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Semiconductors and how the trade war with China could lead to a war on raw materials in a bi-polar world

The chip industry in a nutshell

In general, there are three types of chips: **Processing Chips**, such as microprocessors Central Processing Units (CPUs) and Graphic Processing Units (GPUs) which are more complex chips than Commodity Integrated Circuits (CICs), such as Application Specific Integrated Circuits (ASICs) or Micro Controller Units (MCUs), which perform single repetitive processing routines, for example bitcoin mining, or Field-Programmable Gate Arrays (FPGAs), which are customized to a manufacturer's specifications, **Memory Chips**, such as Dynamic Random Access Memory (DRAM), used for fast, flexible and temporary memory for processing data and running applications and NAND/NOR flash, ideal for large, stable and permanent storage, and **Analog Chips**, which can read and process waveforms such as speech, music and video, creating a bridge to the digital world[1]. Furthermore, there are Mixed Circuit Semiconductors (MCS), such as Analog-To-Digital (ADC) converters, Digital-To-Analog (DAC) converters and Digital Signal Processors (DSPs), which all process analog signals, and so-called System on a Chip (SoC), which is a single chip that combines all three main types of chips in one. Processing chips remain at the front of cutting-edge chips and Artificial Intelligence (AI) that is run on CPUs and GPUs makes use of two types of chips, which are both designed to accelerate AI workloads: Neural Processing Units (NPUs) and Tensor Processing Units (TPUs). TPUs are solely developed by Google and are specifically designed to accelerate deep learning tasks that focus on mathematical operations, such as matrix multiplications and convolutions. NPUs, on the other hand, can be developed by any company and have a broader range of deep machine learning applications compared to TPUs[2]. Last but not least, there is the Cryptographic Accelerator, which is similar to a general-purpose CPU, but works much more efficiently. Finally, there are Sensor-Integrated Chips, which combine sensor technology with processing capabilities on a single chip.

[1] The Main Types of Chips Produced by Semiconductor Companies (investopedia.com), "Chips Wars" by Chris Miller

[2] https://www.bizety.com/2023/01/03/ai-chips-npu-vs-tpu/

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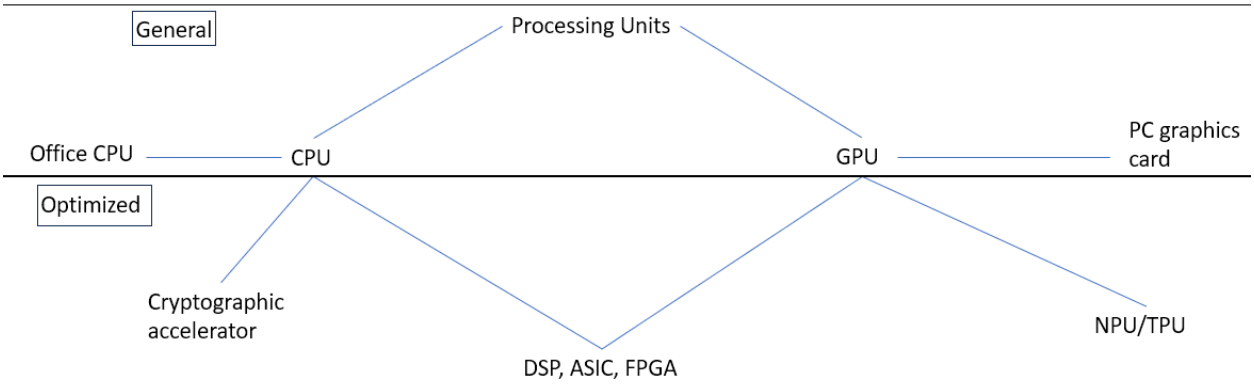
Processing Chips and how it all fits together

How it all fits together:



Cryptographic accelerators and NPU/TPUs can be seen as highly specialized CPUs and GPUs respectively, and perform much faster then them at some specific tasks

DSPs, ASICs and FPGAs may be faster at tasks that draw on both the CPU and GPU simultaneously, or individually. Due to the reprogrammable nature of FPGAs, what they are optimized for can be changed, unlike ASICs or DSPs

Top high-end chip makers

Chip type	Design company	Country of design	Manufacture country	Manufacture company	Nano-metres
CPU	Intel	USA	USA	Intel	10nm
CPU	AMD	USA	Taiwan	TSMC	5nm
GPU	AMD	USA	Taiwan	TSMC	5nm
GPU	Nvidia	USA	Taiwan	TSMC	5nm
DRAM	Samsung	South Korea	South Korea	Samsung	12nm
DRAM	SK Hyinx	South Korea	South Korea	SK Hyinx	10nm
DRAM	Micron Technology	USA	USA	Micron	14nm
SSD	Samsung	South Korea	South Korea	Samsung	5nm
SSD	Kioxia (Toshiba spinoff)	Japan	Japan	Kioxia	14nm
SSD	Western Digital	USA	Thailand	Western Digital	8nm
ASICs	Bitman Technologies	China	Taiwan	TSMC	5mm
ASICs	Canaan Creative	China	Unknown	Unknown	7nm
SoCs	Qualcomm	USA	Taiwan	TSMC	4nm
SoCs	MediaTek	Taiwan	Taiwan	TSMC	4nm
SoCs	Samsung	South Korea	South Korea	Samsung	4nm

