUs), sensors and memory. Automation, electrification, digital connectivity and security will result in the addition of more semiconductor content to automotive electronics and subsystems in the next decade.

The AI semiconductor scene has seen a race not just at the application level, but also at the semiconductor chip level, where different architectures are vying for a piece of the pie. The cloud is the biggest market for AI chips, as their adoption in data centers continues to increase as a means of enhancing efficiency and reducing operational cost.

Finally, China has become a source of income for top global semiconductor companies, many of which generate over half of their revenue from China. Multinationals trying to access the Chinese market should consider a multitude of factors such as policies, technologies, marketing, logistics and global strategies. It is imperative for a multinational to realize the position it is in before entering China to come up with the best entry strategy.

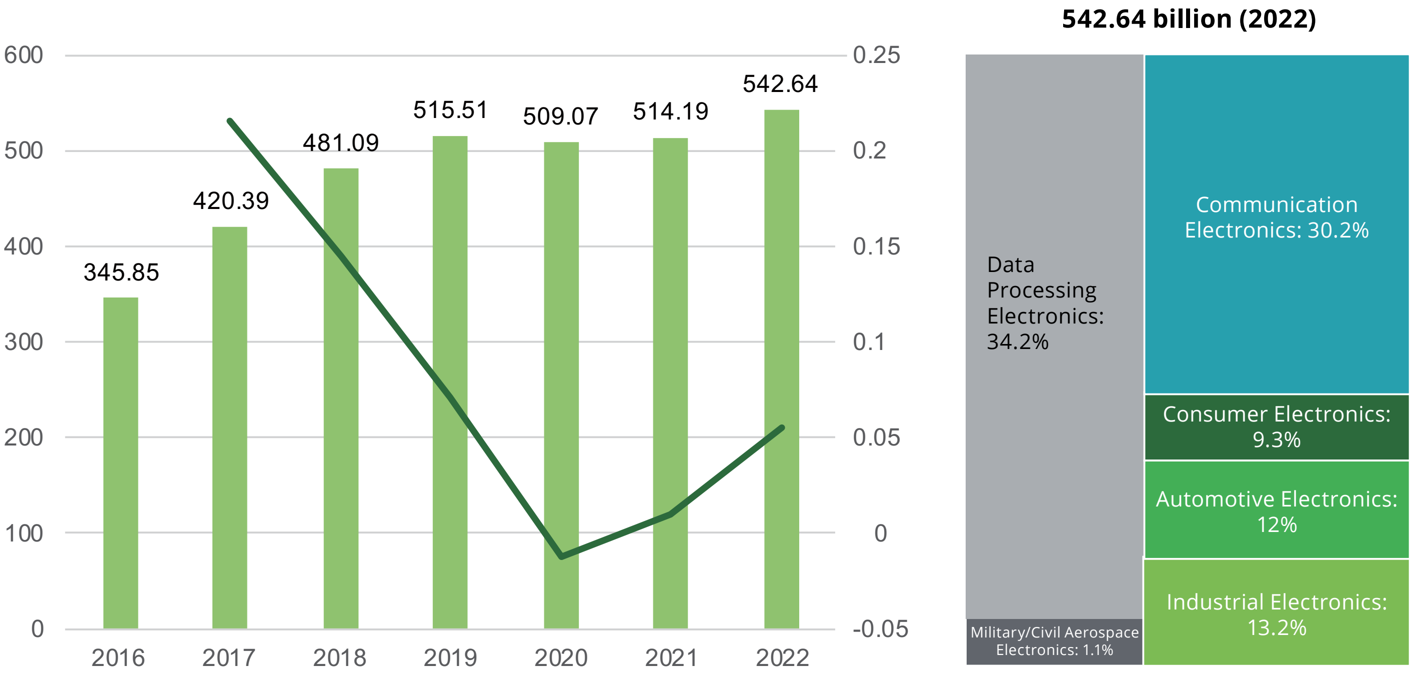


The ever-evolving semiconductor scene

Robust growth expected

In the past few years, growth of the global semiconductor industry has been driven largely by demand from electronics such as smartphones and the proliferation of applications including the Internet of Things and cloud computing. The global semiconductor sector's total revenue is set to increase from USD481 billion in 2018 to USD515 billion in 2019 and continue its robust growth well into the coming decade. Continued enhancements of existing products and the inclusion of emerging technology such as AI in products and 5G networks, as well as rapid growth in automotive and industrial electronics, will be some of the market's key driving forces. The bulk of semiconductor revenue will come from processing electronics (e.g. storage and cloud computing) and communication electronics (e.g. wireless).

Figure: Global semiconductor sales revenue (2016-2022, billion USD)

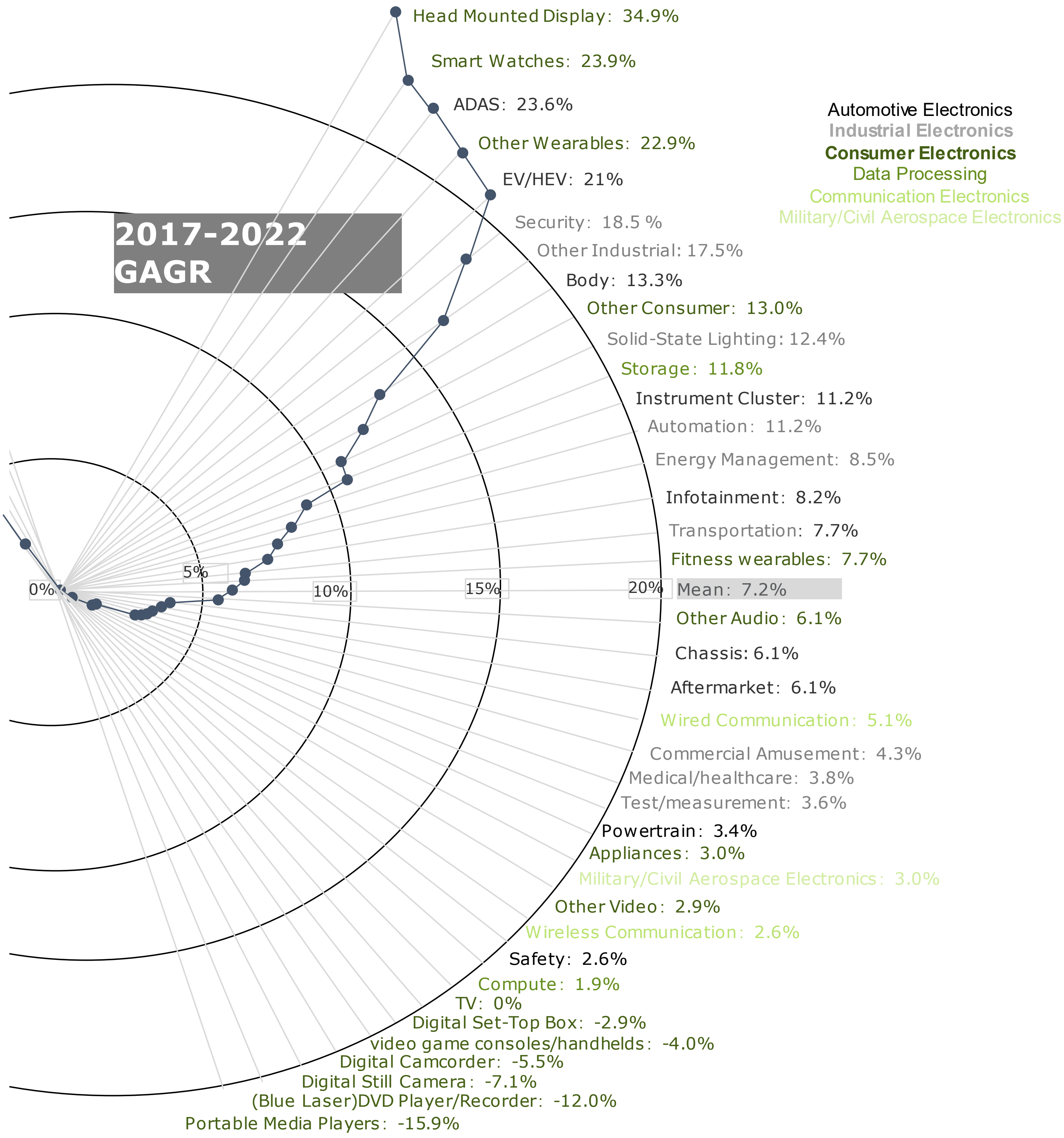


Source: Gartner, Deloitte analysis

Automotive and industrial the run-away segments

Automotive electronics and industrial electronics are expected to be the fastest growing markets in the semiconductor industry, with revenue from consumer electronics, data processing and communication electronics set to grow steadily.

Figure: Semiconductor revenue growth by electronic equipment type (2017- 2022)



Source: Gartner, Deloitte analysis

Consumption of automotive electronic components for safety, infotainment, navigation and fuel efficiency will increase for years to come due to ever-more electronic components being applied in advanced safety features added to vehicles. Among applications driving semiconductor growth, advanced driver-assistance systems (ADAS) will have the largest increase. They will drive demand for ICs (Integrated Circuits), MCUs and sensors.

Industrial electronics encompass security, automation, solid-state lighting, transportation and energy management. Security is the most substantial driver of industrial electronics. New memory technologies enhance the energy savings, security and functionality of IoT devices.

Head mounted displays will be the main driver of semiconductor growth in consumer electronics. In addition, wearables and smart watches will be new point of growth. However, other consumer electronics markets, such as DVD and portable media players, will see sharp declines. Hence, the overall revenue increase of consumer electronics will be somewhat limited.

Data processing electronics include computing and storage. Storage, especially SSDs (solid-state drives), will account for the largest increase. As the price declines seen in 2018 continue, the trend towards greater SSD adoption and increased average capacity will retain strong momentum; particularly in enterprise SSDs as data center demand will remain a key driver.

Communication electronics include wired and wireless electronics. In wireless electronics, traditional phone and cellular modems will experience large declines, while smart phone demand will increase only slightly. Revenue growth from the wireless market could be quite slow. In wired communication electronics, enterprise WANs (wide area networks) deployed as appliances should be the fastest-growing segment.

APAC appetite remains strong

The Asia Pacific region will remain the world's biggest market for semiconductor consumption. An increasing proportion of Chinese products, which is stimulating the growth of the whole Asia Pacific market, will be the major contributing factor. In addition, more M&A will benefit semiconductor sector growth going forward.

Figure: Semiconductor sales by region (2018)

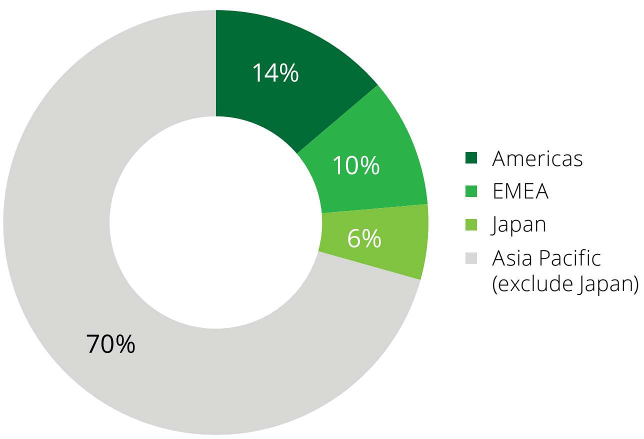
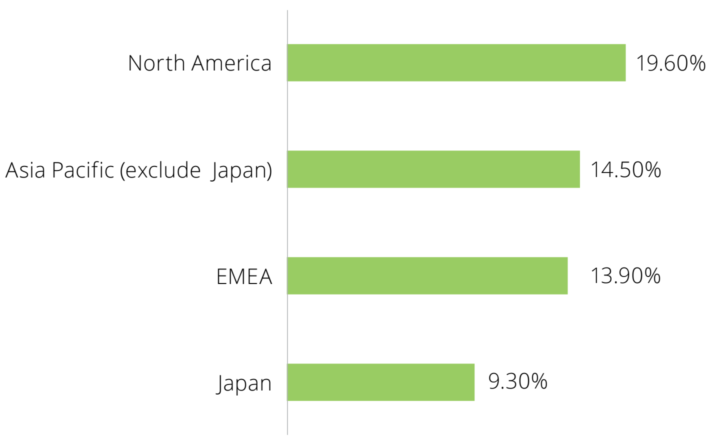


Figure: Semiconductor sales growth (2018)



Source: Gartner

In terms of growth, the US had the fastest growth rate in 2018 due to the rise of DRAM and high demand for MCUs, especially in the storage market. The Asia Pacific region has benefited from a boom in the memory market as the rising price of memory generated great revenue. The integrated circuit (IC) industry in Mainland China grew 24.8%, making a major contribution to Asia-Pacific. Korean semiconductor industry growth depends mainly on IC suppliers, particularly in the memory chip market. On the other hand, the semiconductor industry in Taiwan is based on the foundry model. However, price fluctuations have harmed many foundries. This has prompted vendors in Taiwan to transfer some foundries into Mainland China and re-prioritize to focus on IC design in order to buck the price decline. As for Japan, as semiconductor companies have split and reorganized, they have exited the DRAM business, which has low technical value, and shifted focus to exploit high value-added system chips.

Figure: Semiconductor sales in East Asia

Source: Gartner

China playing catchup

In East Asia, Japan has held a leading position in the semiconductor R&D and materials industry, with semiconductor giants including Toshiba, Sony and Renesas. South Korea and Taiwan are strong in memory and foundry, respectively. South Korea leads in DRAM and NAND and has many top semiconductor companies such as Samsung and SK Hynix, mainly thanks to government support. In terms of NAND, it is increasingly difficult for new players to participate in the competition due to the required accumulation of the technical know-how. However, South Korea also has challenges. The price of DRAM is falling and exports are declining. Hence, South Korean semiconductor vendors are devoting themselves to equipment and materials research as they seek to expand into other sectors to tilt away from a heavy emphasis on memory.

Taiwan has become the world's leading location for semiconductor foundry manufacturing. Taiwan's semiconductor foundry industry is dominated by two contract manufacturers, TSMC and United Microelectronics Company (UMC). Semiconductor foundry is a mainstay of the IT industry. By increasing added value, Taiwan should solve the downside in the IC design industry caused by a lack of capital and talent investment. China is taking up Taiwan's semiconductor market share. Moreover, the expanding Chinese Mainland market will be a business channel for the IC design industry and its companies will continue to invest in the semiconductor industry in Taiwan. Firstly, Mainland China can provide market support. The semiconductor industry in Taiwan needs to be close to the consumer market to support product innovation and economic of scale. Secondly, talent can be provided to allow Taiwan to focus on higher value-added product R&D.

The Chinese semiconductor industry is on an upward trajectory, with double-digit growth. Even though the competitiveness of Chinese semiconductor vendors has improved greatly in recent years, the industry still relies heavily on key components from the West, resulting in a self-sufficiency rate of less than 20%. The Chinese government has paid close attention to this issue, promulgating numerous favorable policies to strengthen the semiconductor industry.

Figure: Major players in the Chinese semiconductor industry

National Team
Headed by the likes of Big Fund and Tsinghua Unigroup, has invested hundreds of billions of dollars into the semiconductor ecosystem.

Local Team
Under the guidance of Large Fund, many local governments have also set up local versions of IC investment fund.

Returnees Team
Many returnees have participated in the development of semiconductor industry in China, often backed by PE/VC.

MNC
Intel, TSMC and other MNCs have been in China for a long time. Many joint venture has been setup across China.

Broadly speaking, there are four categories of players in the Chinese semiconductor industry—the "National Team", "Local Team", PEVC funds and MNCs—each of them vying to make China a world-leading semiconductor powerhouse. The National Team is spearheaded by Large Fund and Tsinghua Unigroup, which have invested hundreds of billions of dollars in the value chain. The "Local team", on the other hand, acts under the guidance of Large Fund, with many local governments having set up investment funds such as the Beijing IC Industry Fund and Shanghai SummitView Capital Fund. These local semiconductor funds are estimated to have exceeded RMB200 billion. In the PEVC system, many overseas returnees have participated in the development of the semiconductor industry in China, including UNISOC and Veri Silicon, Giga Device and Montage etc. These enterprises are normally founded by returnees, focus on IC design and in most cases are backed by PEVC. Among MNCs, Intel, TSMC and many other foreign-invested companies have been in China for a long time. In recent years, a growing amount of foreign capital has paid attention to China opportunities. Global Foundries has a factory in Chengdu. ARM and Qualcomm have established joint ventures in China. In particular, after Taiwan loosened restrictions on high-tech investment in the mainland, TSMC set up factories in Nanjing and Unicom entered Fujian via Jinhua.

Looming uncertainties from the Sino-US trade war

2019 is destined to be a bumpy one for the tech sectors of China and the US. Tit-for-tat tariffs will likely continue and could even escalate, if no agreement from both side can be reached in areas such as intellectual property, technology transfer and cyber-attacks. The hardest hit sector in the trade war will be semiconductors, where the US imports USD2.5 billion worth of goods a year.

Figure: China imports: IC chips vs Crude Oil

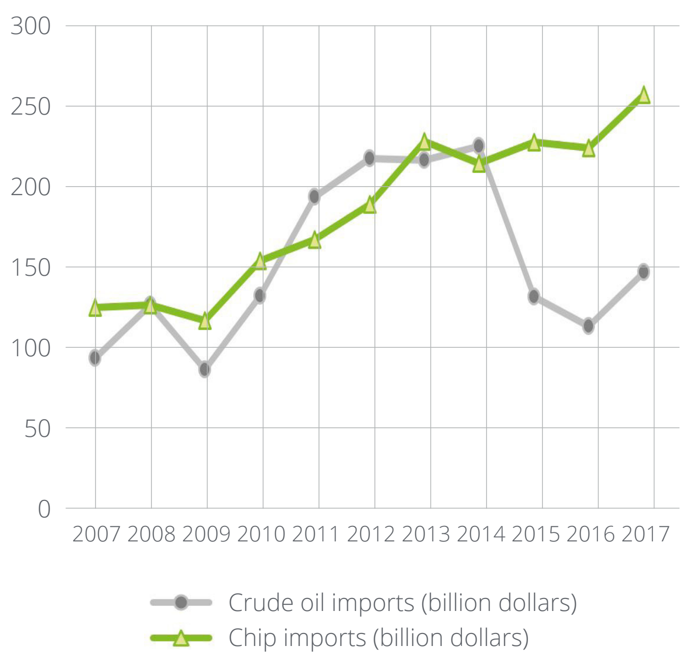
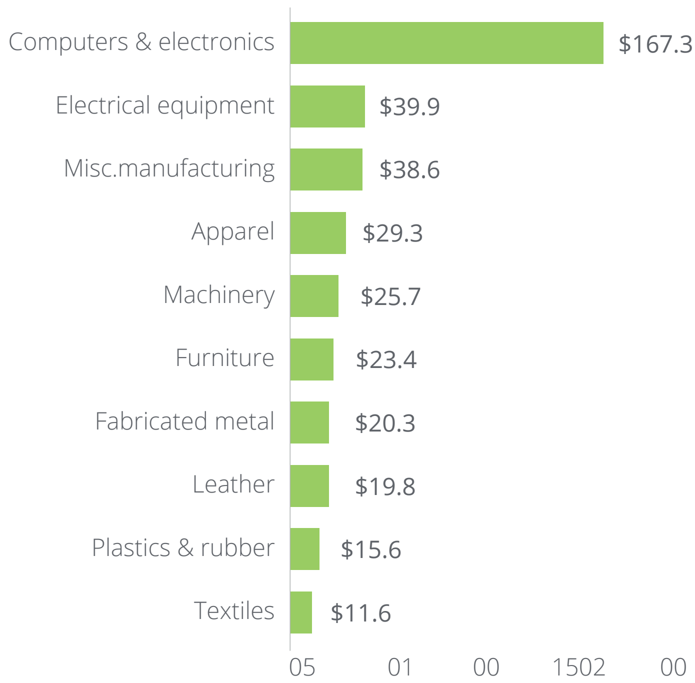