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TPU	Google	USA	Unknown	Unknown	7nm
FPGA	Xilinx	USA	Taiwan	TSMC	20nm
FPGA	Intel	USA	USA	Intel	10nm
FGPA	Lattice Semiconductor	USA	Unknown	Unknown	28nm
DSP	Texas Instruments	USA	USA	Texas Instruments	28nm
DSP	Analog Devices	USA	USA	Analog Devices	28nm
NPU	Huawei	China	Taiwan	TSMC	7nm
NPU	Apple	USA	Taiwan	TSMC	5nm
Cryptographic Accelerator, ASIC	Infineon	Germany	Germany	Infineon	28nm
Cryptographic Accelerator, ASIC	NXP Semiconductors	Netherlands	Taiwan	TSMC	5nm
Sensor-Integrated chips	STMicroelectronics	Switzerland	Unknown	STMicroelectronics	Not specified
Sensor-Integrated chips	Bosch Sensortec	Germany	USA	Bosch Sensortec	Not specified
Sensor-Integrated chips	Texas Instruments	USA	USA	Texas Instruments	45nm

Source: Individual companies

Which industry uses what chips and where does China fit in

Chips are quite simply being used everywhere. That is whenever you need screens, buttons, communication or digital transactions. Oil is known as the commodity that makes the world move. However, in today's world you might instead say it is semiconductors that moves the world. And while oil is a US$2.8trn industry at 102mio bopd consumption at $75/bbl, the chip industry was only worth around US$600bn in 2022[3](keep this in mind though, as this value could quickly grow to a multiple when the currently smooth supply chains are broken apart). At the same time, China imports nearly 1/3 of the annual semiconductor production, which is almost the same value of annual oil imports, and therefore it is their second largest imported product[4]. In effect, China imports raw materials and semiconductors, builds the products and then exports them to the world. Therefore, China is a key customer for chip designers and manufacturers and critical in developing chips further, as this revenue gets translated into more R&D spend. If China was to become self-sufficient on chips and, similarly as say the solar industry,

[3] infineon.com/dgdl/2023-05-04+Q2+FY23+Investor+Presentation.pdf?fileId=8ac78c8b8779121b0187e2f1daad0043

[4] China (CHN) Exports, Imports, and Trade Partners | OEC - The Observatory of Economic Complexity

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where huge state subsidies made Chinese producers more competitive globally, capturing nearly the entire global market share, it could become a big problem for the Western chip producers. The US would be particularly hard hit, as China could become a serious military power with the use of the latest high-end chips and could even challenge the US as a major military exporter to the world.

Chips used by industry and product

Industry	Chips	Used for
Consumer Electronics	Microprocessors	Smartphones, tablets, laptops, smart devices
	GPUs	Gaming consoles, high-end graphics cards, video editing applications
	SoC	Smartphones, smart TVs, portable devices
Automotive	MCUs	Engine control units, braking systems
	ASICs	Advanced driver assistance systems, infotainment
	FPGAs	Computing platforms, autonomous driving systems, in-vehicle networking
Health Care	ASICs	X-ray, MRI scanners and other medical imaging devices
	DSPs	Signal processing, such as digital stethoscopes and electrocardiograms
	MCUs	Insulin pumps, pacemakers and glucose monitors
Aerospace and Defense	FPGAs	Aerospace systems for image processing, radar systems and communication
	DSPs	Real time signal processing and communications
	Radiation-hardened chips	Satellites and space exploration
Financial Services	ASICs	Financial algorithms and crypto mining
	GPUs	Complex financial modeling and data analysis
	Secure chips	Enxryption and secure transactions in payment systems
Energy and Utilities	PMICs	Efficient power management and regulation in energy generation, distribution and storage systems
	DSPs	Smart grid systems for real-time monitoring, data analysis, and optimisation of energy distribution
Mining	PLCs (ASIC)	Control and automate machinery, such as excavators, conveyor belts and drilling equipment
	Sensor Interfact Chips	Monitoring environmental conditions, equipment performance, and worker safety
	MCUs	Integrated into mining equipment and vehicles for control systems and data processing
Oil and Natural Gas	FPGAs	Real -time data processing and control in exploration, refining and distribution
	Communication Chips	Secure and reliable communication between remote facilities and central control centres

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	Digital Processors	Downhill drilling tools, sensors for data acquisition, analysis, and exploration & production processes
Industrial Automation	PLCs (ASIC)	Automation and control of manufacturing processes, assembly lines, and robotics
	Industrial Ethernet Switches	High-speed and reliable communication networks in industrial automation systems
Telecommunications	ASICs	Network equipment, including routers, switches and optical transceivers
	DSPs	Telecommunication systems for signal processing, voice compression and data transmission
	Network Processors	Packet processing, traffic management, and security in high-speed data networks
		*PLCs = Programmable Logic Controllers

Source: 14 different sources, including Intel, BAE Systems, ScienceMuseum.org, Arm

The chip manufacturing process

Not all chips are manufactured in exactly the same way, and the details of how each step is conducted do vary. Below is an outline of a "typical" process:

1. Chip Design

During this stage, engineers create the blueprint of the chip's architecture and functionality. They use Computer-Aided Design (CAD) tools to design the intricate circuitry and logic gates that make up the chip[5]. In the past, many chips were designed and manufactured by the same company. This has changed in recent years, as companies prefer to outsource the capital-intensive manufacturing of the chips (mostly to TSMC in Taiwan) and spend more capex on R&D for chip design. The top 15 chip designers are mostly based in the US, South Korea, Europe (Netherlands or Germany), Taiwan and Japan (top 20). China's Huawei was a major chip designer as well, but got crushed by US sanctions from 2019 until this day[6].

[5] "Chip Design" by anysilicon - https://anysilicon.com/chip-design/
[6] Huawei ban timeline: Detained CFO makes deal with US Justice Department - CNET

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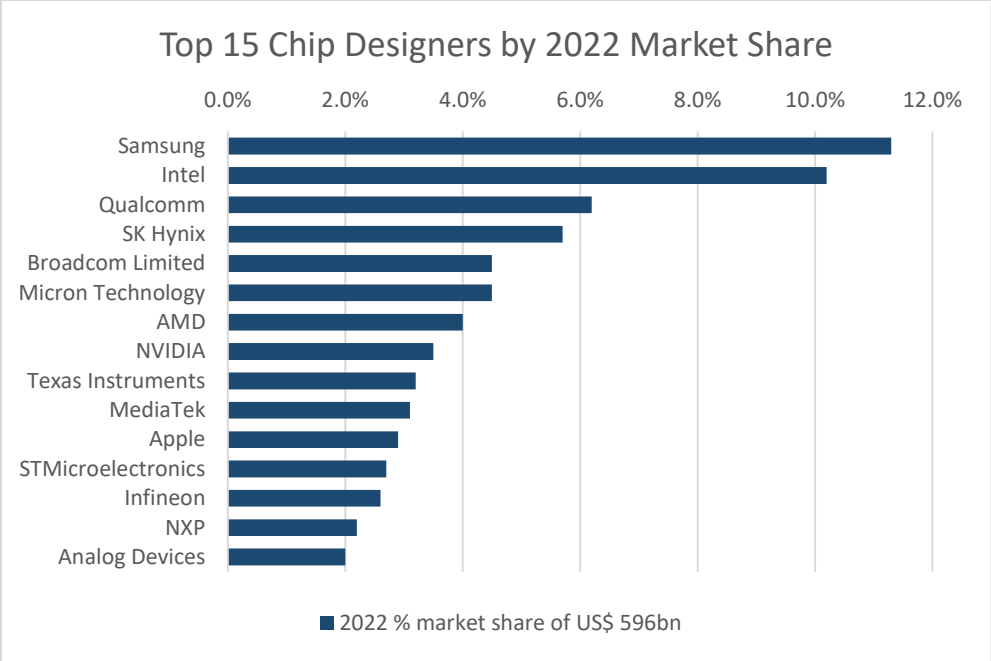

Source: Infineon Q2 2023 presentation

2. Lithography

This process involves transferring the chip design onto a silicon wafer. Photomasks, which are like stencils, are created to define the patterns of the circuitry. The wafer is coated with a light-sensitive material called a photoresist. Ultraviolet light is then shone through the photomask onto the wafer, causing the photoresist to change chemically in the exposed areas[7]. Out of all the six manufacturing processes, Lithography is the most concentrated. ASML has a monopoly on Extreme Ultraviolet (EUV) machines which are needed for <10nm chips and they are also the dominant player in the high-end Deep Ultraviolet (DUV) Lithography machine market. The other two relevant market players, Japanese Nikon and Canon, are mostly focusing on ArF & DUV and KrF & i-line machines respectively. The total market size was estimated to be US$9.5bn in 2022[8] and at US$13bn in 2020 according to BOCI Securities Report[9]. China's Shanghai Micro Electronics Equipment (SMEE) is around 20 years behind and their machines can only produce down to 90nm chips for now[10]. The German company Carl Zeiss SMT has received a EUR 1bn

[7] "Photolithography" by Mohit Uniyal - https://byjusexamprep.com/photolithography-i
[8] Lithography Systems Market Share, Size, Report 2023-28 (imarcgroup.com)
[9] Lithography Machines: ASML, Canon vs. Nikon | by For 4D Sensing, AR, AV/Robot, and AIoT | Medium
[10] Factbox: Chinese chipmaking equipment manufacturers filling void left by U.S. export restrictions | Reuters