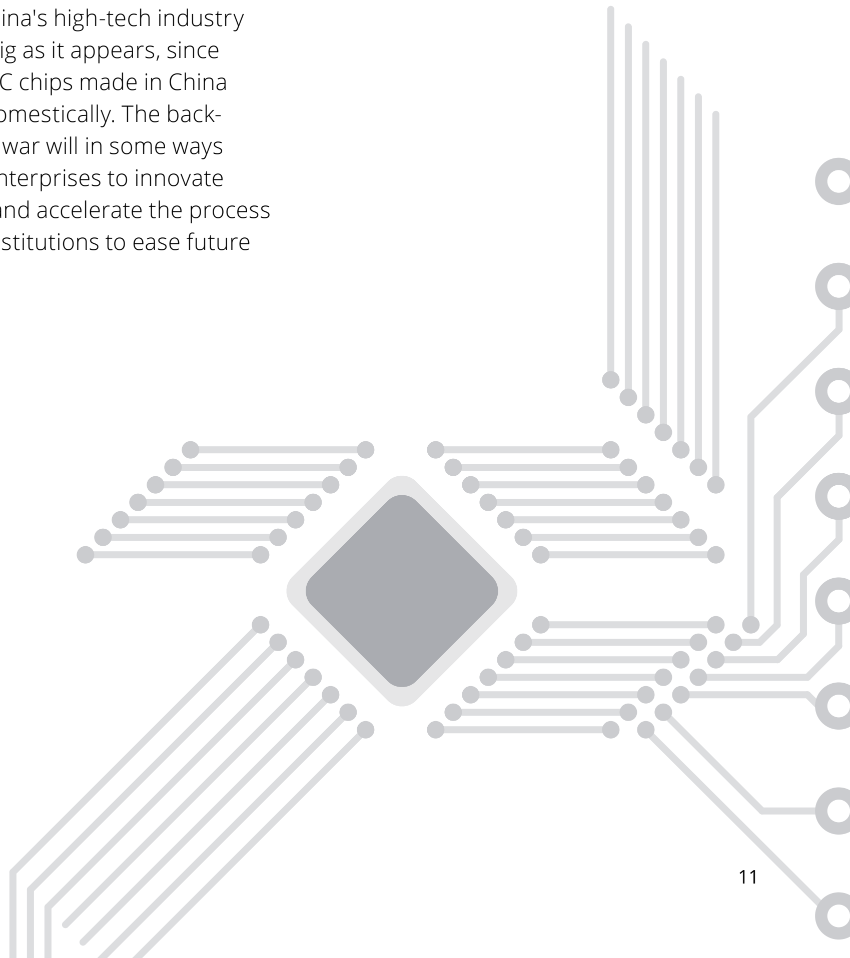
Figure: US deficits with China

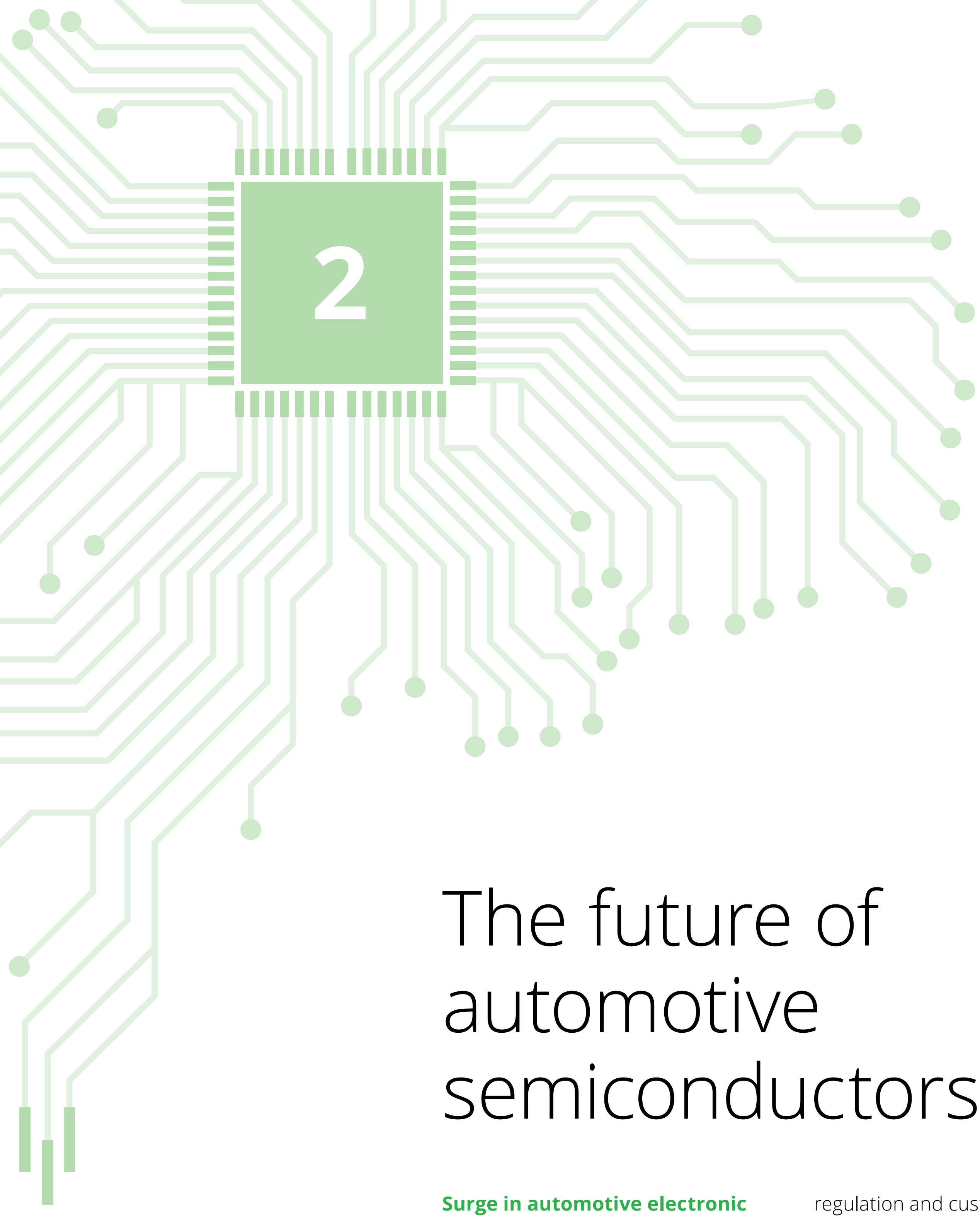


Source: Deloitte analysis

Currently, China imports over USD200 billion worth of IC chips from the US, far exceeding its imports of crude oil. Any hiccups in the semiconductor value chain will have a severe impact on other parts of the industry. As the trade war continues to intensify, a handful of domestic semiconductor giants and MNCs have begun to re-evaluate their positions in the supply chain. Apple, for example, has long used China as its production base for everything from its signature iPhones to iPads accessories. The company's supply chain now spans hundreds of companies. However, these suppliers may consider shift some iPhone production away from China should tariffs on US imports continue to rise.

In the grand scheme of things, however, the short-term impact of the Sino-US trade war on China's high-tech industry may not be as big as it appears, since the majority of IC chips made in China are absorbed domestically. The back-and-forth trade war will in some ways force Chinese enterprises to innovate independently and accelerate the process of domestic substitutions to ease future risks.



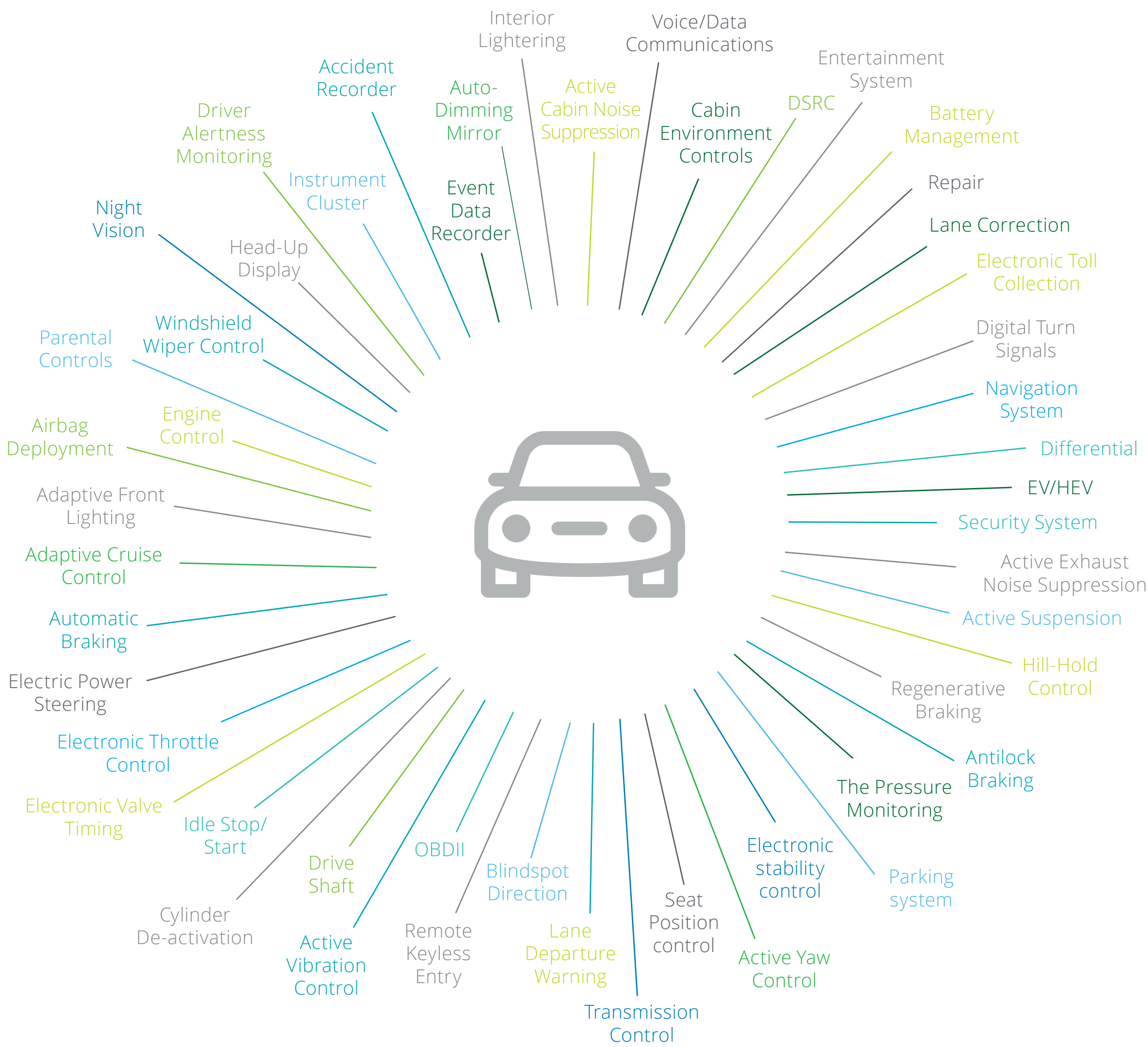


The future of automotive semiconductors

Surge in automotive electronic systems

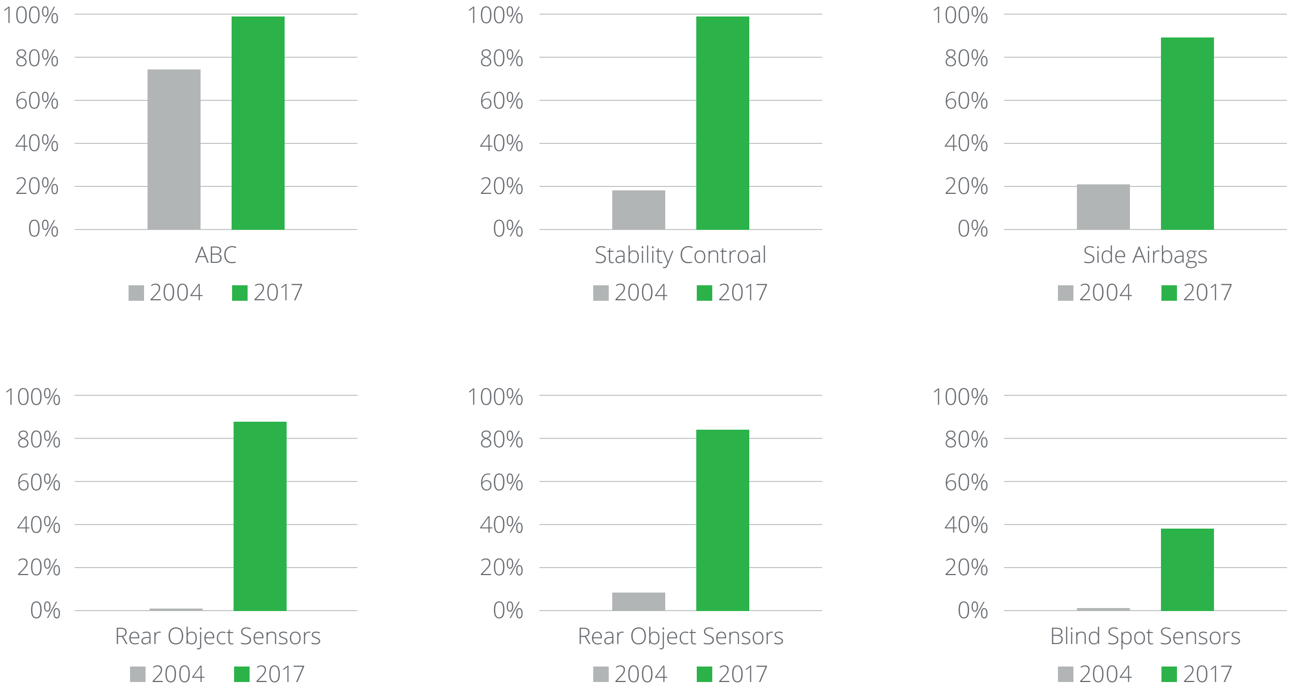
The automotive industry has come a long way in terms of providing factory-installed electronics meant for safety and comfort. Back in 2004, only a quarter of cars had airbags and less than 50% had factory-installed power seats. However, due to government regulation and customer demand, the adoption of safety-related electronics systems has exploded. Most of the automotive innovations taking place today arise from electronics rather than mechanics. The cost contribution of automotive electronics increased from around 20% in 2007 to about 40% in 2017.

Figure: Factory-installed electronics

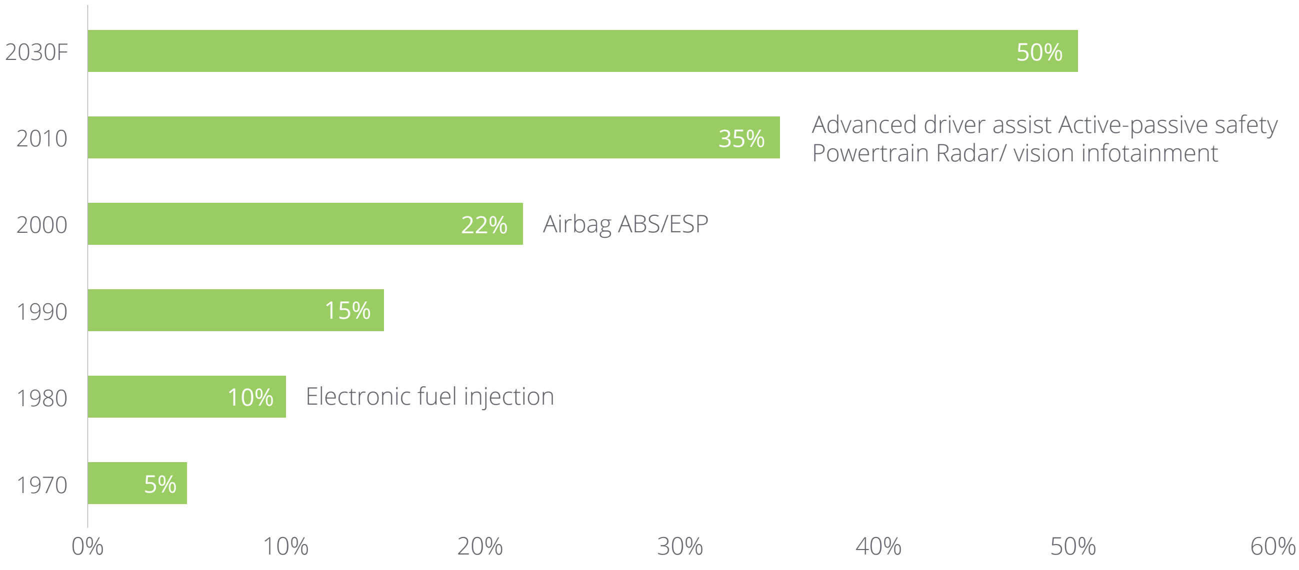


- ADAS: uses sensors installed on the vehicle to sense the surrounding environment at any time of driving process, which can collect data, detect and track potential dangers.
- Powertrain: refers to series of parts and components that generate power on the vehicle and transmit it to the road surface.
- Safety: includes active and passive safety systems that reduce the risk of accidents, as well as their consequences.
- EV/HEV: hybrid vehicle that combines a conventional internal combustion engine (ICE) system with an electric propulsion system.
- Instrument Cluster: a control panel usually located directly ahead of a vehicle's driver, displaying instrumentation and controls for the vehicle's operation.
- Aftermarket: concerned with the manufacturing, remanufacturing, distribution, retailing, and installation of all vehicle parts after the sale of the automobile by the original equipment manufacturer (OEM) to the consumer.
- Body: represents for vehicle components itself, including power door, power window, climate control and mirror wiper control.
- Chassis : the framework of an artificial object, which supports the object in its construction and use.
- Infotainment: provides a combination of information and entertainment based on vehicle integrated information processing system.

The automotive industry has come a long way in terms of providing factory-installed electronics meant for safety and comforts.



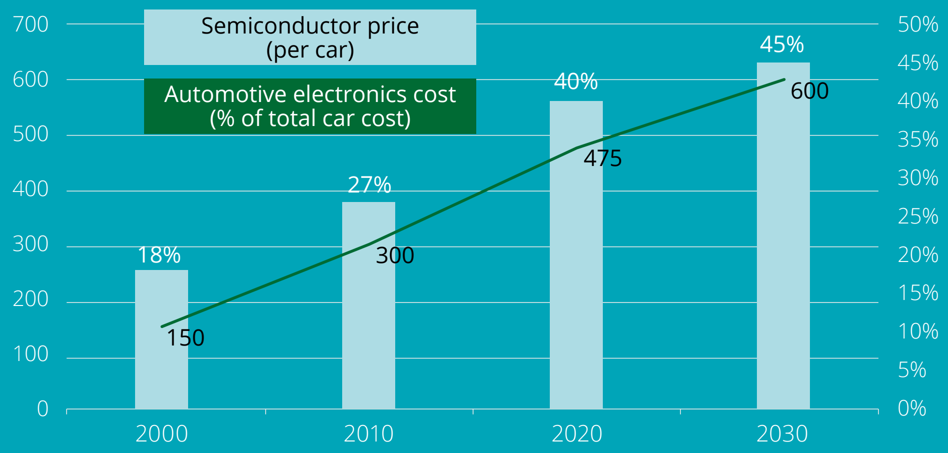
Electronic systems as % of total car cost



Source: Deloitte analysis

The cost of semiconductor content, i.e. the components that make up electronic systems, has grown from USD312 per car in 2013 to around USD400 today. Automotive semiconductor vendors are benefiting from a surge in demand for various semiconductor devices in cars, such as MCUs, sensors, memory and more. By 2022, the figure is expected to reach close to USD600 per car.