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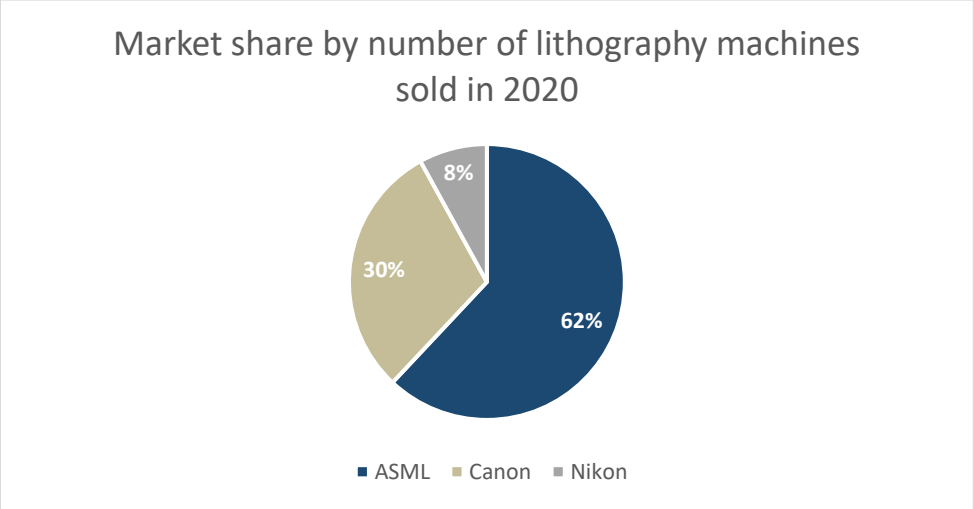
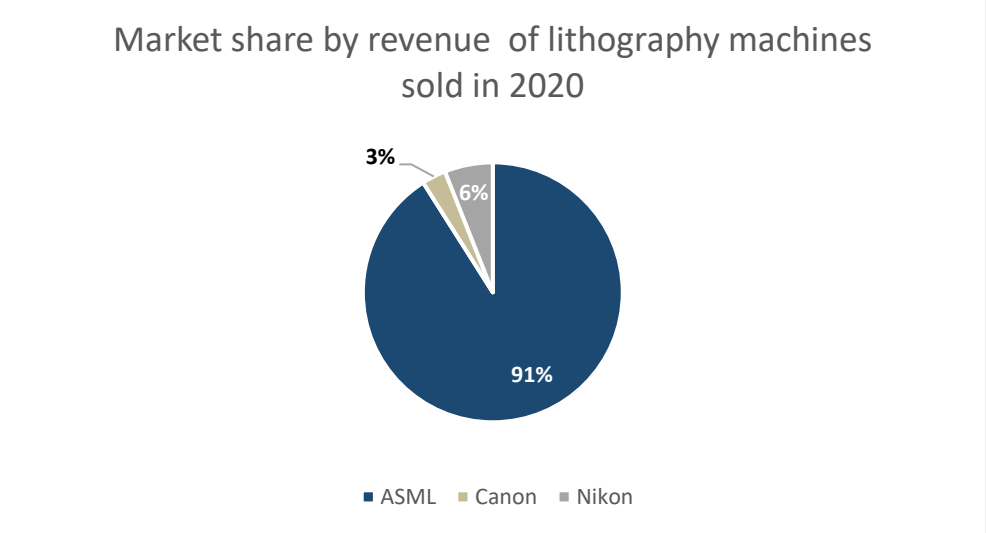
investment by ASML for a 24.9% share in the company in 2016 to develop high-performance optics for its new EUV machines and hence plays a major role in the development of ASML's EUV machines.[11] ASML's EUV machines are made up of hundreds of thousands of models from nearly 800 global suppliers. It is such a complex machine that it is nearly impossible to copy it. China has been involved in refurbishing older lithography systems, such as DUV, to send them to parts of China. This has surely given the country some know-how in how these machines work, but they have yet to develop one of their own[12].



Source: BOCI Securities Report



Source: BOCI Securities Report

[11] ZEISS and ASML Strengthen Partnership for Next Generation of EUV Lithography
[12] Inside ASML, the company advanced chipmakers use for EUV lithography (cnbc.com)

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3. Etching

Etching removes material from the wafer to create the desired patterns. This can be done using chemical etchants or plasma etching, where high-energy ions selectively remove the exposed material. The etching process is carefully controlled to ensure the precise removal of materials, creating the intricate features of the chip[13]. Etching and etching equipment is also a very big market, standing at US$23.65bn. The market is more competitive than Lithography, while still being dominated by a few big players, such as Applied Materials, Lam Research and Hitachi[14].

Major companies producing etching machines

Process type	Company	Country	Notes
Etching	Applied Materials Inc	USA	$17.8bn revenue and market leader (>50%)
	Hitachi	Japan	Mostlly dry-etching machines
	Lam Research Coportaion	USA	Involved in multiple etching applications
	Natura Technology	China	Supports 55nm and 28nm chipmaking technology
	Advanced Micro-Farbication Equipment	China	New machines can use 5nm technology (2.5% of Applied Materials market share)
	Beijing E-Town Semiconductor Technology	China	Removes photoresist chemicals and produces etching machines
	ACM Research	China	Equipment cleans wafers in competition with Lam Resrach, Tokyo Electron, Screen Holdings and Mujin Electronics

Source: Individual companies, Reuters

4. Deposition and Ion Implantation

Various layers of materials and ions, such as silicon dioxide and metal, are deposited onto the wafer. Chemical vapor deposition (CVD) and sputtering are common techniques used for deposition. These layers serve different purposes, such as insulation, interconnects, and transistors and alter the conductivity of

[13] "Etch Overview" by MKS Instruments - https://www.mks.com/n/etch-overview#:~:text=In%20semiconductor%20device%20fabrication%2C%20etching,that%20material%20on%20the%20substrate

[14] Semiconductor Etch Equipment Market Size & Share Analysis - Industry Research Report - Growth Trends (mordorintelligence.com)

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the silicon[15]. Deposition and Ion Implantation are often done by separate firms. The Ion implantation industry's market size stood at US$1.6bn in 2021[16]. The industry is again dominated by a few large players and is likely to remain that way. The deposition market is currently valued at US$13bn[17]. China's Natura Technology can service 14nm to 28nm process nodes, but not down to 5nm yet.

Major companies in the semiconductor deposition and ionization market

Process type	Company	Country
Deposition & Ionization	Applied Materials Inc	USA
	Axcelis	USA
	Veeco	USA
	Hitachi	Japan
	Carl Zeiss	Germany
	Natura Technology	China

Source: Individual companies, Transparencymarketresearch, Straitresearch

5. Metal Wiring

Metal Wiring is a process that allows electricity to flow by depositing a thin metal film using materials such as aluminum, titanium or tungsten so that electricity can pass through the semiconductor wells. These interconnects allow for the flow of electrical signals between transistors. The metal layers are patterned using photolithography and etching techniques[18]. Metal wiring was valued as a US$11.87bn industry in 2020[19]. The market is considered to be relatively competitive according to Transparency Market Research, but again dominated by big players.

[15] "Deposition" by Horiba Semiconductor - https://www.horiba.com/int/semiconductor/process/deposition/ and Ion Implantation Wikipedia - https://sst.semiconductor-digest.com/2015/12/ion-implantation/
[16] Ion Implantation Machine Market Insight and Trends by 2031 (transparencymarketresearch.com)
[17] https://straitsresearch.com/report/semiconductor-chemical-vapor-deposition-equipment-market#:~:text=The%20global%20semiconductor%20chemical%20vapor,period%20(2023-2031)
[18] "Metalization" by City University of Hong Kong - http://www.cityu.edu.hk/phy/appkchu/AP6120/10.PDF
[19] Wire Bonding Market Demand and Research Insights by 2031 (transparencymarketresearch.com)

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6. Testing and Packaging

After the manufacturing process, each chip undergoes rigorous testing to ensure quality and functionality. Testing involves checking for defects, verifying performance, and conducting electrical tests. Once the chips pass the testing stage, they are packaged. Packaging involves placing the chip in a protective casing with electrical connections to external devices[20]. Lastly, the annual testing and assembly market was valued at around US$34.85bn in 2021[21]. Here again we have similar competition dynamics to the other processes. Taiwan plays a major role in this last part, largely due to being the manufacturing hub of chips.

Major companies in the semiconductor Testing and Packaging market

Process type	Company	Country
Testing and Packaging	Advanced Semiconductor Engineering	Taiwan
	Amkor	USA
	Powertech Technology	Taiwan
	Silicon Precision Industries	Taiwan

Source: Individual companies

Where does China fit in?

China's most advanced chip manufacturer SMIC (Semiconductor Manufacturing International Corporation), is currently able to produce 7nm chips[22], after copying large parts of TSMC's process. They will therefore be unable to export most of these chips, however they will still be useful for domestic applications. While this may sound impressive, this is still 5 years behind TSMC and Samsung who have had this technology since 2018[23]. They have been using a 5nm process for a couple of years and are rumored to already have 3nm capabilities, but are waiting to commercialize them[24]. Furthermore, due to import restrictions, it may take China even longer than 5 years to reach 5nm size, as ASML are prevented from selling their EUV Lithography machines to them, which are crucial in getting the most out of the 7nm

[20] "Assembly, Packaging and Testing," by National Academic Press - https://nap.nationalacademies.org/read/5977/chapter/7
[21] Semiconductor Assembly and Test Services Market Size [2028] (fortunebusinessinsights.com)
[22] The truth about SMIC's 7-nm chip fabrication ordeal - EDN
[23] 3 nm process - Wikipedia
[24] Apple's 3nm iPhone chip advantage (and why it doesn't really matter) | Macworld