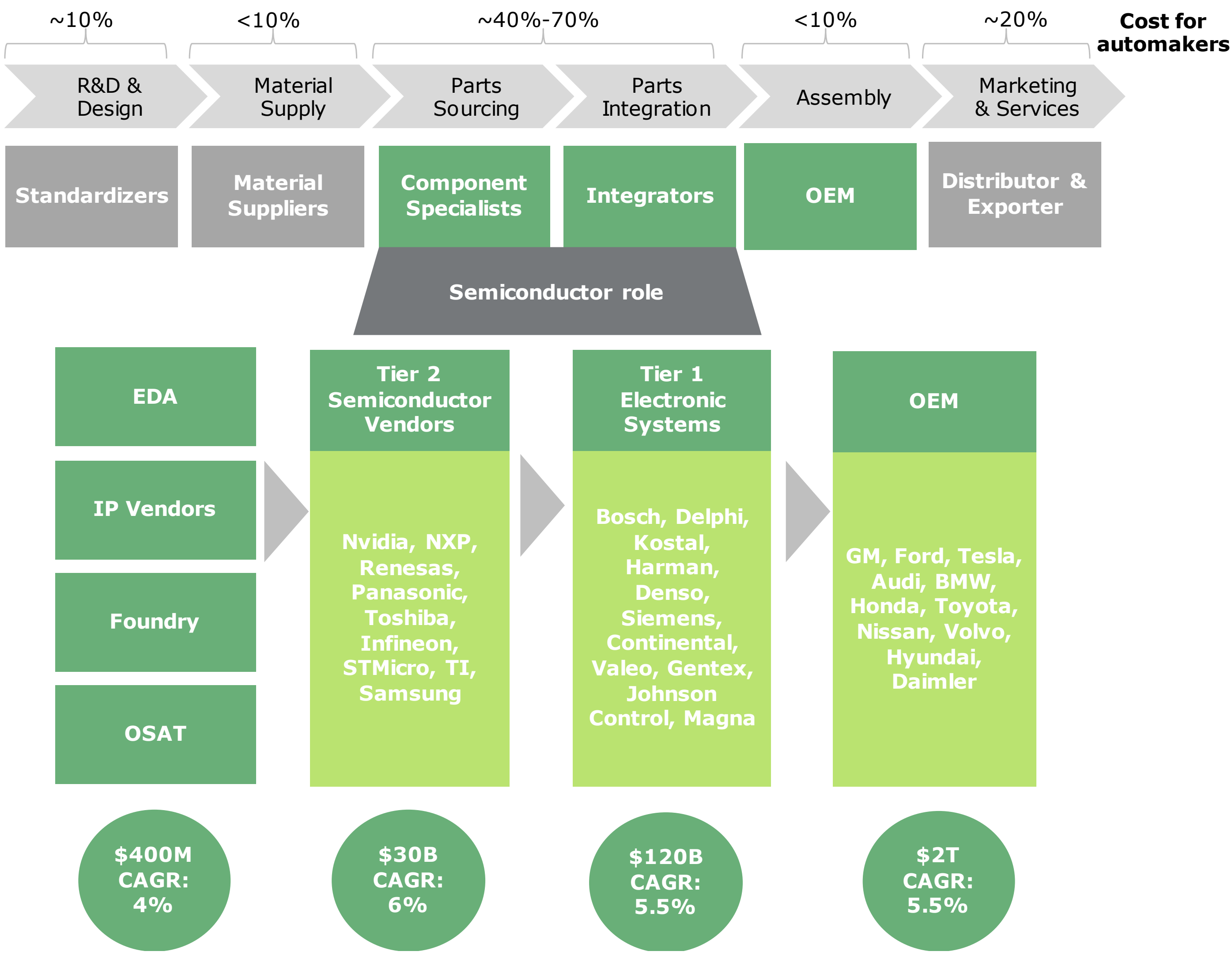
Figure: Cost contribution of automotive electronics and semiconductor content per car



Source: IHS, Deloitte Analysis

Semiconductor vendors play a critical role in the automotive industry supply chain. In the classic automotive ecosystem, semiconductor vendors sell to Tier 1 electronic systems vendors, which then integrate technology into modules and send these to the automaker (OEM) for assembly. In recent years, the automotive industry has been undergoing massive transformations that will re-invent the entire ecosystem for years to come. Advances in technology such as AI, electric vehicles (EVs), autonomous driving, energy storage, and cyber security; social awareness of topics such as safety and ride-sharing; environmental concerns like pollution; and economic considerations including infrastructure spending and growth in Asian markets are all set to reshape the automotive industry.

Figure: Role of semiconductors in the automotive ecosystem

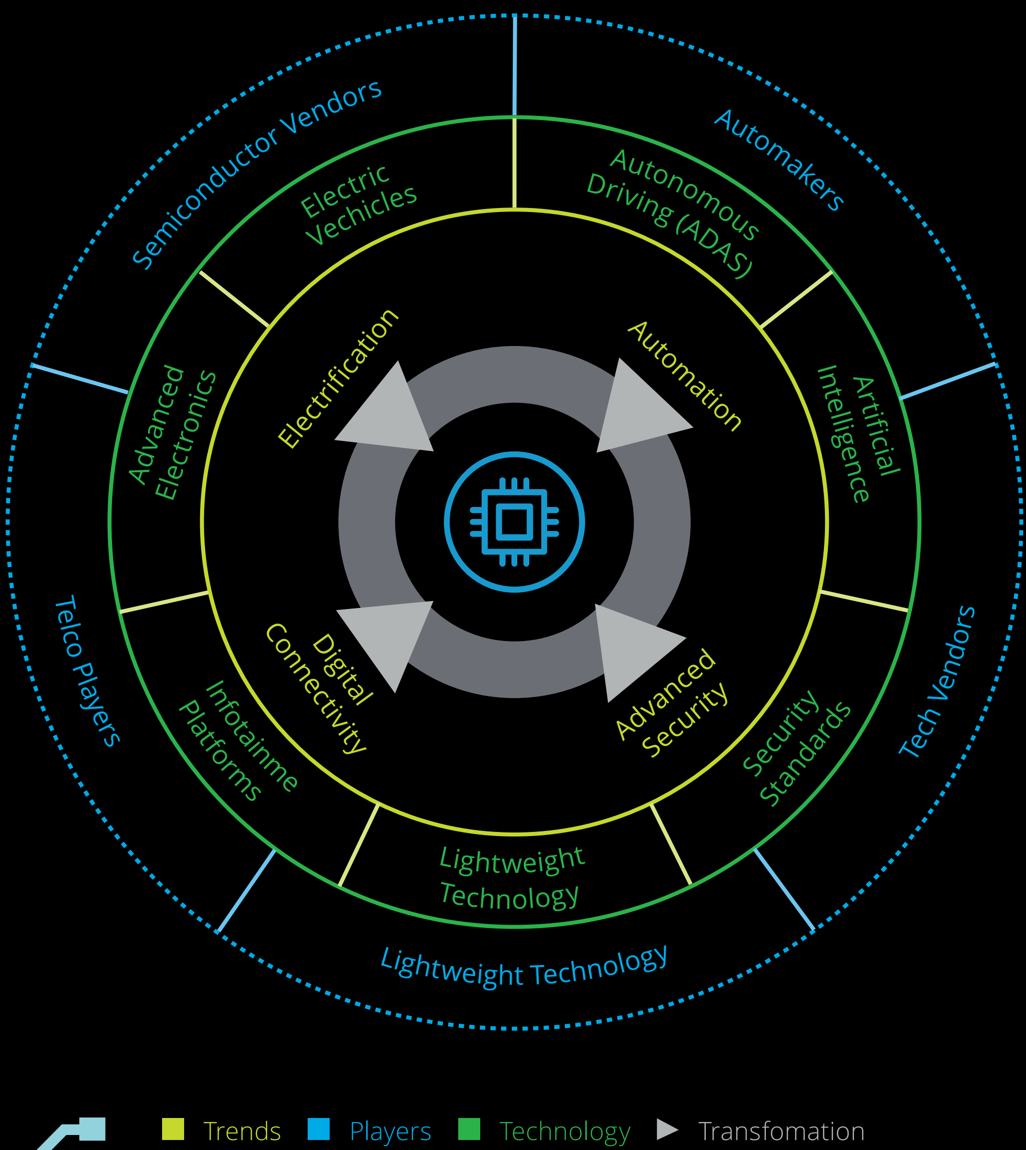


Source: Cadence, IHS, Deloitte analysis

Key words: Automation, electrification, connectivity and security

Four mega trends will result in more semiconductor content being added to automotive electronics and subsystems in the next decade.

Figure: Mega automotive semiconductor trends



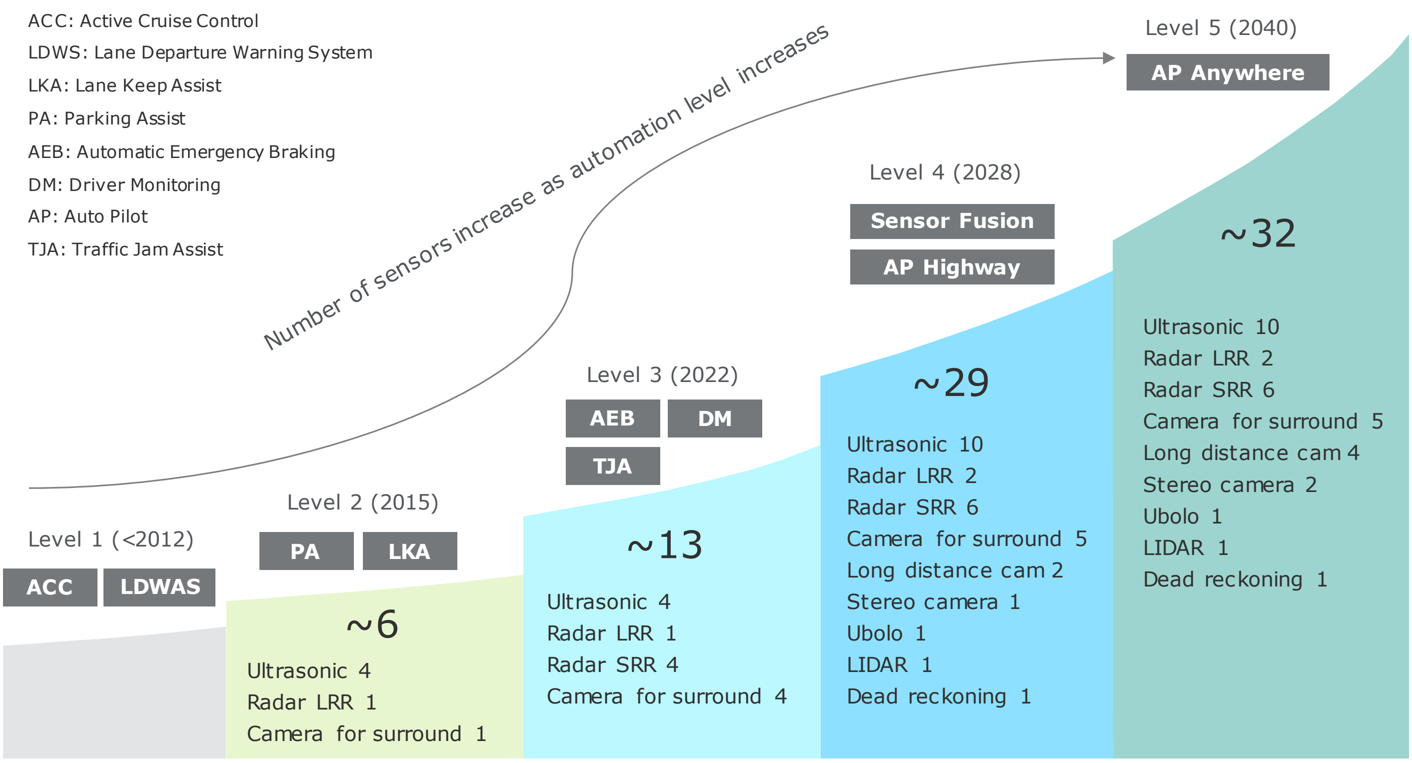
Source: Deloitte analysis

1. Automation

Widely considered as the ultimate goal for the future of mobility. Automakers and Tier-1 suppliers, as well as technology providers (e.g. semiconductor vendors) and smart mobility companies (e.g. ride-sharing companies) not traditionally involved in the automotive industry, are all racing to develop and invest in related technologies. Semiconductor vendors in particular are actively developing a wide-range of microchips, fusion and system-on-a-chip devices incorporating AI and machine learning technologies.

Safety is a key selling point for autonomous vehicles. However, getting to full autonomy (Level 5), requires advancements in technologies such as ADAS safety systems that can reduce the number of traffic accidents, including electronic stability control, lane departure warning, anti-lock brakes, adaptive cruise control and traction control. All of these require complex electronic components that include high-speed processors, memory, controllers, sensors and data links to ensure the reliability and safety of a vehicle. For example, sensors will play a critical role in the shift to autonomous driving. More sensors are required to enable autonomous capabilities. The number of sensors used in vehicles will increase as autonomy levels rise. At Level 4, the number of sensors could reach 29. These features will not be limited to high-end cars, but will move into mid-range and economy models where volume movement is going to be much higher in the next few years.

Figure: Number of sensors for different levels of autonomous driving



Source: Deloitte analysis

2. Electrification

The need for cars to be more fuel-efficient, and the impetus of government regulation to lower emissions, are driving up semiconductor demand for both traditional vehicles and EVs/hybrid electric vehicles (HEVs). In today's traditional internal combustion (ICE) engines, there is still huge potential to lower CO2 emissions. Many sensors and controls are required to run an engine efficiently and significant improvements can still be achieved. The Chinese government, for example, will introduce the new "6A" emission standard by 2020 to further lower vehicle emissions.

At the same time, EV/HEV advances require progress on the electrification of power trains. Governments in many countries are beginning to ban, or in the process of banning, ICE-based cars completely. China is targeting increased EV production by automakers (10% of total production from 2019). Many global automakers have also set goals to have EVs account for 15%-25% of their sales within 10 years, thereby bringing EVs to the masses. As major OEMs pursue their EV goals, growth of the semiconductor industry will increase proportionally. Thus, conditions are ripe for innovation in electronic powertrain technologies that will be used to reduce total emissions, thereby accelerating more demand for semiconductors.

3. Digital Connectivity

Then there is digital connectivity—advanced vehicle connectivity (V2I, V2V, in-vehicle)—that connects both the inside and outside of a car and makes it a part of the Internet of Things. Automakers have begun to provide operating systems (OS) to act as platforms for potential app stores, as well as developed tailored apps, services and media content. Digital technology players are adapting their mobile platforms to cars and developing in-car entertainment platforms. Some media-streaming services and device manufacturers have formed partnerships with automotive OEMs. Digital tech players especially have an advantage in this area, due to their core capabilities and aggressive capital investment. From a consumer's perspective, in-car digital connectivity and content will become the norm, particularly with Asian customers who consider entertainment a basic automotive function with flawless integration of their personal mobile devices. Connectivity is not just entertainment; vehicle-to-vehicle communication is a critical technology for autonomous cars to realize driverless technology and avoid accidents. It is expected that by 2023 over 90% of vehicles produced will be connected.

Figure: Components of the connected car

Source: Deloitte analysis

4. Security

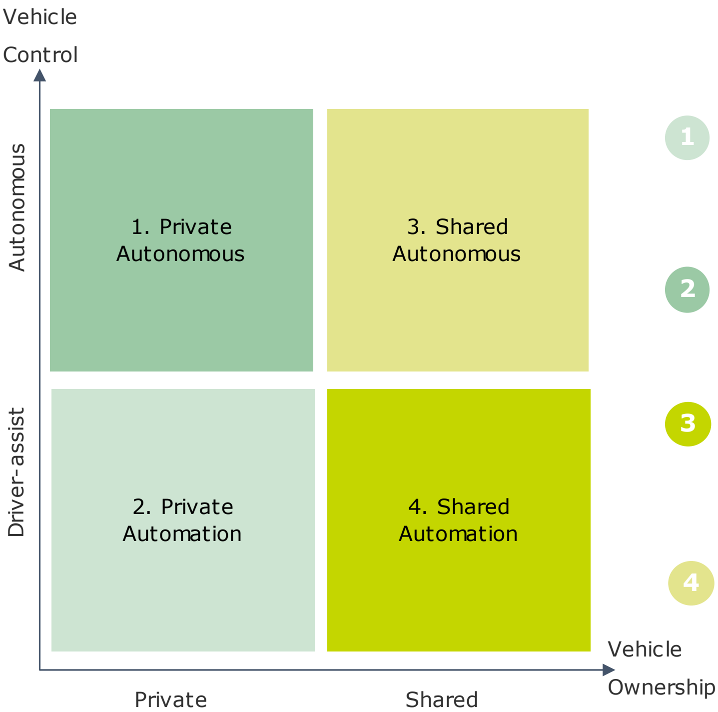
As vehicles become more connected, hardware and software platforms will be increasingly exposed to hacking risks. A failure in one vehicle component could have an avalanche effect. For example, if vehicle communications were attacked maliciously, advanced vehicle systems would not be able to receive vital situational awareness information and integrated vehicle security systems (control braking, acceleration and crash avoidance, etc.) would fail to react. Thus, automotive electronics vendors today are more focused than ever on the safety and reliability of vehicles.

Two levels of protection are being considered to deter any potential threats. The first is developing policy and establishing cybersecurity standards, so that manufacturers can follow a rigorous process for establishing the safety of connected vehicles. Standards alone may not be sufficient, however, as automakers and technology players will need to build components that are highly secured with no introduced back doors or Trojans, assess vulnerabilities in software and firmware, provide over-the-air (OTA) updates and have communications links.

Future states of mobility will coexist

We envision that these transformations will create four co-existing states in future mobility, where vehicle ownership diverges between the shared and the personal, while vehicle control continuously moves towards complete automation.

Figure: Future states of mobility



	Technology	Landscape
1	Level 3 & Level 4 of autonomy. Advanced driver assistance system (ADAS). Cheaper technology.	Tech players and startups play a critical role with automakers. Autonomous vehicle become economical.
2	Connected vehicle. Level 0 & Level 1 of autonomy, adaptive speed steering, ABS, speed control.	Little change to the existing ecosystem. Automakers continue to push unit sales. Tech players emerges.
3	On-demand mobility services, entertainment, navigation, apps.	High asset utilization, high efficiency autonomous ride-sharing network. Greater collaboration between players in disruptive environment.
4	Mobility and data-driven services, mobile devices such as smartphone on the rise.	Ride-sharing proliferates. Multi-vehicle households reduces. Tech players to offer more personalized services.

Source: Deloitte analysis

In Private-Autonomous (state 1), vehicle ownership remains private, but the automation level has achieved an all-time high due to decreases in the cost of technology, thereby boosting the number of autonomous vehicles. Collaboration between OEMs and technology players is the norm in this state.

In Private-Automation (state 2), where vehicles are personally owned with limited ADAS. Auto OEMs will continue to focus on unit sales and bring in incremental technological advances. There will be little change in the ecosystem.

In Shared-Autonomous (state 3), the majority of cars are shared with autonomous capabilities. In this landscape, there will be a rise in on-demand mobility services such as entertainment, and we will see deepened collaboration between automakers, technology players, fleet owners and regulatory bodies to create a complex urban ecosystem.

In Shared-Automation (state 4), where vehicle ownership is shared, a rapid increase in adoption of shared mobility will emerge. Point-to-point transportation will be created via ride sharing and cost per-mile will decrease. The landscape in this state will allow technology players to offer more enhanced and personalized services.

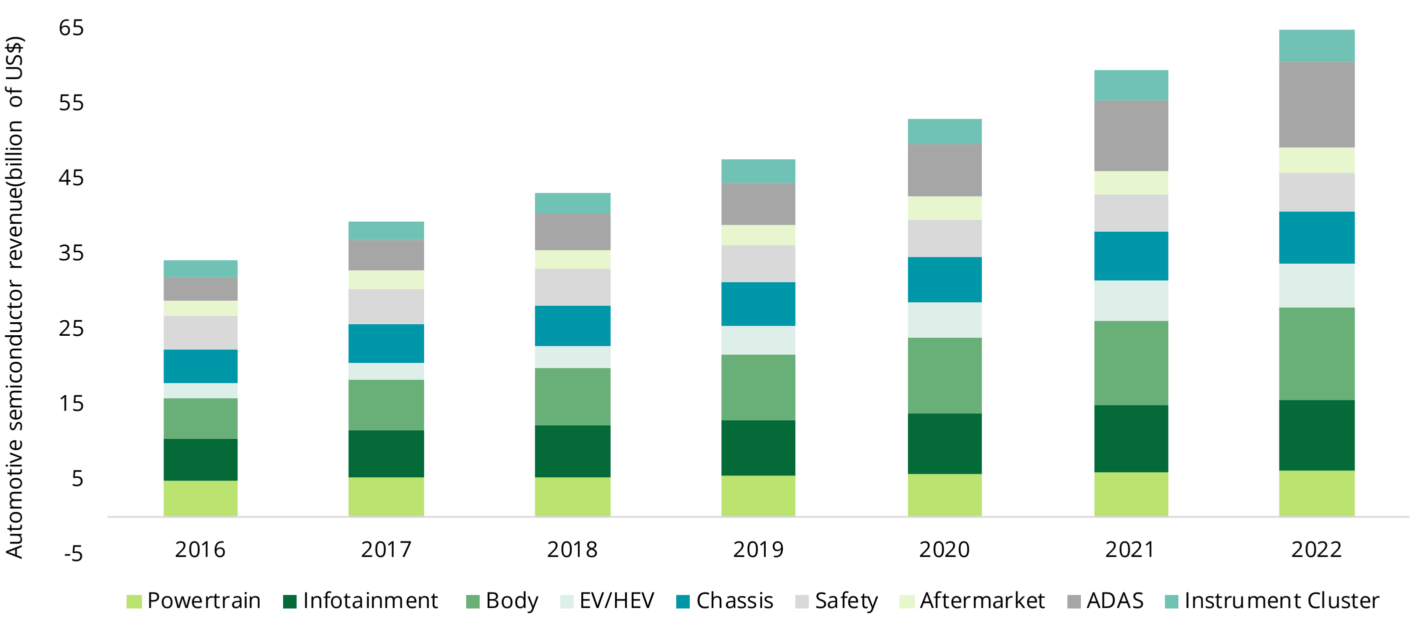
Opportunities in automotive semiconductors are emerging

Although mobile is, and will remain, the largest market for semiconductor companies, overall growth has been saturated for many years. The only exception is the automotive semiconductor segment, where demand is strong as more electronic components are being added to vehicles, such as ADAS and in-vehicle infotainment (IVI), becoming an important growth market for semiconductor players.

Asia Pacific the most attractive region

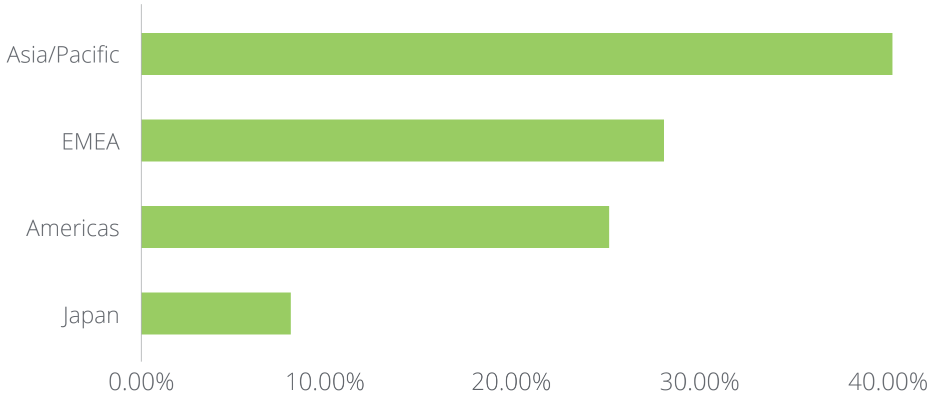
Overall automotive semiconductor revenue is projected to reach USD40 billion (an all-time-high) in 2018, before hitting USD60 billion in 2022. The Asia Pacific region is expected to lead the world with 41% growth, driven by supportive government policy and consumer demand for safety, particularly in China. China is now the largest market for the automotive industry, with almost 29 million cars sold in 2017. China is also becoming a major auto-manufacturing center, attracting global automakers, accounting for close to 29% of worldwide light vehicle production. All this makes the region highly attractive to semiconductor vendors.

Figure: Automotive semiconductor revenue and unit production by region



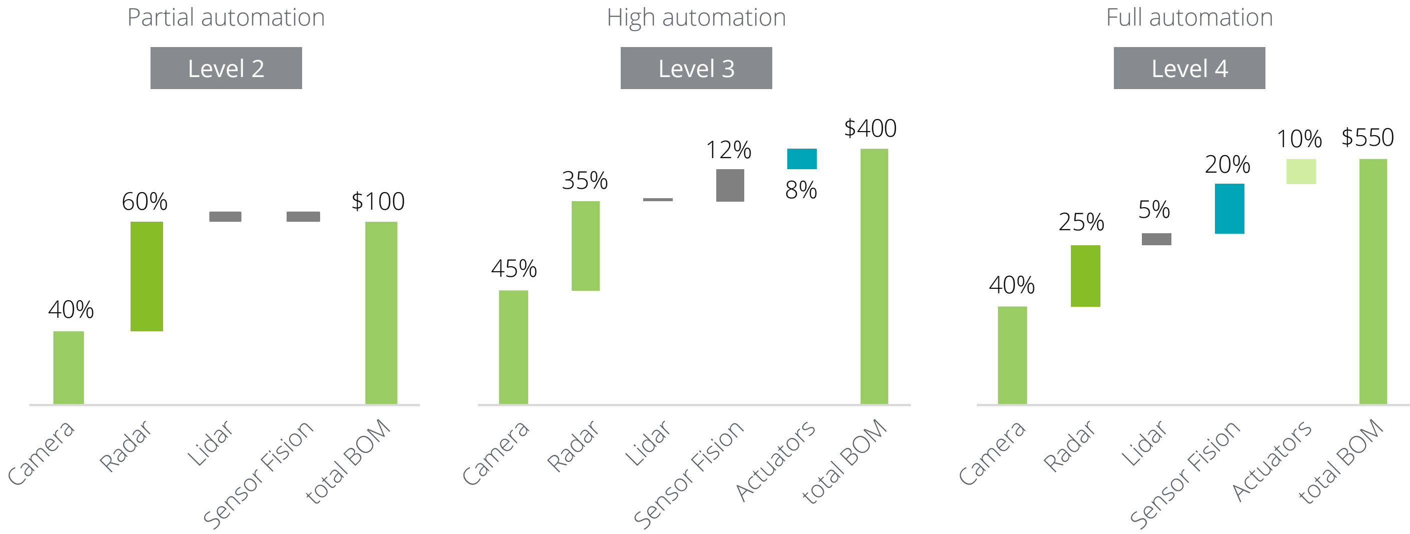
ADAS to lead growth

The growth of the automotive semiconductor market depends on electronic equipment and semiconductor content growth in vehicles. The ADAS application segment is expected to have the highest growth rate. ADAS semiconductor content will rise along with the level of automation. In fact, partially automated cars will have about USD100 in added-in semiconductor content, with a highly automated car potentially having USD400 added. A fully automated car would have about USD550 of semiconductor content. In other segments such as powertrains, there is huge demand for microcontrollers, sensors and power semiconductors, because in hybridization and electrical vehicles, semiconductors are the primary driver for the efficiency of the electric drive train.



Source: Gartner, Deloitte analysis

Figure: Average ADAS semiconductor content at different levels of automaton



Source: Infineon

From a device perspective, different types of components will be required for increasingly complex functionality sets. Some segments will grow faster than others do. For example, autonomous driving will generate large demand for sensors and microcontrollers as well as processing for each of these sensors. The industry is also in the process of developing more powerful MCUs/MPUs to handle the data. For example, when vehicles reach Level 4 or 5, systems need to be able to process all sensor data to create a holistic view that allows the car to make the right judgement.

Figure: Automotive semiconductor application and device growth (2022)

USD 600
semiconductor content per car by 2022

	Segment	Growth (2017-2022)	Size (2022)	Sub segment
by Application (Gartner)	ADAS	23.6%	11b	Blind spot detection/Collision warning/Park assistance/V2X/Front view camera
	Aftermarket	6.1%	3b	Vehicle parts/Equipment/Service repair/Collision repair
	Body	13.3%	12b	Power door/Power window/Climate control/Mirror wiper control
	Chassis	6.1%	7b	Suspension/Differential/drive shaft
	EV/HEV	21%	6b	Hybrid vehicle
	Infotainment	8.2%	9b	Connectivity/Telematics/Car navigation/Car audio
	Instrument Cluster	11.2%	4b	Instrument panel, instrument wiring harness
	Powertrain	3.4%	6b	Engine Control/Transmission
	Safety	2.6%	5b	EPS/ABS/Airbags/Traction control/Tire pressure monitor
by Device (Gartner)	General-Purpose Logic IC	12.5%	2b	Data Converter, Switch, Multiplexer, Voltage Regulator, Reference
	Memory IC	10.9%	4b	DRAM, Emerging Memory, Flash Memory, NAND
	Optoelectronics	18.9%	8b	Image Sensor, LED, Photosensor
	Discrete	9.9%	9b	Power transistor, Diodes
	Nonoptical Sensors	7.2%	6b	Environmental Sensors, Fingerprint Sensors, Inertial Sensors, Magnetic Sensors,
	Micro-Component IC	7.7%	11b	Digital Signal, Microcontroller, Microprocessor
	Analog IC	7.4%	4b	Data Converter, Switch, Multiplexer, Voltage Regulator, Reference
	ASIC	6%	3b	ASIC
	ASSP	12.3%	19b	ASSP

Source: Gartner, Deloitte analysis

Seizing the opportunities

The automotive segment is not really a new market for semiconductor vendors. In fact, many of them have been participating in this market for several years. However, it was not considered a big revenue source since there were not enough customers, it took a very long time to qualify a process and volume was low compared to consumer electronics. However, sentiment has changed due to rising demand for automotive electronics such as ADAS, AI, connectivity and sensors. To seize these opportunities, leaders in the semiconductor industry should consider the following actions and approaches to the market:

1. Understanding the automotive sector's unique hurdles

When it comes to requirements, the automotive electronics market is vastly different from the consumer electronics market. For example, consumers seek the latest, leading edge technologies in cellphones. However, in automotive, some sensors are still being manufactured at 150nm. This is because automotive design requires substantial redundancy and size is less of a concern, so there is little incentive to move to 7nm sensors like those in cellphones. In addition, the failure rate requirement is much more stringent in the automotive space, because when a cellphone goes down a simple reset can fix the issue, which is not possible for a car on the road. A 10% failure rate might be acceptable in the mobile space for suppliers, but automakers will want less than one defective part per billion (DPPB) for 15 to 20 years.

Furthermore, in the mobile world, designs regularly reach 3GHZ, where frequency and speed are top priorities. On the other hand, automotive frequencies and speeds vary. But, as 5G-connected cars soon become a reality, the two domains might eventually merge, with connected cars in a way become cell phone-like. Automotive chips also need to operate at a wider range of temperatures: -40°to 155°centigrade versus 0°to 40°centigrade for a mobile device. Voltages also vary greatly between automotive and mobile. In mobile applications, voltages are kept low to conserve battery life. However, there are high voltages in cars and many semiconductors are still analog, which requires devices to operate correctly in a wider range.

Figure: Automotive IC requirements versus mobile

Mobile		Automotive
28nm → 7nm	Process	>180nm → 7nm
100M+	Design Sizes(μP/C)	<1M → 1000M+
900MHz → 2.7GHz	Frequencies	30MHz → 5.9GHz
0.5V to 1.8V	Voltages	~1V → >60V
0 → 40℃	Temperatures	-40 → 155℃
1-3 years	Operation Lifetime	~10-15 years
<10%	Target Field Failure Rates	Target Zero Failure

Source: Synopsys, Deloitte analysis

2. Expect stringent and challenging qualification requirements

In the automotive industry, chips, components, modules and subsystems must meet stringent specifications on quality, reliability, cost, power and safety, since operating conditions in cars are much more demanding than in typical consumer electronics. For instance, the Automotive Electronics Council (AEC) has developed a failure stress test qualification (AEC-Q100) for integrated circuits (IC). Qualified ICs should met a series of reliability stress tests (electrical, lifetime, etc.), as well as be subjected to testing under various intense temperature ranges. Electronics and semiconductor suppliers are expected to support qualification testing pre-shipment as well as failure analysis post-shipment. Ultimately, product development and manufacturing are all linked back to safety regulations and everything should be traceable.

These requirements create an assortment of challenges for semiconductor vendors. For example, semiconductor foundries normally develop a process technology and qualify it using a relatively normal sample size. In automotive however, foundries need to conduct more inspection, testing and screening to achieve higher levels of quality and yield. Latent reliability is another focus, in which failure may not occur until components have been operating out on the road during a vehicle's useful lifetime, due to age, latent manufacturing defects, thermal stress or electromagnetic interference.

This is especially important since future autonomous driving will rely on components working together perfectly. How devices will fare over time in a harsh external environment is yet to be determined. A typical car model can be on the market for 10-15 years, a refresh cycle that is much longer than that in consumer electronics.

It will be incumbent on semiconductor vendors to conduct more simulation, inspection and testing of larger sample sizes to ensure reliability while controlling time and added cost throughout the process. Suppliers have to be ready and plan for long product life cycles to support manufacturing and maintenance.

3. Leverage M&A to jumpstart market entry

For many semiconductor vendors, gaining access to the automotive semiconductor market is not a trivial task. They must weigh the pros and cons of building in-house capabilities versus acquisition. With semiconductor vendors seeking new areas of growth and expansion, M&A deal activity has been quite active over the last few years. For example, NXP and Freescale's merger enabled the resulting entity to become a leader in automotive semiconductor solutions, while Intel's acquisition of Mobileye allowed it to enter the market and filled gaps in its automotive product offering.

Table: Automotive semiconductor related M&A

M&A	Amount (USD)	Date
NXP/Freescale	118 million	March 2015
Avago/Broadcom	370 million	May 2015
Intel/Altera	167 million	June 2015
Western Digital/Sandisk	178 million	October 2015
Analog Devices/Linear	130 million	July 2016
Softbank/ARM	302 million	July 2016
Qualcomm/NXP	459 million	October 2016
Intel/Mobileye	153million	March 2017

Source: Mergermarket, Deloitte analysis

Thus, M&A should be considered an integral part of an overall strategy to maintain competitive edge. The potential benefits M&A brings include filling gaps in product line, accessing state-of-the-art technology and gaining access to a wider customer base. These are especially important in the automotive semiconductor industry, because it takes great effort to secure long-term partnership agreements with automotive companies. Added to this is the fact that most automotive semiconductor projects are lengthy, often taking years from concept initiation, product development and qualification process all the way to production. In addition, customers are seeking integrated, comprehensive solutions from one company instead of many.

From a technology perspective, automotive semiconductor components have to adhere to stringent quality standards, and semiconductor vendors with cutting-edge manufacturing capabilities have the best chance of producing high quality components. M&A allows quicker access to this expertise to strengthen competitiveness and increase market share.

Oversaturation of the smartphone market has pushed many big semiconductor players to explore possibilities in the automotive semiconductor market to broaden their portfolios and diversify revenue streams. The connected car provides an entry point for the expanded role semiconductor vendors can play.

For example, Samsung acquired Harman to build its infotainment capability in connected cars. The move allowed Samsung to gain a foothold in the automotive market, as Harman is a global leader in connected autonomous vehicles. The acquisition not only allowed Samsung to position itself as a key supplier of infotainment systems using an established brand name, but the autonomous vehicle market is also seen by Samsung as a new and profitable revenue stream. Samsung will expand its reach across the connected car market, ADAS, cybersecurity and over the air (OTA). The acquisition also aligns with Samsung's IoT universe strategy to achieve volume.

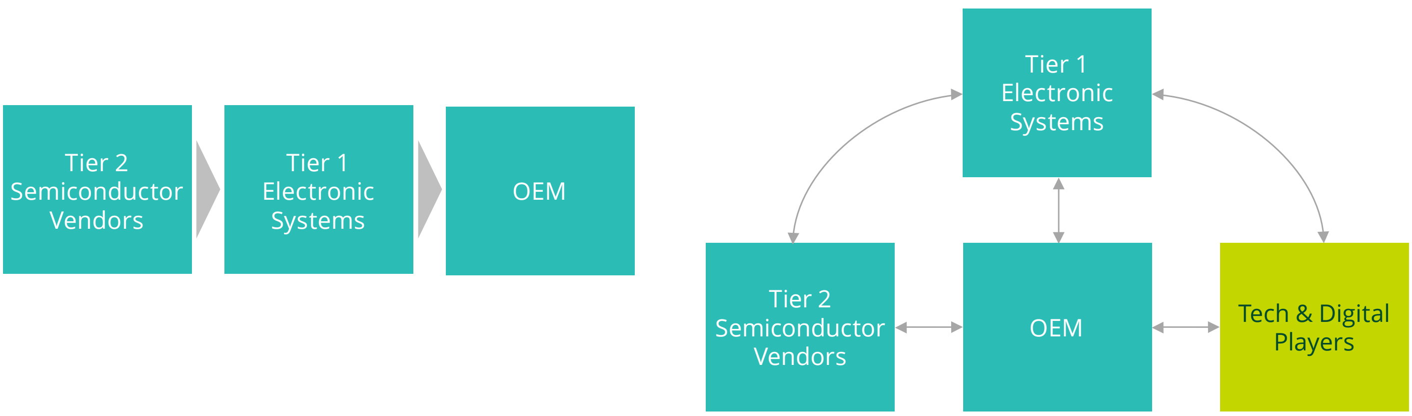
Meanwhile, Panasonic is refocusing its work from home electronics to high-tech auto parts, leveraging its expertise in electronics to build advanced capabilities in the automotive electronics market. Panasonic has made several acquisitions in the last few years, coupling these with building autonomous driving capability in-house. Panasonic has begun testing autonomous cars, teamed up with Google and Qualcomm on infotainment, and formed a joint venture (JV) in China to provide key EV components.

4. Rethink collaboration models and roles

The ecosystem and collaboration models of the traditional automotive semiconductor are no longer static but more intertwined than ever. Players' roles are shifting and new players are rising. Customers are becoming partners or competitors and vice versa. From acting as a supplier and forming strategic partnerships to entering M&A deals or JVs, the roles in the supply chain are blurring. As vehicles become more autonomous, systems within them are ever more connected and cannot run in isolation.

Figure: The evolving automotive semiconductor supply chain

Classic automotive semiconductor supply chain **New automotive semiconductor supply chain**



This market landscape adds a layer of complexity to the existing supply chain. Some automakers are now designing their own IC (e.g. Tesla) and extending their activities beyond core hardware business into the provision of software OSs designed to serve as platforms for potential app stores, as well as developing specific apps and other services or media content. Other Tier 1 players are also designing ICs and getting involved in software. Continental's purchase of Elektrobit is an example of this trend. Furthermore, semiconductor vendors are now developing electronic control units, as are some IC houses.

Automotive suppliers are also trying to become less dependent on OEMs by establishing direct relationships with end customers. For example, Bosch's app allows customers to monitor car functions and provide a direct connection to the nearest Bosch repair center.

Technology players are applying their existing capabilities to digital automotive platforms. Tech players have significant advantages, including capabilities, operating models and capital for aggressive investment, as they focus on making horizontal moves to create new revenue models. Several high-tech players are developing autonomous-driving systems that are quite likely to merge into operating systems. Leading online and technology companies are focusing on in-car entertainment platforms, which they hope will become the standard for such applications. New tech entrants are positioned to take the lead in software-focused elements. Digital players are adapting their smartphone platforms to car-specific customer needs, integrating infotainment OS and software platforms into car systems and cars' human-machine interfaces. Media-streaming services and end user equipment manufacturers have already formed partnerships with some automotive OEMs. Semiconductor vendors can expand their roles by not only serving traditional automakers and their suppliers, but also through collaborating with technology vendors to offer more products.

At the same time, semiconductor vendors are increasing collaboration with both automakers and tier-one automotive suppliers. For example, Nvidia and Audi are collaborating to build an AI platform with deep learning technology for autonomous driving. Utilizing neural networks to understand the surrounding environment and determine safe routing to incorporate into Audi's line of L3 cars. This type of strategic partnership brings in skills from both side that complement one other and create a mutually beneficial situation.