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process and allowing them to go below (they have also now banned DUV machines from export to China[25]). EUV machines will not be easy to steal or copy either, as they cost more than $100m each and contain more than 100k parts[26]. The next generation of EUV machines, necessary to go sub 3nm are expected to be even more complicated and cost more than $300m each with almost half a million parts each[27]. That said, Chinese propaganda claims that China has developed 14nm EUV already, so they will not need to build this industry completely from scratch[28]. US sanctions are also believed to try and limit China's abilities to stay at the cutting edge in other ways, as well as preventing imports of certain chips, in order to limit their military technological capabilities. However, China currently is a large manufacturer of lower quality and mature chips, which is a position they will seek to expand. These chips face less of a threat from sanctions, as they are mainly used in everyday consumer electronics and cannot be weaponized as effectively. As a result, there has been a surge of investment in this area[29]. With regards to import vs export, China produces approx. 35% of the world's chips, but is still a net importer, accounting for more than half of worldwide chip sales depending on the source[30].

The trade war has begun: USA vs. China

In October 2022, the US has banned companies such as Nvidia, AMD and Intel from exporting their most advanced chips to China. The rules prohibit the sale (to Chinese customers) of advanced chips with both high performance (at least 300 trillion operations per second, or 300 teraops) and fast interconnect speed (generally, at least 600 gigabytes per second). Nvidia's A100, for comparison, is capable of over 600 teraops and matches the 600 Gb/s interconnect speed. Nvidia's more-impressive H100 can reach nearly 4,000 trillion operations and 900 Gb/s. Both chips, intended for data centers and AI trainers, cannot be sold to Chinese customers under the new rules. Additionally, the rules restrict the sale of fabrication equipment if it will knowingly be used to make certain classes of advanced logic or memory chips. This includes logic chips produced at nodes of 16 nanometers or less (which the likes of Intel, Samsung, and TSMC have done since the early 2010s); NAND long-term memory integrated circuits with at least 128 layers (the state of the art today); or DRAM short-term memory integrated circuits produced at 18

[25] China's semiconductor ambitions dealt fresh blow by new Dutch export rules on ASML chip-making machines | South China Morning Post (scmp.com)
[26] "Chips Wars" by Chris Miller
[27] Intel orders ASML system for well over $340 mln in quest for chipmaking edge | Reuters
[28] FINALLY HAPPENED! China breaks through 14nm EUV lithography key technology! - YouTube
[29] 'De-Americanize': How China Is Remaking Its Chip Business - The New York Times (nytimes.com)
[30] China's semiconductor industry: A bumpy way to self-sufficiency (daxueconsulting.com)

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nanometers or less (which Samsung began making in 2016)[31]. The motivations are believed to be aimed at limiting the ability to perform exceptionally accurate calculations for military purposes. Secondly, there is a constraint on chip-to-chip transfer speeds, which has an impact on artificial intelligence. For instance, technologies like ChatGPT rely on models that are too vast to be contained on a single chip, necessitating distribution across thousands of chips that need to intercommunicate[32]. The US has also imposed a ban on US government agencies from procuring products or services that include Chinese semiconductors[33]. This is to try and prevent espionage and also a dependency on Chinese chips. There are also likely to be restrictions placed on US investments in China and specifically its technology sector soon, with Venture Capitalists like Sequoia Capital already looking to spin off their Chinese venture[34]. In spite of this, there are reports that China has been finding ways to evade these sanctions, by smuggling chips and and renting through the cloud[35]. It is unclear for how long this will remain viable or what measures the US will be taking to counter this. During the Cold War, the Soviet Union notoriously smuggled US chips, and tried to reverse-engineer them. However, this strategy ultimately proved unsuccessful and left them far behind the US. With how complex modern manufacturing is, stealing chips alone is not likely to be enough, and substantial manufacturing information and equipment would also be required.

US allies vs. China

Japan has proposed arguably the most extreme sanctions on China, by seeking to prevent the export of 23 essential types of chipmaking devices, without government approval. These sanctions however could extend beyond just those necessary for advanced chips below 14nm like the US, and extend all the way up to 45nm[36]. This could potentially impact the chips used in vehicles and Internet of things items, which are typically 28nm. If these licenses are refused for Chinese export, they could have a very large impact on the Chinese and global economy, as it could bring its electronics manufacturing industry to a halt. In anticipation of this, many Chinese firms have been ordering as many parts as they can from Japan, as the rules only come into place in July[37]. The UK and several EU members have also imposed sanctions on China.