Meanwhile, many IDMs have stopped building leading-edge fabs and turned to "fabless/fablite" over the last 20 years due to leading-edge fabs' prohibitive cost. But, they have in general kept their proprietary processes in-house while outsourcing some production to foundries. Initially, this involved a few critical automotive products such as infotainment and display drivers, with critical components such as power train or chassis control components still made by IDMs themselves. However, the trend is shifting, as IDMs are now outsourcing critical applications to foundries. For example, ADAS requires advanced MCUs but many IDMs do not have the in-house capabilities to create them.

5. Keep an eye on start-ups and their disruptions

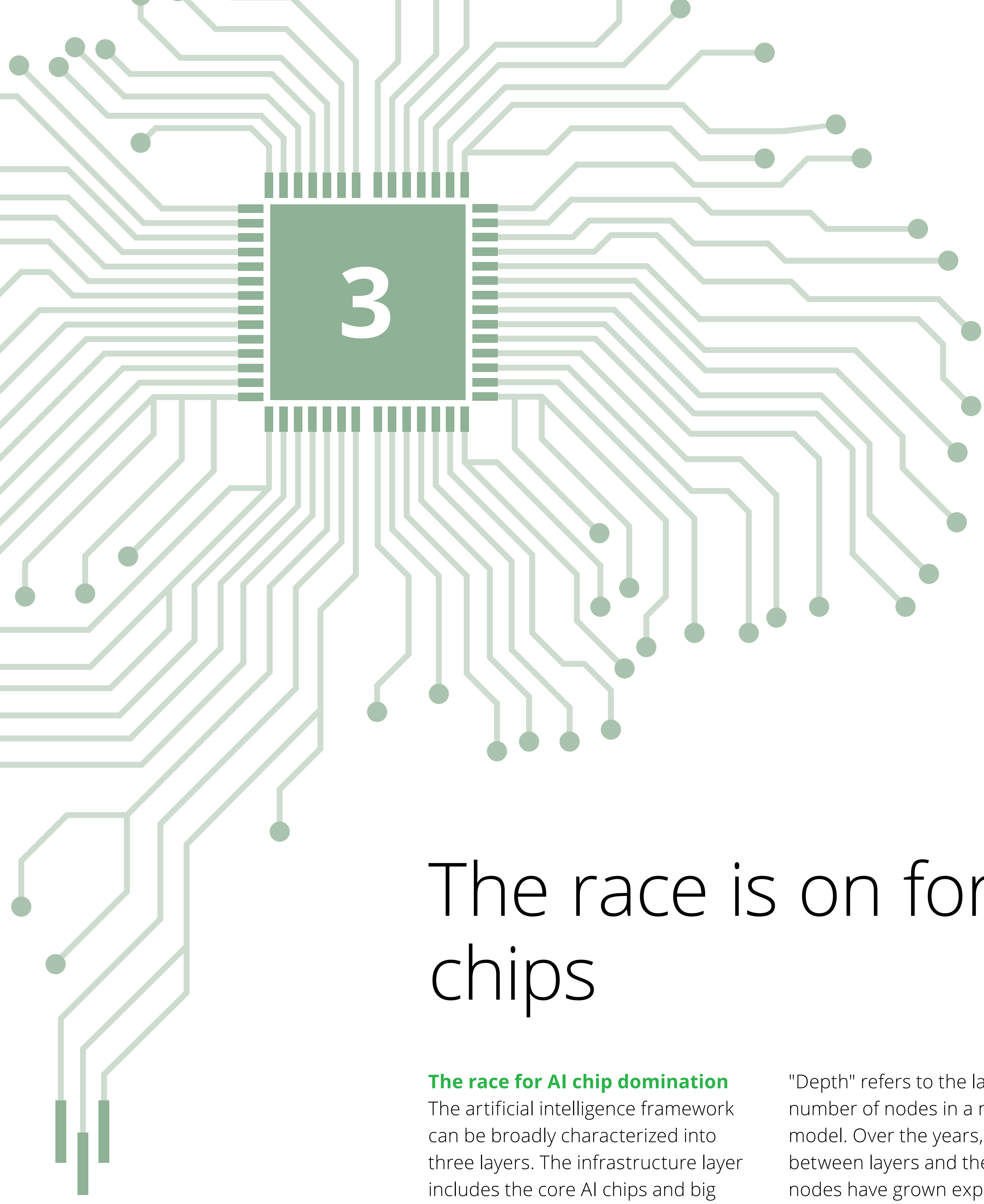
Start-ups are a hotbed of activity in connected cars, VRV/V2X communication, mobility services, cybersecurity and the AI/machine learning space. Investments in these auto tech companies have also seen huge increases in recent years. There is a wide variety of startups in the industry to address different pain points. For example, new hardware startups are looking at ways to address the pain points associated with light detection and ranging (LiDAR), which is integral to the safety of autonomous vehicle. First, LiDAR is still quite expensive and many big automakers do not use it; second, (dynamic) range is a big issue with the technology, i.e. how near, far and widely can LiDAR accurately build a 3D picture from millions of pixels. Robustness is another issue, with LiDAR having to withstand the vibration and shock, wear and tear, and cleaning that is normal to the harsh conditions of driving. Finally, there are still edge cases to be resolved, such as bright sun against a white background, blizzards that causes whiteout conditions and early morning fog.

There are several reasons why semiconductor vendors should pay attention to startups. First, the emergence of these startups in the connected vehicle space affords the opportunity to cooperate with them. Second, gaining access to technologies such as digital connectivity and AI will be increasingly important for semiconductor vendors and OEMs, as R&D cost and risk are high. Third, these startups could be potential acquisition targets for semiconductor vendors to acquire innovative technologies or enter niche markets.

Figure: Automotive startups' areas of specialization

Connected Car	V2V/V2I/ V2X	Driver assistance/ robotics	Fleet Telematics
Cybersecurity	Safety tools/system	Mobility Services	LIDAR/ mapping systems
Autonomous platforms	Machine learning/ AI/ Deep learning/	Computer Vision/ Detection	UX/ Design

Source: Deloitte analysis



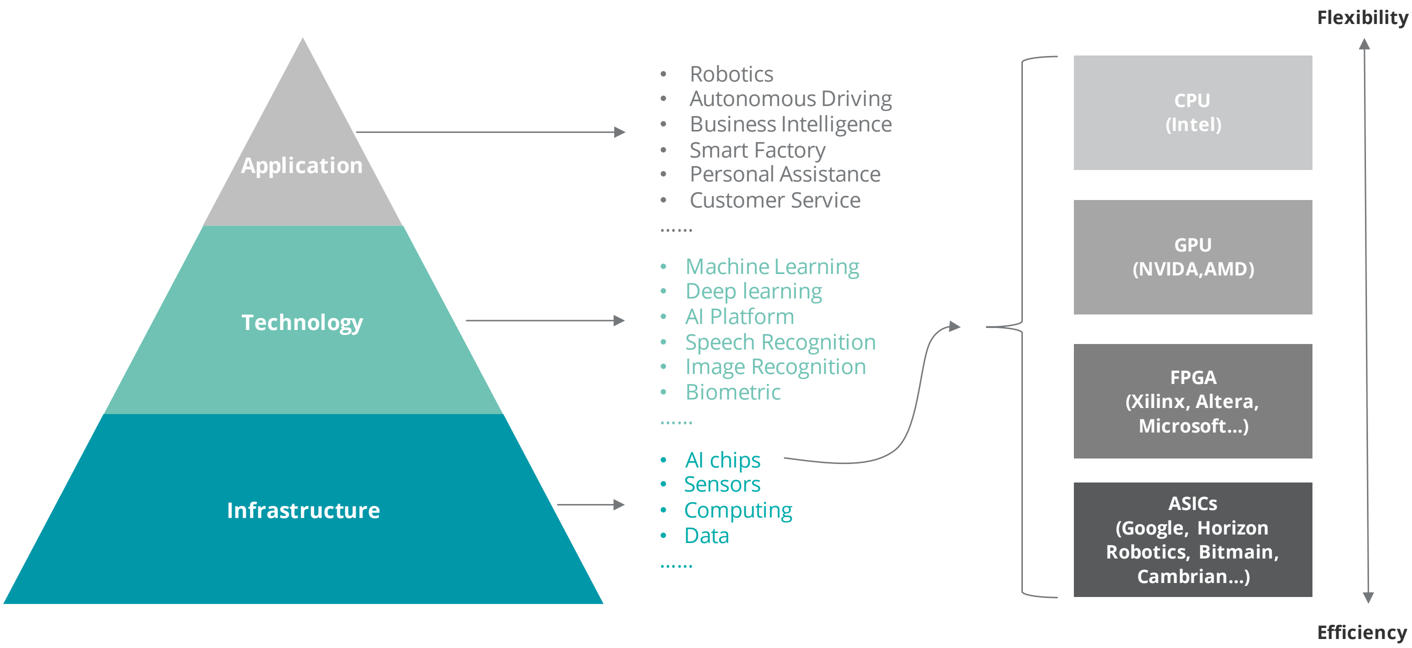
The race is on for AI chips

The race for AI chip domination

The artificial intelligence framework can be broadly characterized into three layers. The infrastructure layer includes the core AI chips and big data that support the sensing and cognitive computational capabilities of the technology layer. The application level sits at the apex, providing services such as autonomous driving, smart robotics, smart security and virtual assistance. AI chips form the heart of the AI technology chain and are central to the processing of AI algorithms, particularly for deep neural networks (DNN).

"Depth" refers to the layers and number of nodes in a neural network model. Over the years, the complexity between layers and the number of nodes have grown exponentially. This presents a significant challenge for computation. Traditional central processing units (CPUs) excel at general workloads, particularly if they are rules-based. However, CPUs can no longer keep up with the parallelism required of AI algorithms.

Figure: AI chips' role in the layers of AI



Source: Microsoft, Deloitte analysis

There are two major ways to address the parallelism issue. One is to add a dedicated accelerator based on existing computational architecture. The other is to re-develop completely to create a new architecture that simulates the neural networks of human brains. The latter approach is still in the early phase of development and unsuitable for commercial rollout. The addition of AI accelerators will therefore be the primary method. Numerous types of AI chips are available for acceleration: mainstream ones including GPUs, field-programmable gate arrays (FPGA) and application specific integrated circuits (ASIC), with variations including TPU, NPU, VPU and BPU, etc. Each has its own strengths and weakness.

GPUs used to process graphic intensive tasks such as games are built with parallelism in mind. GPUs have very high performance suitable for deep learning AI algorithms that require a lot of parallelism. This new role makes GPUs a great choice for AI hardware. GPUs are now widely used in cloud and data centers for AI training. They are also used in the automotive and security sectors. The GPU is currently the most widely used, most flexible AI chip available.

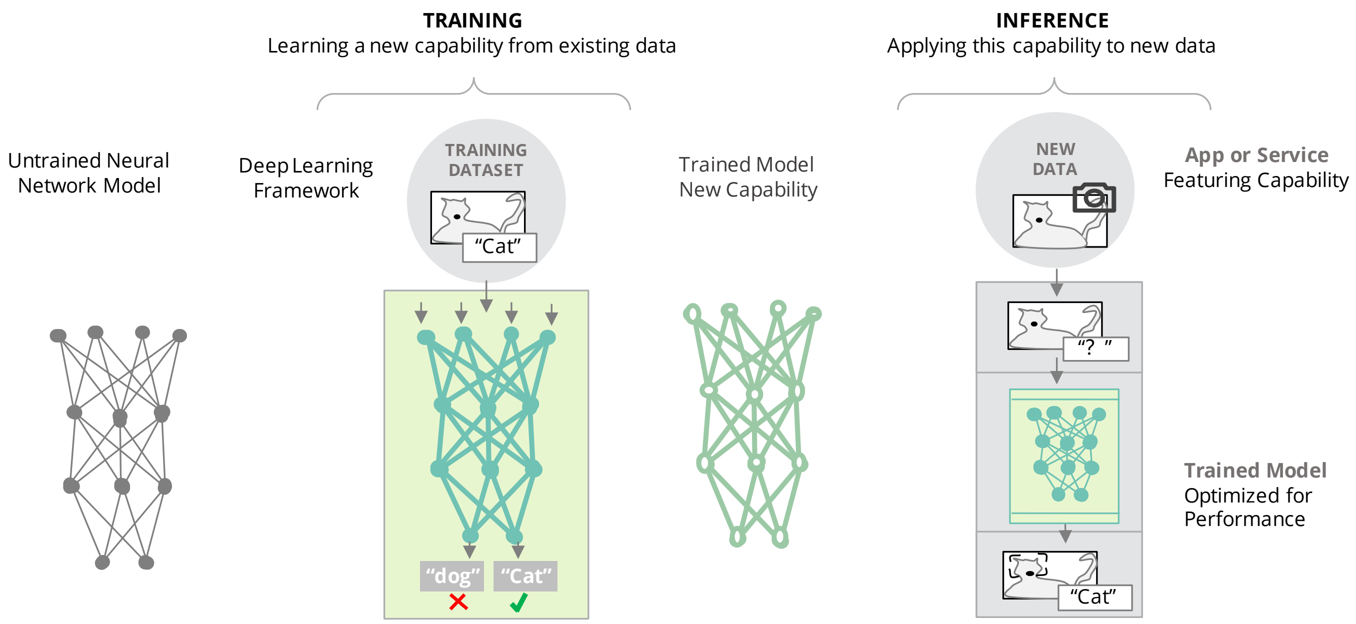
FPGAs, meanwhile, are programmable arrays suitable for clients that want to reprogram based on their own requirements. FPGAs are characterized by a faster development cycle (versus ASIC) and low power requirements (compared to GPUs). But, their flexibility makes their cost relatively high. FPGAs can be seen as a good compromise between efficiency and flexibility, especially when an AI algorithm has not been finalized. This allows vendors to optimize custom chips for their applications while avoiding the cost and potential technology obsolescence of the ASIC approach.

ASIC AI chips, on the other hand, have dedicated architecture for AI applications. ASIC-based AI chips have many variations, including TPU, NPU, VPU and BPU, etc. These are all aimed at diverse, computer-intensive, rules-based workloads with high efficiency and performance and the flexibility of a CPU. Typically, ASIC AI chips have higher efficiency, a smaller die size, as well as lower power consumption than GPUs and FPGAs. But, ASIC chips' development cycle is longer and less flexible, which has contributed to its slow commercial adoption.

There are two distinct AI deployments in deep learning: training and inference. AI utilizes big data as a foundation to "train" neural network models, using training datasets to obtain these newly trained models. A newly trained model is then armed with new capability to "infer" from new data sets to reach a conclusion.

The training phase requires a tremendous amount of computational power because it requires the application of a huge data set to a neural network model. This requires high-end servers that have advanced paralleled performance to be able to process large, diverse and highly parallel datasets. Therefore, this phase is typically done via hardware in the cloud. The inference phase, on the other hand, can be handled either in the cloud or on devices (products) at the edge. Compared to training chips, inference chips require more thoughtful consideration of power usage, latency and cost.

Figure: The two-phases of deep learning



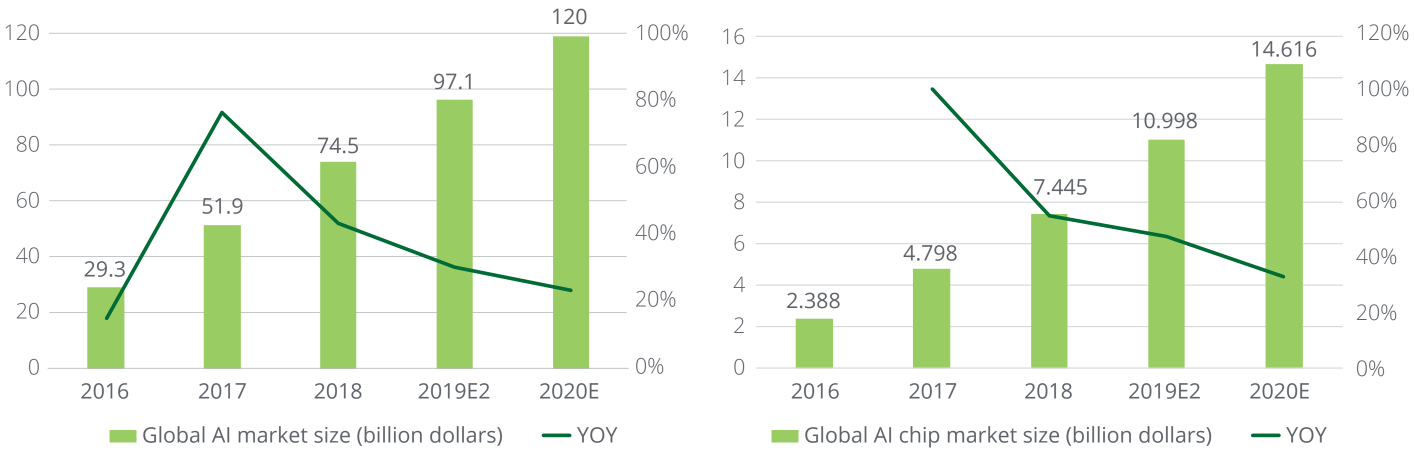
Source: nVidia

Innovation in AI chips has just begun, with vendors taking different approaches to chip acceleration. Google, for example, has taken the ASIC path, whereas Microsoft has demonstrated that comparable, and sometimes even better results can be achieved using an FPGA. Meanwhile, Xilinx, Baidu and Amazon are all working to lower the traditional barriers to FPGA adoption.

AI chips to enjoy explosive growth

The AI chip market is expected to account for over 12% of the total AI market by 2022, with a CAGR of 54%. The Americas is expected to lead the market, followed by EMEA and then APAC. The Americas overall will dominate the market throughout 2022.

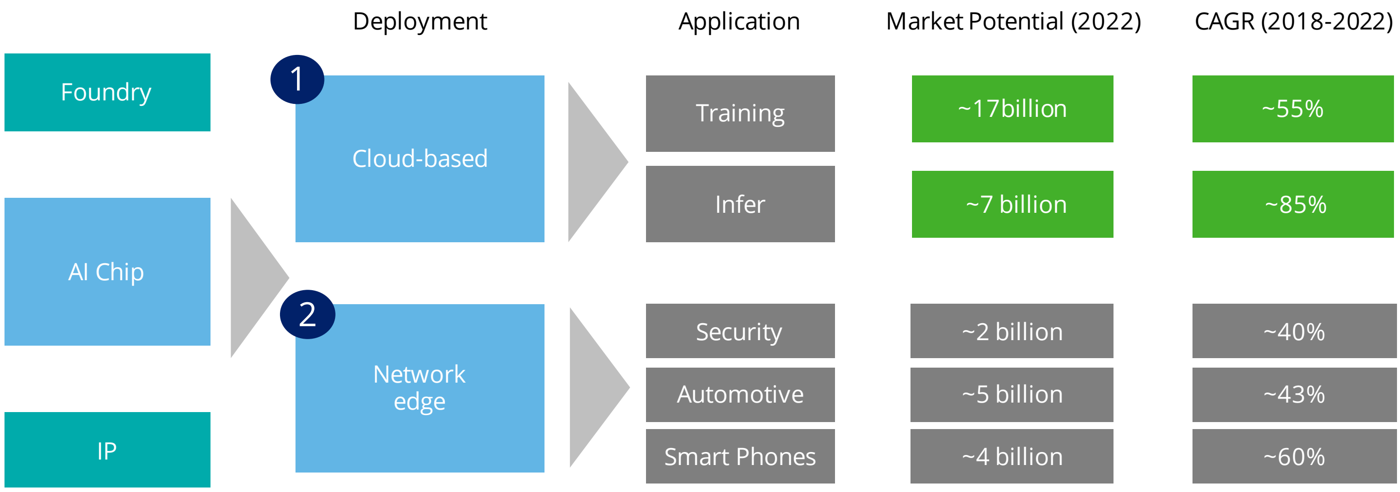
Figure: The global AI and AI chip market (2022)



Source: CDIC

Cloud-based AI chips the most promising segment

The AI chip market can be split into two categories based on deployment methods: cloud-based and network edge.



Source: CICC, Deloitte analysis

The cloud is the biggest market for AI chips, as their adoption in data centers continues to increase, enhancing efficiency, reducing operational cost and improving infrastructure management. In particular, the AI training market will reach almost USD17 billion, with inference chips on the cloud accounting for USD7 billion. By product type, GPUs have become the mainstream choice for AI chips and have the largest share, accounting for over 30% of the market.

Network edge AI chips are emerging

AI chip deployment is not limited to the cloud, but can also be seen in a wide variety of network edge devices such as smartphones, autonomous vehicles and security cameras. Most AI chips at the edge are inference chips, and they are becoming increasingly specialized. The AI inference chip market is expected to grow at a CAGR of 40% and reach USD2 billion by 2022.

AI chips drive smartphone ASP

AI chip vendors could benefit from the rising cost of their products. For example, Apple's A11 chip cost has risen to USD27.50. The rise in cost of AI chips will in turn increase prices of smartphones, providing smartphone manufactures with increased revenue. AI chips have also moved down from high-end phones to mid-range ones, potentially bringing even more revenue to smartphone vendors.

Inference AI chips in smartphones are now part of a three-way race between smartphone manufactures like Apple, Samsung and Huawei; independent chip providers such as Qualcomm and MediaTek; and IP license providers including ARM and Synopsys. AI chips from smartphone manufactures are typically optimized for their own phones with the goal of improving performance and user experience. However, independent chip providers could come out with better chip specifications to compete for the rest of the market.

Autonomous driving the ideal application for AI chips

Autonomous driving is not only a complex application scenario for artificial intelligence but also an important one. It is expected be a major driver for AI inference chips, with an estimated market value of USD5 billion and a CAGR of 40%.

Sensing, modelling and decision making are the three-step process normally required for autonomous driving, and inference chips are involved every step of the way. Whether they are used for environment sensing or obstacle avoidance, autonomous driving has high requirements for the computational power of AI chips.

Owning to limitations in latency, computation in autonomous driving should ideally be done on the edge rather than in the cloud because decisions need to be made in near real-time. According to Toyota, computational power of 12 tera operations per second (TOPS) is required to realize L5 autonomous driving, but most chips today are only capable of supporting 2-3 TOPS. There is a clear urgency for AI chips to migrate to the edge instead of doing the heavy lifting in the cloud.

OEMs are testing chips from vendors to identify the most suitable candidates. Large OEMs have prefer constructing their own autonomous driving platforms and purchasing AI chips separately, whereas newer OEMs normally prefer buying complete autonomous driving platforms. Over time, the number of AI applications that can benefit from local processing is likely to grow, such as Apple's Face ID.

Smart surveillance systems have high demand

Surveillance systems are getting smarter thanks to AI. The surveillance system industry has gone through three phase of transformation in the past 10 years. The first wave was the "high definition" phase, where a system is capable of recording ultra-clear videos. The second wave was the "networking" phase, where networking and interconnection capabilities are added to the system. The addition of AI can be seen as the "third wave" of transformation. AI inference chips are now added to cameras at the edge, allowing real-time processing of video data. This saves storage space on the cloud and increases the performance of surveillance systems as massive amounts of data are generated on the edge each day.

China now the hotspot for AI chips

AI chip funding activity in China has been active and M&A is also on the rise. One example is the acquisition of DeePhi, a start-up with industry-leading capabilities in machine learning, deep compression, pruning, and system-level optimization for neural networks, by global giant Xilinx. Tech giants are also getting entering the field of play, led by Alibaba, Baidu and Huawei. In particular, Huawei has lit up AI chip competition in the smartphone sector. Some Bitcoin mining equipment manufacturers are also getting into the AI optimization game.

AI companies in China are generally swift at identifying viable business applications for AI, especially business model innovation and rapid implementation. However, original AI model creation capabilities are a rarity among Chinese players, with most domestic research in AI focused on tweaking and perfecting existing models, rather than creating an original and systematic AI framework. In addition, training devoted to AI is also limited in China compared to countries such as the US.

Navigating the AI scene
The rise of artificial intelligence has certainly created new opportunities in semiconductor devices, particularly for AI chips. Semiconductor companies already in or planning to enter AI systems should adhere to the following key observations to stay competitive.

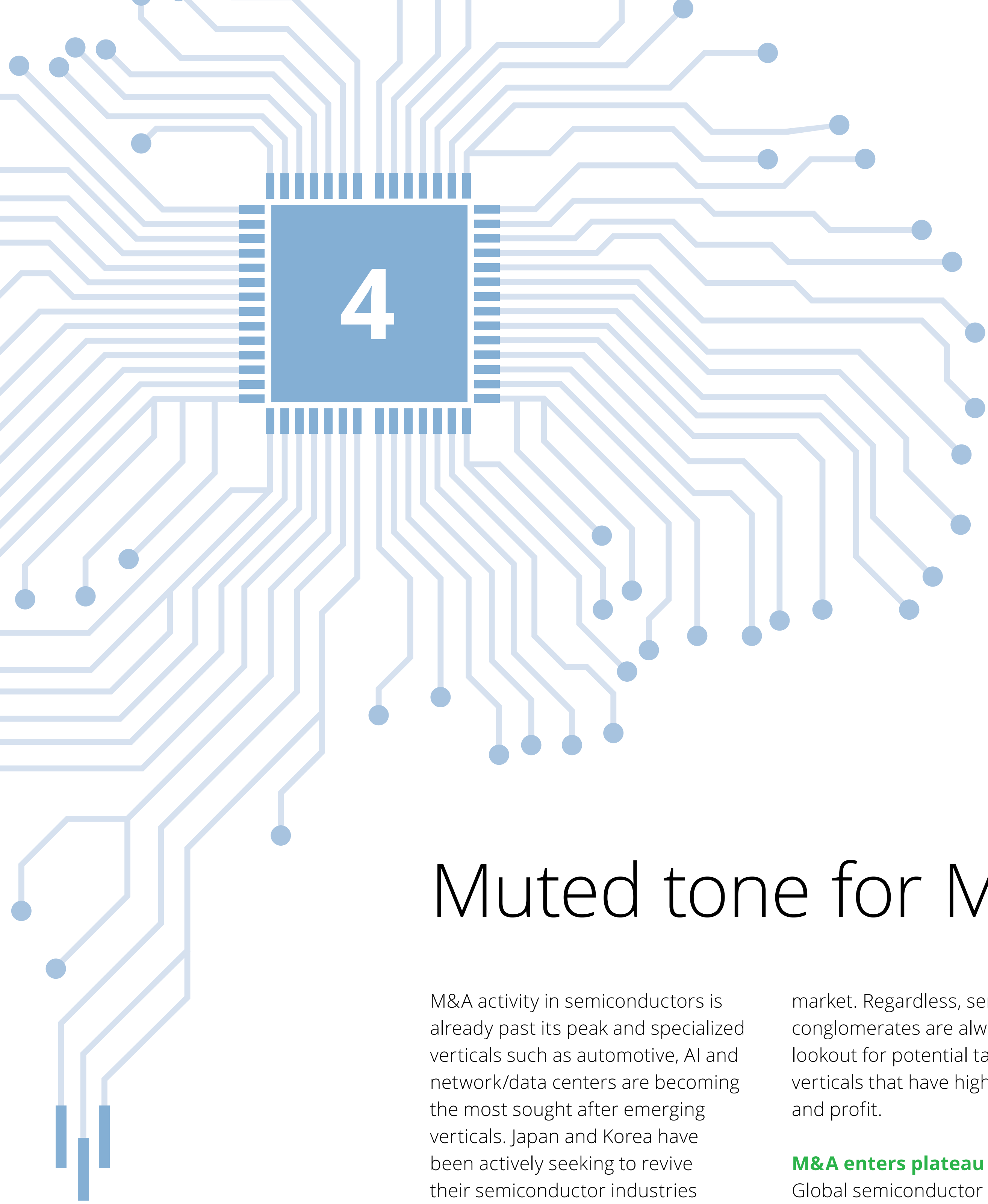
Specialization is key to AI chips: In future, AI chip companies should no longer be content just to be hardware companies, but possess a deep understanding of the requirement of their customers to create suitable products. Customers today are not just looking for a general-purpose chip with some added AI capability; they are looking to see whether it can satisfy their business requirements at a reasonable cost. They should balance power, performance and cost. Computational density (computational power per unit of power consumed) will become a core competitiveness for AI chip vendors.

Moving from the cloud to the edge: Opportunities have begun to pop up at the network edge and many large players are moving from the cloud to the edge to offer comprehensive AI solutions that span the spectrum, from training to inferencing workloads. It is worth noting that most AI systems today run on von Neumann architecture, in which processing and memory are separate. This has led to AI becoming power hungry and left neural networks stuck in the cloud. Efforts are being made to create a new architecture that allows more tightly coupled processors and memory, which improve performance and energy efficiency. The idea is to add new functions to memory that will make devices smarter without replacing the processor. The semiconductor industry should embrace such designs so AI can be brought out of the cloud and onto the edge.

Select the appropriate semiconductor process technology: Unlike CPUs, which need the most advanced processing technology available according to Moore's law, it is not always necessary for AI chips to be designed on the latest process technology due to AI's use of parallel processing. For example, 40nm and 28nm processes are sufficient to provide 1 TOPS of computational power. In addition, older-generation processes have access to mature toolsets and building blocks. Many large foundries offer a wide range of advanced process technologies, ranging from 28 nm all the way to 7 nm, depending on their mix of performance and power capability. For semiconductor vendors, selection of the appropriate semiconductor process technology should ideally be based on criteria such as computational capability and power consumption, as well as form factor.

Software tool support is essential: The amount of support semiconductor companies have for standard open-source software frameworks is key to winning the AI race, particularly for challengers trying to catch up with leaders that already support literally all deep learning software and tools for their semiconductor chips. To be a viable contender in this market, semiconductor vendors should at a minimum support major open source software frameworks such as TensorFlow, Caffe2, Theano, CNTK, MXNet and Torch. Tools to help developers build applications are also required. Semiconductor vendors will need to invest in software and collaborate with software developers to access their AI device architecture. The number of software frameworks for processing neural networks is growing. Many will be developed and released over the next few years, so there is still room for new entrants to grow.

Look for opportunities beyond AI chips: Artificial intelligence does not rely on AI chips alone to achieve its processing power. Memory is also an important component in the advancement of AI, where high throughput parallel processing places multiple strains on data bandwidth in memory systems. The demand for AI system memory will create opportunities for memory vendors. In addition, as AI systems scale up, the performance of interconnects between subsystems and devices will become a bottleneck. Thus, opportunities also exist for semiconductor vendors to create high speed interconnects to meet the demand of high volume data flowing between systems. Further, AI chips today can contain multiple processors to achieve maximum parallelism, resulting in a very large die size. This presents a great challenge for thermal and high voltage power management in which custom cooling solution may be required. This creates opportunities for packaging vendors to come up with products that have thinner form factor and less thermal dissipation for a more cost-effective solution.



Muted tone for M&A

M&A activity in semiconductors is already past its peak and specialized verticals such as automotive, AI and network/data centers are becoming the most sought after emerging verticals. Japan and Korea have been actively seeking to revive their semiconductor industries via acquisitions of mid-sized companies in the US and Europe, as well as cooperation with China. At the same time, disputes over intellectual property and national security issues will dampen China's ambition to go global. The tightening of Chinese outbound investment in high-tech companies from the US will become the new norm, shrinking the overall size of the global M&A market. Regardless, semiconductor conglomerates are always on the lookout for potential targets in various verticals that have high market share and profit.

M&A enters plateau phase

Global semiconductor M&A transactions peaked at over USD120 billion in 2016. In 2017, the value of M&A in the semiconductor industry fell sharply. In addition to fewer M&A targets due to previous transactions, tightened regulatory reviews by Europe and the US were an important factor. M&A transaction value rose again in 2018 due to value per deal. For example, US-based Broadcom acquired CA Technology for USD17.99 billion.

Figure: Global semiconductor M&A transactions (2014-2018)

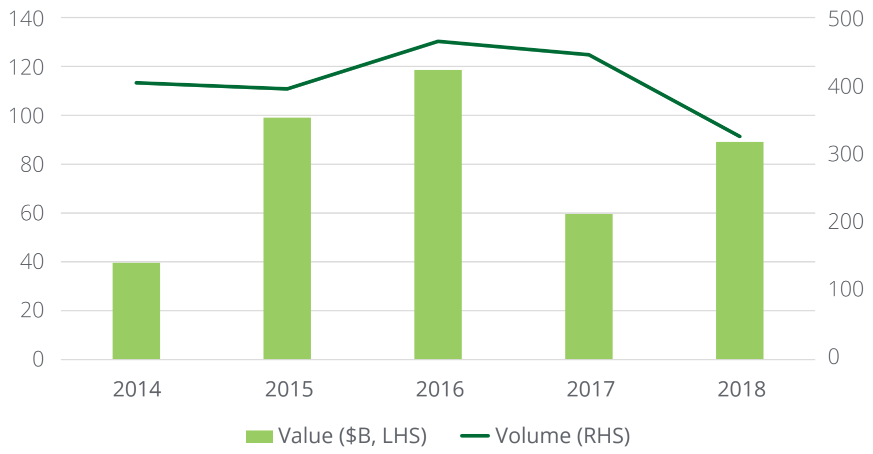


Figure: The Top 10 Global semiconductor M&A transactions (2018)

Date	Bidder	Districted bidder	Target	District of target	Value ($B)	Motivations
2018.07.11	Broadcom Inc.	US	CA Technologies	US	17.987	Expand industry supply chain
2018.03.01	Microchip Technology Incorporated	US	Microsemi corporation	US	9.836	Expand industry supply chain
2018.09.11	Renesas Electronic	Japan	Integrated Device Technology	US	7.004	Search for cutting-edge application
2018.07.25	Tsinghua Unigroup	Mainland China	Linxens Group	France	2.632	Acquire advanced technology
2018.08.15	Will Semiconductor	Mainland China	Beijing OminiVision Technologies	Mainland China	2.178	Strengthen market position and expand market share
2018.05.25	Beijing Electronics	Mainland China	Beijing Yandong Micro-electronics	Mainland China	0.626	Strengthen market position and expand market share
2018.09.14	UKC Holdings	Japan	Vitec Holdings	Japan	0.529	Strengthen market position and expand market share
2018.06.29	United Microelectronics	Taiwan	Mie Fujitsu Semiconductor	Japan	0.519	Strengthen market position and expand market share
2018.11.10	Ingenic Semiconductor	Mainland China	Beijing Xicheng	Mainland China	0.38	Expand industry supply chain
2018.01.31	GigaDevice Semiconductor	Mainland China	Semiconductor	Mainland China	0.268	Strengthen market position and expand market share

Source: Mergermarket, Deloitte

In East Asia (China, Japan, South Korea and Taiwan), M&A volume showed rapid growth between 2014 and 2015, amounting to over USD22 billion. However, after several years of rapid expansion, the pace stalled somewhat in 2017 and 2018. In 2017, the volume of semiconductor M&A in East Asia declined 1%, while value grew a modest of 2%.

Figure: East Asia (China, Korea, Japan and Taiwan) M&A transactions (2014-2018)

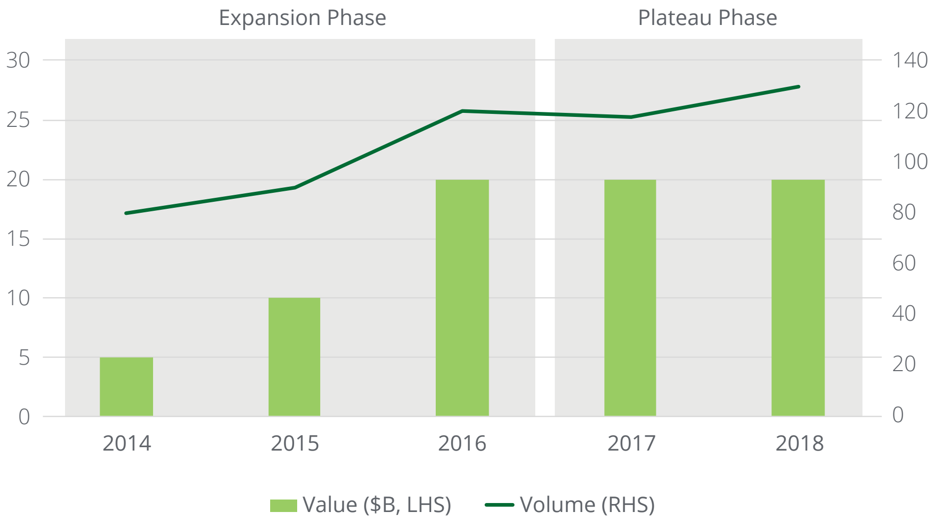


Figure: M&A transaction value - China, Japan, South Korea and Taiwan (2014-2018)

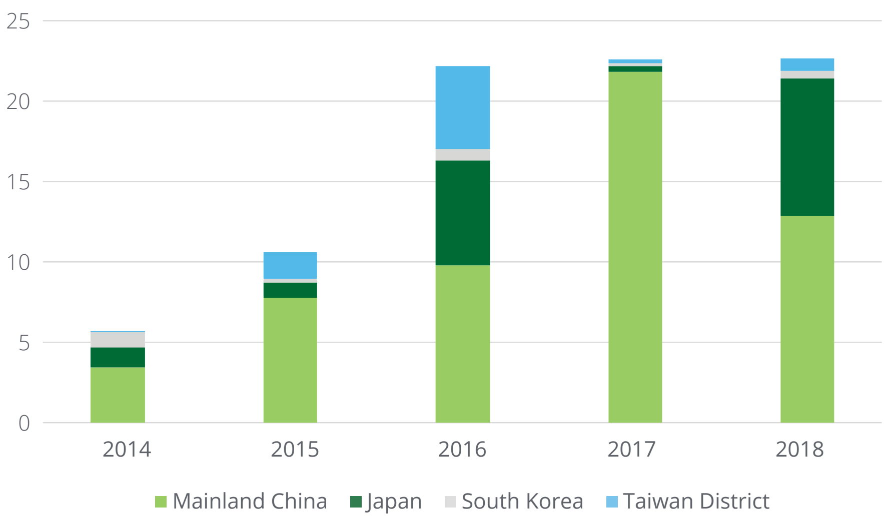


Figure: **Top 10 M&A deals in China, Japan, South Korea and Taiwan (2018)**

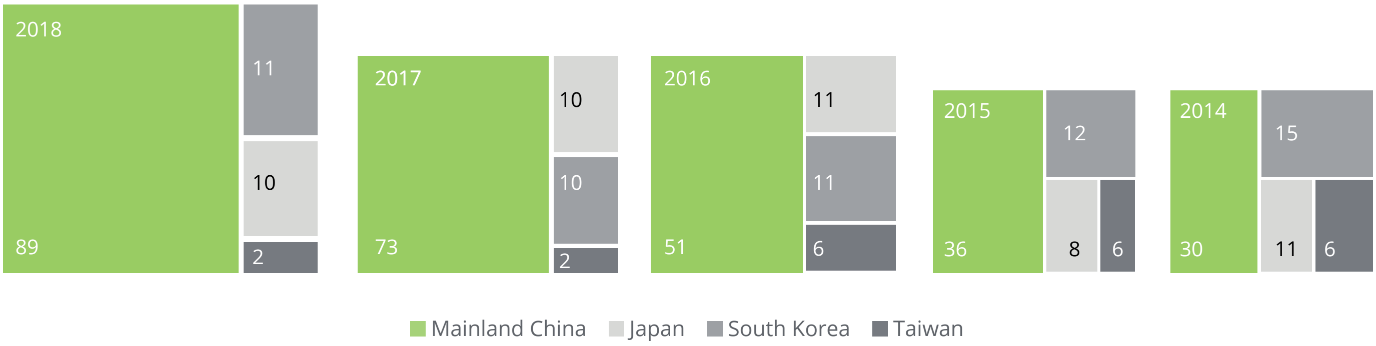
Date	Bidder	Districted bidder	Target	District of target	Value ($B)	Motivations
2018.09.11	Renesas Electronics	Japan	Integrated Device Technology	US	7.004	Search for cutting-edge application
2018.06.29	United Microelectronics	Taiwan	Mie Fujitsu Semiconductor	Japan	0.519	Strengthen market position and expand market share
2018.03.27	Advanced Semiconductor Engineering	Taiwan	Suzhou ASEN Semiconductor	Mainland China	0.127	Strengthen market position and expand market share
2018.07.10	SK Hynix System	South Korea	Hoejin Semiconductor	Mainland China	0.075	Strengthen market position and expand market share
2018.06.26	Taiwan Semiconductor	Taiwan	ON Semiconductor	US	0.006	Strengthen market position and expand market share
2018.02.09	NEC Corporation	Japan	XON Holding	South Africa	0.023	Strengthen market position and expand market share
2018.01.11	Shanghai Fortune Techgroup	Mainland China	Upstar Technology	Hong Kong	0.022	Strengthen market position and expand market share
2018.09.07	Huada Semiconductor	Mainland China	Salantro Semiconductor	Canada	N/A	Acquire advanced technology
2018.05.09	TDK	Japan	Faraday Semi	US	N/A	Strengthen market position and expand market share
2018.02.28	TDK	Japan	Chirp Microsystems	US	N/A	Acquire advanced technology

Source: Mergermarket, Deloitte

China leading the way in domestic M&A

Regardless of the volume or value of transactions, Mainland China is undoubtedly the most active region for semiconductor M&A. From 2014 to 2018, the volume of M&A in China's semiconductor industry ballooned from 48% to 72% in 2018 at a compound annual growth rate of 18%.