[31] The U.S.-China Chip Ban, Explained - IEEE Spectrum
[32] China's Chip Industry remains largely unaffected by US sanctions - Gizmochina
[33] The NDAA Includes Prohibitions Targeting Semiconductors Similar to Section 889: Wiley
[34] US venture capital giant Sequoia to split off China business | Financial Times (ft.com)
[35] Chinese Firms Are Evading U.S. Semiconductor Sanctions (foreignpolicy.com)
[36] China fears Japan's chipmaking curbs go further than US restrictions | Financial Times (ft.com)
[37] https://www.ft.com/content/768966d0-1082-4db4-b1bc-cca0c1982f9e

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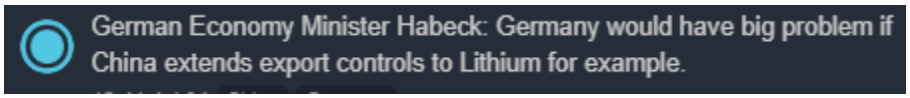
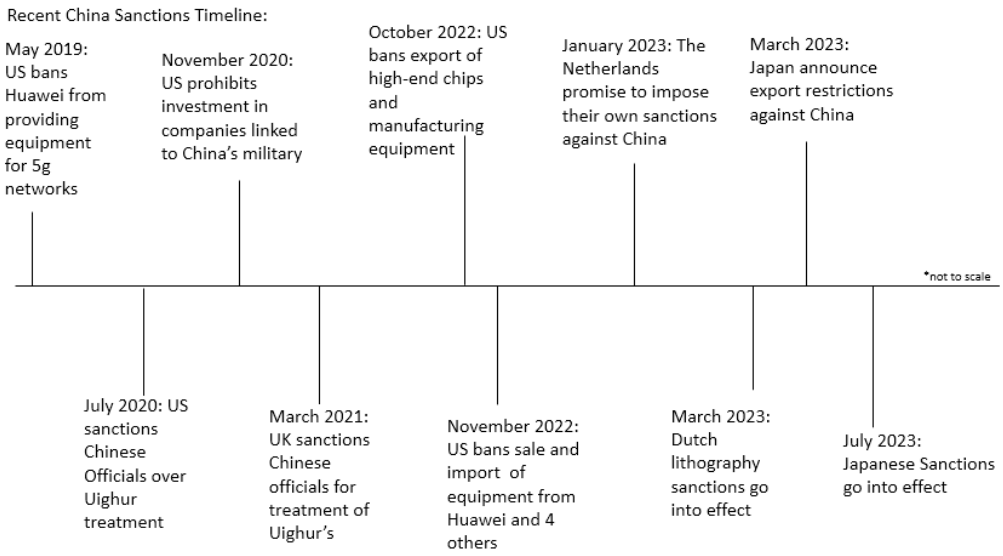
The most common of these is preventing Huawei from accessing 5G networks, citing safety concerns[38]. The EU has also singled out 7 other Chinese and Hong Kong based firms for providing assistance to Russia, and has proposed sanctioning them. There are however cautions about sanctioning China, and Germany in particular, has expressed reluctance to go beyond sanctioning individual companies at this stage[39]. German Economy Minister Habeck recently gave away that the German auto industry is highly reliant on Chinese raw materials, such as lithium:



Source: FinancialJuice.com

The Netherlands has placed Sanctions on exporting ASML's most advanced Lithography machines (EUV) since 2019, hence none have ever been delivered to China. However, the sanctions have now been extended to some DUV machines, which were previously shipped to China[40]. This measure went into effect in March 2023. South Korea are yet to impose any sanctions on Chinese chip making. As Western Allies, Washington will likely be pressuring them to do so. However, China have previously sanctioned South Korea for obtaining US military technology, thus will be weary of retaliation[41].

Sanctions against China timeline



[38] https://www.ft.com/content/a6900b0f-08d5-433d-bfb0-f57b6041e381
[39] Germany warns EU on hitting China with Russia sanctions - sources | Reuters
[40] https://www.ft.com/content/e911774c-a048-4ed1-9f90-e4bb684a3156
[41] South Korea pushes back against Chinese economic coercion | East Asia Forum

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China's retaliation

China retaliated in May by imposing a ban on US firm Micron Techonologies memory and storage chips in some critical sectors[42]. Although China sites security concerns, these are not as clearly obvious as those over processors. This is more likely an attempt to get back and America and weaken US-Korean relations, as both Samsung and SK Hyinx (Korean Firms) are set to benefit greatly from the loss of competition. Now, China has imposed export restrictions for Germanium and Gallium, two critical ores that are key raw materials for high-speed computer chips, defence and renewable energy sectors. China control 80% of the world's Gallium production and around 60% of the world's Germanium production[43]. And this could just be the beginning given that China controls over 50% of world production in over 27 minerals, with many of these minerals being also supplied by countries like Russia. The trade war has certainly begun, and what is next to follow could likely be uglier: A raw material war, which is often fought with weapons… The West & NATO is overall looking weaker than the East & SCO when it comes to raw materials, energy production and reserves. When it came to condemning Russia invading Ukraine, the UN vote provided a good glimpse into the new bi-polar world, where again the East & SCO seem to be in the majority vs. the West & NATO with neutral countries like India benefitting the most (more on this here "The new bi-polar world"). One thing should be kept in mind, nonetheless, despite the West looking weaker on the commodity supply chain, to a large degree this comes down to higher cost of extraction and emission hurdles and therefore lower exploration. If Western countries cannot rely on China and others on raw materials, they could always explore on their own, although this would take time and would be highly inflationary.