Figure: Domestic M&A transaction volume growth – East Asia (2014-2018)



Source: Mergermarket, Deloitte

Government policy has been the largest contributor to the rapid development in China over the past five years. China today is the largest importer of semiconductor chips globally and the government's overall strategy is to reduce reliance on foreign imports and build up its domestic semiconductor base, which has fueled Chinese companies' entrance into the industry and acquisition of advanced technologies.

In domestic M&A, Mainland China is undoubtedly the most active region in East Asia. Its M&A volume had a compound growth rate of 24% from 2014 to 2018. For example, in 2018, Alibaba acquired Hangzhou CSKY. Before this, Alibaba had invested in five chip companies: Cambrian, Barefoot Networks, Deephi Tech, Kneron and ASR.

M&A activity in Japan, South Korea, and Taiwan was relatively quiet compared to China. The main motivations for deals there are strengthening market position and expanding market share, as well as searching for emerging applications.

Outbound M&A mixed

Overall, volumes of cross border M&A from East Asia declined after 2016, particularly as the US strengthened its investigations of Chinese companies seeking leading-edge technologies. In 2017, the White House published the report, Ensuring Long-Term US Leadership in Semiconductors, which sets out the perceived threat posed by China's semiconductor policy to the United States and suggests the US government take steps to prohibit or heavily restrict Chinese acquisition, as well as tighten rules that restrict the flow of critical semiconductor intellectual property. Yet, despite increasing government reviews of M&A, North America and Europe are still the main destinations for East Asian semiconductor companies.

The motivations for M&A are clear

Semiconductor companies today are motivated to conduct domestic and cross-border M&A primarily for four reasons: to acquire advanced technology; strengthen market position and expand market share; search for cutting-edge applications; and expand their industry supply chains.

Figure: Motivations for M&A in the semiconductor industry

Source: Deloitte analysis

Acquiring advanced technology: The semiconductor industry in China relies heavily on imports. In 2018, there have been some urgent moves from Chinese tech players. For instance, Chinese semiconductor cleaning equipment company NAURA acquired Akrion, a semiconductor wafer cleaning equipment company in Pennsylvania, to expand its business into silicon wafer fabrication, MEMS and packaging, becoming the first case approved by the Committee on Foreign Investment in the United States (CFIUS) since the Trump administration took office.

Despite possessing more advanced semiconductor technology, Japan, South Korea and Taiwan are still seeking semiconductor-related technologies through M&A. Taiwan-based company United Microelectronics acquired a 84% stake in Japan-based wafer foundry company Mie Fujitsu Semiconductor for USD519m in June 2018 to enable UMC to leverage its IC production experience. Meanwhile Taiwan Semiconductor Company acquired US-based ON Semiconductor for USD6M to expand its semiconductor application portfolio and strengthen its core business.

Strengthening market position: By acquiring competitors, enterprises play a synergistic role to increase market share and enhance profitability. In 2018, Shanghai Will Semiconductor acquired a 85% stake in Beijing SuperPix Micro Technology and a 96% stake in Beijing OmniVision Technologies for USD2.18bn to take advantage of the high-end technics of OmniVision and cost control capabilities of SuperPix. M&A also paves a path to quick market entry, particularly overseas. South Korean foundry SK Hynix acquired a 50% stake in Chinese foundry company Haejin Semiconductor (Wuxi) by investing USD75m as a strategy to expand its foundry business. China-based company Huada Semiconductor has acquired Canadian Solantro Semiconductor, which designs integrated circuits, to establish and grow its presence in Ottawa.

Accessing emerging sectors: The rapid development of emerging technologies such as artificial intelligence and autonomous driving has greatly stimulated demand for semiconductor chips. Chip companies are now expanding their business areas to emerging sectors through M&A. For instance, Samsung Electronics has acquired Haman, one of the largest suppliers of connected, intelligent automotive component globally. In 2018, Japan-based developer and manufacturer of semiconductors Renesasa Electronics acquired US-based company Integrated Device Technology (IDT) to enhance its competence in self-driving car technology.

Expanding industry supply chain: The semiconductor industry chain includes design, manufacturing, packaging and testing from upstream to downstream. By entering other parts of the value chain, incumbents not only create new revenue streams, but also create synergies. In 2018, Ingenic Semiconductor, the leading embedded CPU chip and solutions provider in China, acquired a stake in Beijing Xicheng Semiconductor, which will enable Ingenic to expand into the high-end memory chip business.

Look out for M&A risks

Despite the many benefits of M&A, a host of issues can arise pre and post- merger, including mistakes in judging the target, failure to conduct detailed due diligence and poor implementation.

Risks Related to M&A Target Screening and Valuation

The Chinese technology industry faces various political and legal risks in overseas M&A. Governments in the US and Europe have very tight restrictions on foreign acquisitions or investments, especially in semiconductors as a high-tech industry. It will be difficult for Chinese companies to acquire high-tech companies with the advantage of high technology and high commercial value, which can increase the difficulty of selecting M&A targets. In addition, although Chinese enterprises can obtain intangible assets (such as technology and brand) and advance their industry level by acquiring foreign enterprises, the premium paid is generally high, which brings substantial operational and financial risks to Chinese enterprises. High financial leverage is the most significant characteristic of overseas M&A for Chinese enterprises. And high leverage inevitably brings high risks. If M&A fails or companies fail to integrate, leading to losses, M&A companies will face great financial risks.

Risks Related to Financial Information and Due Diligence

Compared with domestic M&A projects, overseas M&A projects have a different quality of financial information, interpretation, supply method and verification. Accordingly, due diligence procedures should be reasonably arranged to deal with these differences.

M&A involving foreign semiconductor companies needs to focus on the risks in shareholders' backgrounds:

1) Small and medium-sized enterprises managed by founders: these companies often do not pay enough attention to daily accounting, have relatively confused financial data, and do not employ well-known accounting firms to audit their financials. It is difficult to obtain financial data to conduct business analysis through written materials.

2) Private-equity fund management enterprises: Private-equity funds tend to plan business expansion in the early stage, and sell at better performance points. Therefore, financial data is detailed and comprehensive, corresponding written materials are available and financial data is highly authentic. However, good historical financial performance can often be caused by short-term incentives. Although current profits are high, the development prospects may be limited.

Risks Related to Overseas M&A and Integration

There are many challenges for cross-border mergers and acquisitions in the process of transaction and integration, including the complexity of restructuring, lack of local integration resources and teams, management of external stakeholders and loss of talent, differences in management information systems, and differences in culture, salary and welfare systems. Specifically, these include:

Differences in culture and subsidy benefits systems: Different performance appraisal systems will have an impact on employee performance. Generally, the higher the degree of company localization, the lower the basic wage and the higher the sales commission; whereas the basic wages of foreign enterprises are generally higher and sales commission relatively low; these differences may cause inequalities in wages and subsidies in the integration of two enterprises, affecting the enthusiasm of employees.

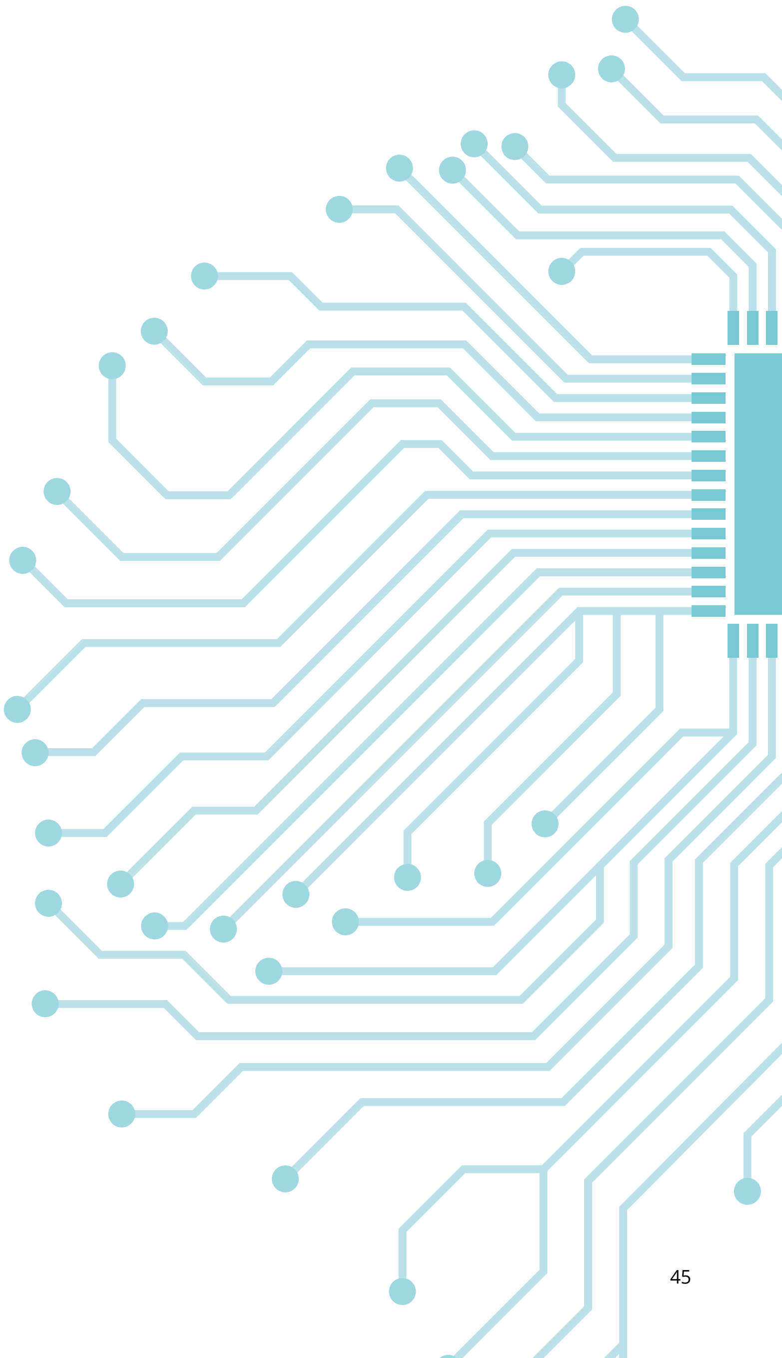
Brain drain and management: M&A can result in the loss of core managerial personnel, thus affecting the normal operations of a company's business. Core personnel include: people who master key technologies/processes, those who master government and customer resources. Senior managers with multiple roles will have greater resistance to corporate restructuring. A company is likely to lay off employees after reorganization and its leadership responsibilities can change.

Complexity and chain reaction in restructuring: Foreign labor laws highly favor the employees' side; if restructuring could cause social instability, local governments might interfere with factory relocation/restructuring plans.

Lack of local project teams with the function of supervising the reorganization process: M&A and reorganization projects are typically headquarters-led, but a lack of local team participation can lead to local problems that cannot be submitted to a preparatory committee for resolution; a lack of local team leadership will reduce the effectiveness of the implementation of a reorganization plan. Language and cultural barriers can hinder project teams' ability to communicate effectively with local staff.

Low-efficiency in external stakeholder management: customers and suppliers may think restructuring will bring uncertainty to a company's business, and lose confidence in cooperation or confuse future partnerships; disruption of supply flow and customer losses may be difficult to reverse; competitors could seize the opportunity to compete for passenger flow during the restructuring run-in period.

Differences in management information systems: Most Chinese companies adopt a native enterprise resource planning (ERP) system, such as UFI, which will hinder information sharing with companies using Oracle/SAP ERP systems to a certain extent, resulting in some delays in information reception and operation.



Accessing the Chinese market

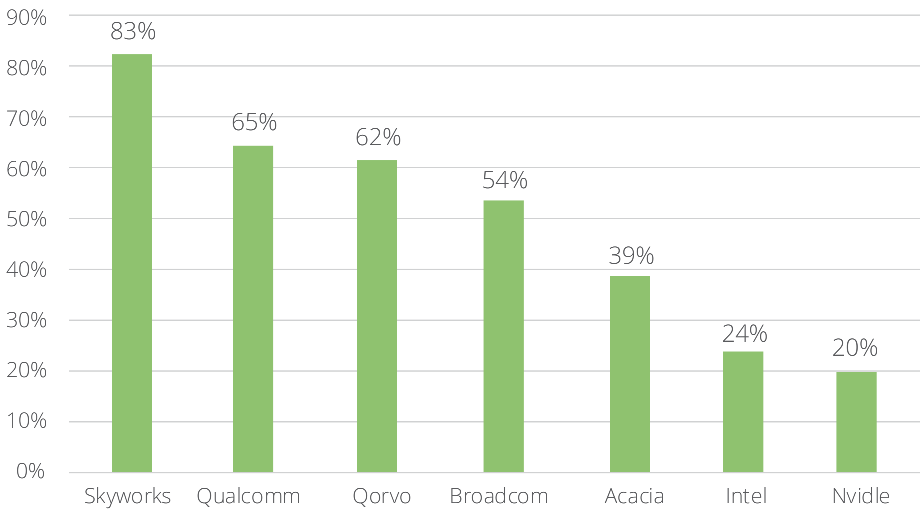
Semiconductor cash cow for MNCs
China is expected to maintain its position as the world's largest semiconductor consumption market. In 2018, China's semiconductor consumption accounted for 41% of the global total. Commercialization of artificial intelligence, adoption of the Internet of Things and 5G will further drive growth. By 2024, China will account for 57% of global semiconductor consumption.

It is no surprise then that China is a source of income for many of the top global semiconductor companies, several of which generate over half their revenue from China. Qualcomm, for example, gets 65% of its revenue from China.

No one-size-fits-all solution for market entry

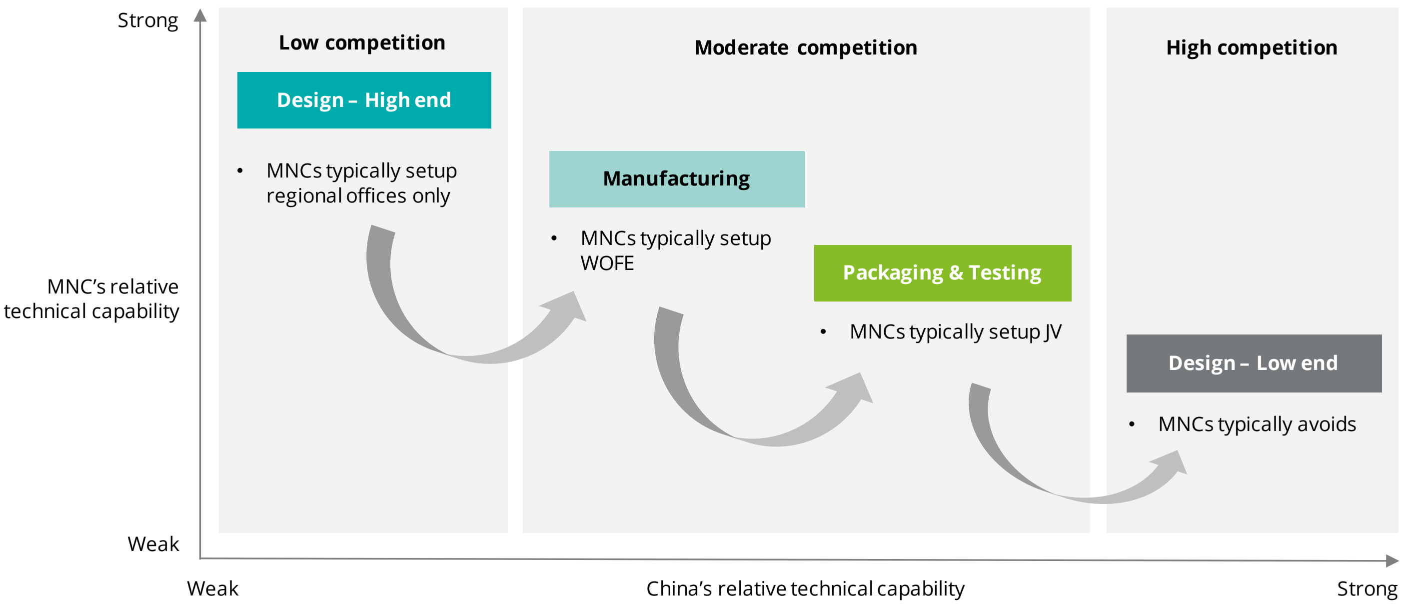
Multinationals trying to access the Chinese market should consider a multitude of factors such as policies, technologies, marketing, logistics and global strategies. It is also important for multinationals to realize the position they are in before entering China to come up with the best entry strategy. Obviously, there is no one single correct method, but in general, MNC's technology status as well as China's domestic technology status play a crucial role. When an MNC has the upper hand in technology, it has higher bargaining power and will have less incentive to share intellectual property. However, MNCs might altogether avoid cases where domestic players are already strong. For instance, China is relatively weak in the high-end design of semiconductors and manufacturing, and competition is not high, so MNCs typically set up regional offices or a wholly foreign-owned enterprise (WFOE) to access the market. In areas where China is relatively strong such as packaging, testing and low-end design, MNCs may opt to setup a JV or avoid the market altogether.

Figure: Semiconductor MNC revenue from China (2017)



Source: Mergermarket, Deloitte

Figure: MNC's position/involvement in the Chinese semiconductor industry



Source: Deloitte analysis

Regional office: This model is generally applicable to sectors where technology is completely monopolized by MNCs. There is little incentive to share. For example, Qualcomm has established regional offices in Beijing, Shanghai, Shenzhen and Xi'an.

WFOE: Leading semiconductor MNCs are keen to set up wholly owned plants to meet the enormous demand for semiconductors in China. Overseas foundries from Taiwan, South Korea, and the United States have set up new plants to increase production capacity in China. For example, TSMC will build a 12-inch wafer plant in Nanjing, and its production capacity will reach 20 thousand/month. SK Hynix also plans to build a production plant in Xi'an, with a capacity of 168 thousand/ month.

Company	Headquarter	Location	Capacity (thousand /month)	Commissioning date
TSMC	Taiwan	Nanjing	20	2018
Powerchip	Taiwan	Hefei	10	2018
AOS	US	Chongqing	20	2018
Intel	US	Xi'an	100	-
SK hynix	South Korea	Wuxi	168	2018
Sumsang	South Korea	Xi'an	-	2014

Source: SEMI, company websites, Deloitte analysis

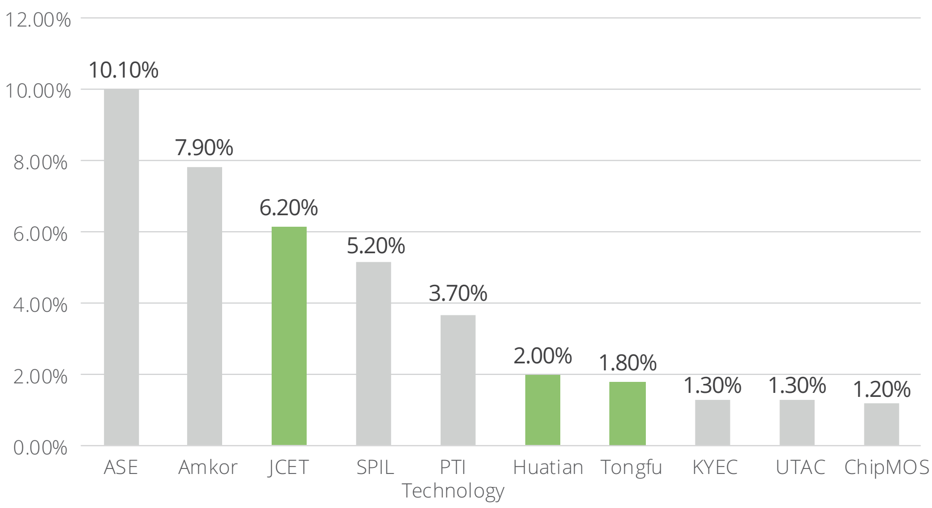
Joint ventures: China, Taiwan and the United States hold the leading positions worldwide in semiconductor packaging and testing. From 2010 to 2016, the output value of China's local packaging and testing industry increased from RMB62.9 billion to RMB156.4 billion at a compound annual growth rate of 20%, higher than the global average. As of 2017, there are three domestic companies in the top 10 globally, namely CJCET, Huatian and Tongfu.

Given local semiconductor companies have become among the best in the packaging and testing sectors, MNCs can further enhance their technology via cooperation with local companies. In 2016, AMD and Chinese advanced technology company Nanjong Fujitsu Microelectronics Co. established a joint venture enterprise, which absorbed the R&D team and advanced equipment assets of AMD in Suzhou and Penang, Malaysia to become the world's top packaging and testing company.

In essence, an MNC has to consider its competitiveness and the strategic value of the Chinese market. Unlike domestic players, MNCs' China initiatives are heavily influenced by their global strategies, which determine their next steps. The majority of MNCs' participation comes in areas where their competitiveness and the strategic value of China are both high. But, there are other options. For instance, if an MNC possesses a strong ability to compete even though the strategic value of China is relatively low, it can take an "opportunistic harvest" approach to select favorable businesses in which minimal incremental investment is required. On the other hand, if the market is already competitive and the strategic value of the market is still high for China, aggressive localization opportunities might be needed to maximize value. In the worst case, where an MNC's capability and strategic value are both low, the MNC should exit the market.

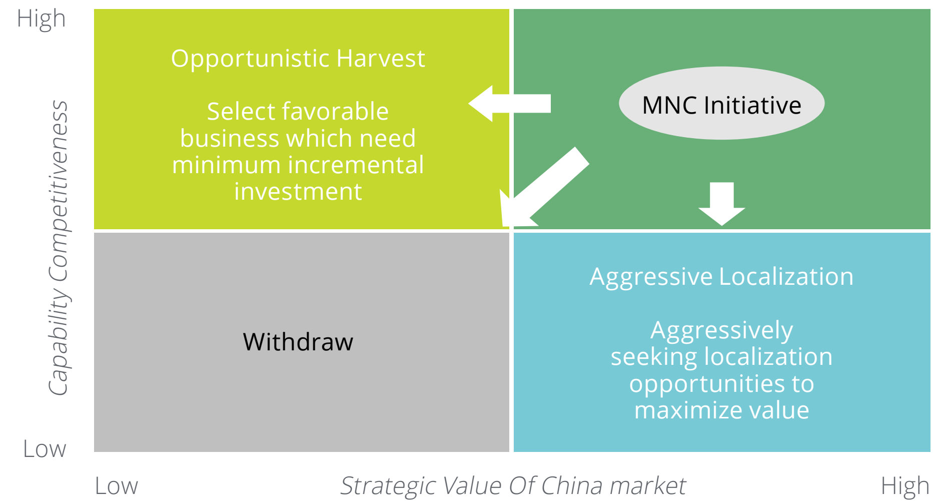
For example, some MNCs gave up medium to low-end cell phone business to focus on advanced, high-end cell phones. Meanwhile, other MNCs cooperate with local IT giants to localize hardware and software technologies, in order to avoid regulatory restraints. Meanwhile, many MNCs have exited China's mobile phone market and withdrawn their investments in JVs.

Figure: Top 10 packaging and testing companies worldwide (2017)



Note: Taiwan based SPIL was acquired by ASE in 2018.
Source: Founder Securities, Deloitte

Figure: MNC's China initiatives



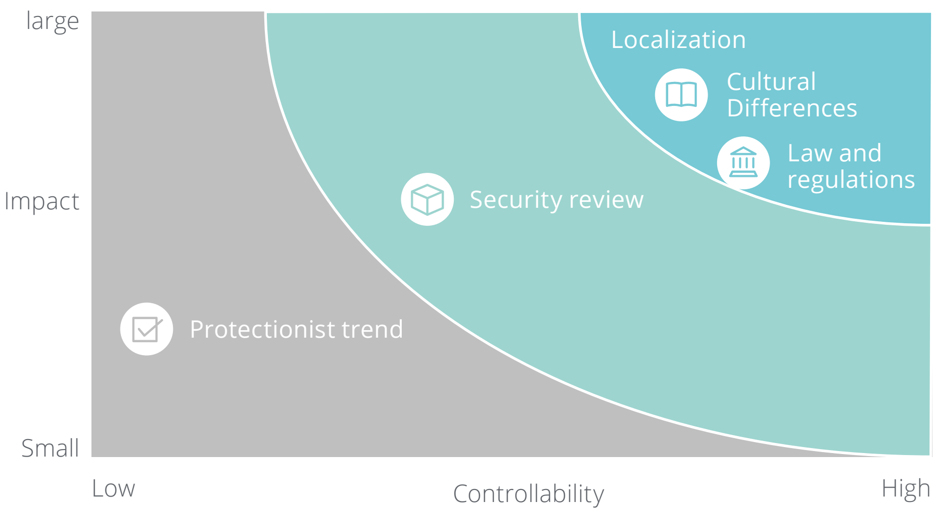
Note: Strategic Value:

- Direct financial value contribution amongst its global portfolio;
- Indirect value (e.g. cost saving by local production, PR building with government for other product sales)

Source: Deloitte Analysis

Navigating risks and challenges
Multinational companies from other countries or regions will encounter a series of challenges when entering Mainland China, due to various differences in culture, laws and regulations. By differentiating the two dimensions of impact and controllability, we have identified four major issues MNCs can encounter.

Figure: Challenges foreign MNCs can encounter:



Notes: Impact denotes the degree to which a certain risk will influence a deal; Controllability measures how well companies can control specific risks.

Source: Deloitte

Cultural differences can hinder multinational companies from obtaining the expected returns. When a foreign company completely replicates its business model in China, its corporate culture and working methods will also be brought in, which will create cultural conflicts and thus become a risk factor for the company's business activities. Completely copying rather than understanding the business model of Chinese companies will also bring certain risks. Moreover, with the expansion of their businesses, overseas companies also need to consider recruiting talent that is familiar with foreign corporate culture and language, and at the same time proficient in the business. It is therefore a challenge to build a talent system that is in line with the business development and corporate culture in Mainland China. At the same time, given laws and regulations in Mainland China are different from those in other countries, so foreign companies entering the Chinese semiconductor market face compliance challenges.

Compared to localization, the trend towards protectionism means security reviews are less controllable and have a greater impact. Since the ZTE event, the Chinese government and enterprises have fully realized the importance to national security and economic development of developing a complete semiconductor industry with advanced technology, and have begun to invest heavily in the semiconductor industry to achieve semiconductor localization. Once Chinese companies make breakthroughs, local products should quickly occupy almost the entire market, which would spell bad news for MNCs.

Digitalization is key to competitiveness

Semiconductor companies tody must be more rapid and agile than ever to remain competitive. The commercialization of new technologies such as AI and big data is promoting the digital transformation of enterprises and the realization of intelligent production, intelligent management and intelligent sales. By investing in digital infrastructure to increase productivity and develop new business channels, companies will have the opportunity to overcome development barriers and digitalization will provide new impetus for their development.

Digital transformation has become the main strategy for many enterprises to meet the challenges they face. For example, the digital transformation of the retail industry has penetrated all areas of the value chainInvolving consumer-oriented demand forecasting, personalized marketing, purchasing experience and intelligent customer service. The main aim is to continuously improve efficiency and effectively attract consumers.

The foundations of digitalization are sound, as chip processing capacity, cloud service popularization, sensor and other hardware prices have declined and computing power has improved a great deal. From the application perspective, technology companies have provided the market with various data analysis tools to improve data utilization rate, improve operational efficiency and reduce production costs.

Many semiconductor companies are already utilizing digital tools to gain competitive advantage throughout the product life cycle. For example, the application of AI and analytical tool applications in the semiconductor industry extends from design, manufacturing, packaging and testing all the way to management.

Figure: Digital tools utilized by semiconductor companies

	Current situations	Improvement
Design	• Companies have to correct errors in physical designs (R&D) • Hard to find errors based on past experience (Upgrade)	• Correct design errors using virtual tools • Obtain data from device and tool to find out the factor creating mistakes and instruct next design
Manufacturing	• Data generated from each devices cannot be connected • Manual maintenance are required and cannot predict the machine failure	• Connect data from all equipment and create data set • Analyzing data set to predict the equipment failure in advance
Packaging and testing	• Consume a lot of time during testing	• Build plat platform for data sharing between testing companies and component suppliers • Reduce the time required to achieve acceptable shipping quality
management	• Pricing based on subjective opinions • Difficult to obtain data from other players along the supply chain • Hard to spot potential customer and provide service for them	• Data-based analysis could provide more accurate information for pricing • Create system to track all information related with chip and make it easier to find mistake • Spot potential customers that could contribute more on revenue

Source: Public information, Deloitte

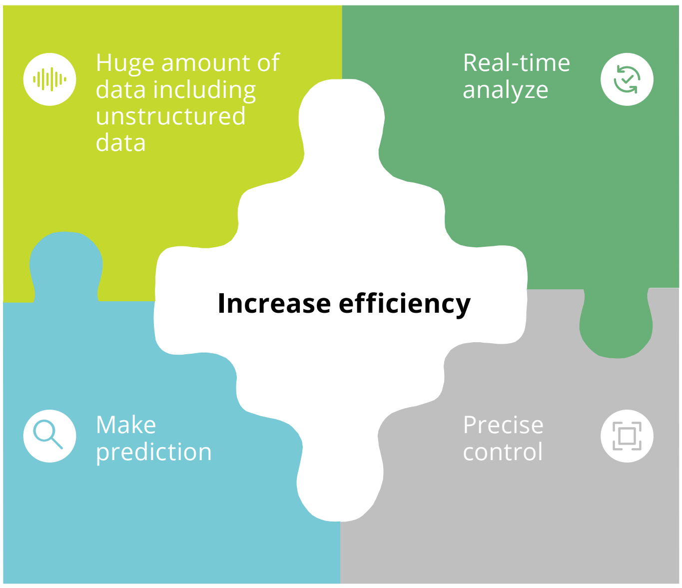
Artificial intelligence paves way for efficiency

AI technology will play an indispensable role in all aspects of semiconductor production and company operations. Massive amount of data is generated in the semiconductor manufacturing process and traditional data analysis methods can only utilize parts of the structured data for post-mortem analysis. But intelligent analytics based on AI can perform comprehensive real-time analysis of data sets to improve production and management efficiency.

Design: Artificial intelligence can alter the process of design. Each step in the semiconductor design produces a large number of parameters. Unlike traditional analysis tools, new analysis technology can help semiconductor designers comprehensively analyze all the data they obtain, and learn from experience, as well as analyze past data and extract relationships from the data and results. Whether it is high frequency or low- to medium-frequency data, data combination can be used to spot potential errors and increase yield, providing insights into newly generated data to make decisions or correct errors by simply changing a certain parameter. In addition, using data as a basis for decision-making can avoid communication barriers between design teams and process teams. .

Some leading Japanese semiconductor firms have already used AI extensively in the manufacturing process. For example, in the manufacturing and transportation process, a large amount of images and vibration data are collected and analyzed, and the effect of improving productivity and yield is already shown. The adoption for AI at the moment is mostly concentrated in manufacturing, but it will be relevant in various fields in the future such as quality control and demand forecast.

Figure: The benefits AI brings to semiconductor manufacturing



Source: Deloitte analysis

Manufacturing: In the manufacturing process, data generated by each process are shared, as well as directly analyze and report errors, thereby reducing manual inspections that may contain errors, and improving efficiency. An AI system can check data thousands of times in a minute, providing nearly 600 times the efficiency of staff. AI detection and maintenance system connections cover the entire process of production data, and can build real-time predictions about equipment failures, reducing losses caused by production interruptions.

Packaging and testing: The full use of data shortens testing time and accelerates time to market. Data integration and connectivity can greatly improve data utilization efficiency. On one hand, building a data exchange platform between semiconductor testing companies and component suppliers can enable the causes of errors to be found in time, and on the other hand, it can reduce the number of malfunctioning chips. These platforms have reduced the number of malfunctioning chips by 50%.

Management: An AI customer service system starts with semantic understanding and problem identification derived from customer questions, searches for big data in the identified problems, analyzes the meaning of the problem, produces a knowledge map and performs answer matching and decision-making. An AI customer service system realizes 24-hour customer service online, answers questions at any time, improves customer satisfaction and saves the labor costs of semiconductor enterprises, as well as frees staff from boring and high-pressure work to do more valuable work.

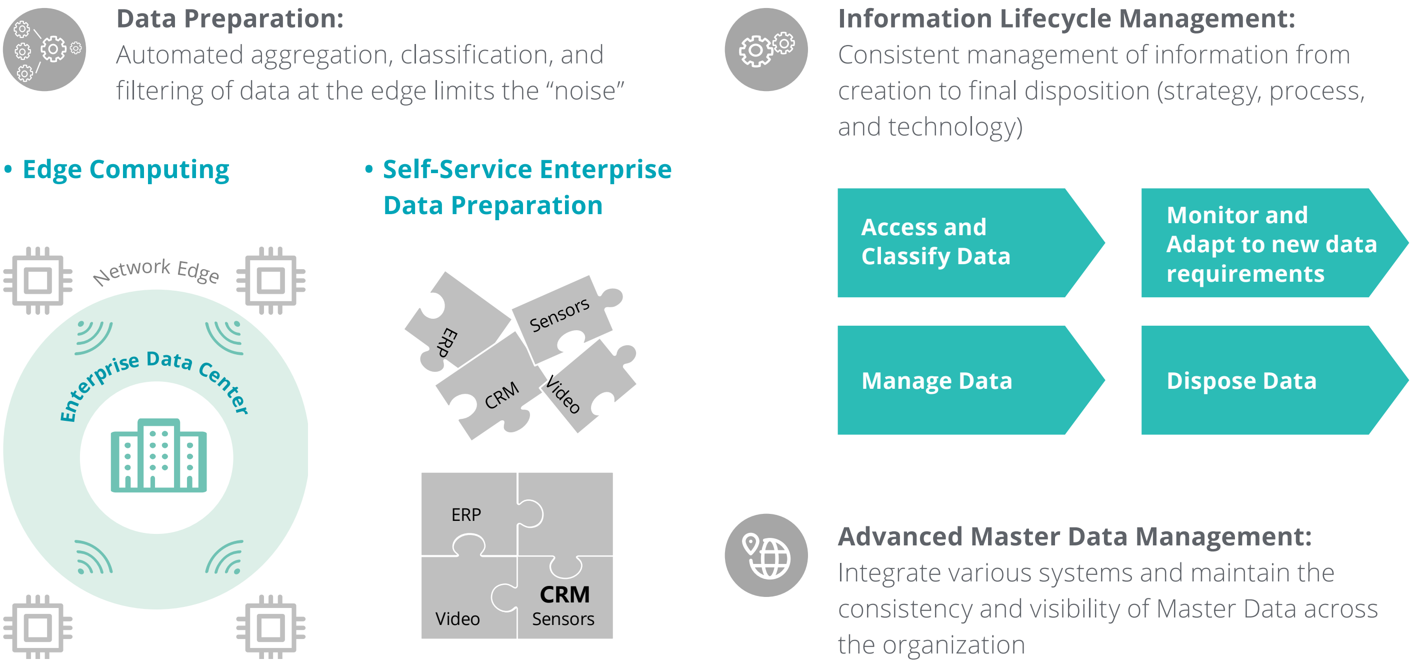
Analytical tools to know customers better

Analytical tools are mainly being used in management, including decision-making and customer development. Data-driven decision support has undoubtedly become an important strategy to help semiconductor companies gain insights into potential customers, thereby making more rational decisions and reaching out to more customers. The application of data analysis tools includes information on changes in enterprises' daily income and the corresponding sales data. Combined with customer information and external auxiliary data, analytical tools can provide strategies and suggestions for the pricing of semiconductor products and form a smart pricing plan. A large amount of data is generated in interactions with customers. Through the continuous accumulation of customer demand data, a company can analyze and understand preferences and needs in depth, as well as support precision marketing and large-scale personalized recommendations and services.

Master data management (MDM) is important

Master data management involves data collection, classification, management, cleaning and other areas within different organizations. It is the basis of AI data analysis and various data analysis tools.

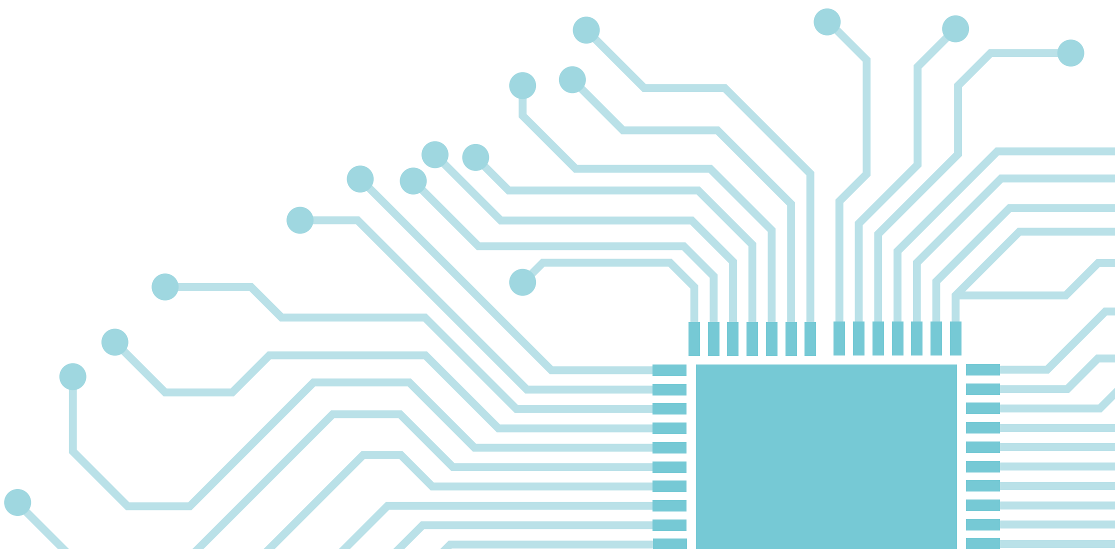
Figure: Master data management



Source: Deloitte analysis

The digitization of semiconductor companies is based on the use of data, as well as more refined management of enterprises' production and operations. Can the data generated by various sensors and smart devices be stored in the data set in time? How is the data classified? How can structured and unstructured data be managed and cleaned? How is the data from each area shared? MDM can solve all of these issues.

In the semiconductor design and manufacturing process, MDM can alsoprovide intelligent device data-to-data analysis. In the packaging and testing process, it can link the data of packaging and testing enterprises and component suppliers. In management processes, it can deal with business operations and financial data.



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