Conclusion

In conclusion, semiconductors remain at the heart of the world's technological advancements and economic growth in the developed world. It drives everything from productivity to consumer demand. Stalling China's effort to catch up with the West in this sector will leave China stuck at the state of the world in 2023. What the USA has done to Japan by implementing the Plaza Accord, which in turn led to a rapid appreciation of the Yen, putting Japanese's export economy into jeopardy, the same could the export restrictions of semiconductors, and especially EUV and DUV machines, to China mean, keeping

[42] China's ban on Micron chips is 'economic coercion' and won't be tolerated, says Gina Raimondo | Fortune
[43] https://www.reuters.com/markets/commodities/where-are-strategic-materials-germanium-gallium-produced-2023-07-04/

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China stuck at the current state of development. Different to Japan, China was not nuclear bombed by the US and therefore tries to stand up to the US by retaliating. This could lead to further de-coupling of the West and the Chinese economy. Ultimately, China is more dependent on the West than vice versa though. Even though the US imported $225mio worth of gallium and germanium and 50% of China's supply[44], these metals can be extracted from other, allies countries. However, this could be quite inflationary, which would drive up the prices of everything where chips are being used in. The key will be what South Korea and Germany are going to do as this will depend on whether China could become a serious automotive supplier and exporter to the world, since automotive chips are generally less advanced than those used in military and AI.

Largest producing countries of key energy, food, minerals and metals

Type	Raw Material	Uses	#1 country of supply	% of world share	#2 country of supply	% of world share	#3 country of supply	% of world share
Energy	Oil	Fuels and plastics	USA	14.50%	Russia	13.10%	Saudi Arabia	12.10%
Energy	Coal	Power	China	50%	India	10.46%	Indonesia	7.40%
Energy	Gas	Power	USA	23.70%	Russia	16.60%	Iran	6.50%
Energy	Uranium	Power	Kazakhstan	43%	Canada	13.00%	Australia	12.00%
Food	Corn	Food	USA	31.00%	China	23.40%	Brazil	9.00%
Food	Wheat	Food	China	18%	India	14.20%	Russia	11.30%
Minerals	Copper	Electrical equipment	Chile	26.60%	Peru	10.90%	China	8.90%
Minerals	Silver	Electronics, coins, photography, jewelry	Mexico	23%	Peru	14.00%	China	12.00%
Minerals	Gold	Jewelry, electronics, coins	China	11.70%	Australia	9.90%	Russia	9.30%
Minerals	Iron ore	Steel	Australia	38%	Brazil	16.70%	China	14.17%
Minerals	Platinum	used in catalytic converters (diesel)	South Africa	72.00%	Russia	12.20%	Zimbabwe	8.30%
Minerals	Palladium	used in catalytic converters and as a catalyst agent (gasoline)	South Africa	38%	Russia	35.20%	Canada	8.10%
Minerals	Rhodium	used in catalytic converters, electrical components and as a catalyst (N2O)	South Africa	84.60%	Russia	6.94%	Zimbabwe	5.50%
Minerals	Aluminum	used in almost all sectors of the economy	China	56%	India	5.80%	Russia	5.60%
Minerals	Titanium	used as a white pigment or metal alloys	China	52.40%	Japan	23.80%	Russia	15.70%
Minerals	Cobalt	used in rechargeable batteries and superalloys	DRC	70%	Russia	4.30%	Australia	3.60%
Minerals	Nickel	used to make stainless steel, superalloys and rechargeable batteries	Indonesia	30.40%	Philippines	12.80%	Russia	11.20%
Minerals	Lithium	used for rechargeable batteries	Australia	55%	Chile	26.00%	China	10.86%
Minerals	Graphite	used for lubricants, batteries and fuel cells	China	79.00%	Brazil	6.50%	Mozambique	2.90%

[44] What are Gallium and Germanium? China curbs exports of metals for tech (cnbc.com)

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Minerals	Manganese	used in steelmaking and batteries	South Africa	34%	China	16.20%	Australia	15.70%
Minerals	Vanadium	primarily used as alloying agent for iron and steel	China	60.00%	Russia	17.00%	South Africa	7.00%
Minerals	Zinc	primarily used in metallurgy to produce galvanized steel	China	47%	South Korea	6.50%	India	5.40%
Minerals	Tungsten	primarily used to make wear-resistant metals	China	83.50%	Vietnam	5.70%	Russia	3.00%
Minerals	Magnesium	used as an alloy and for reducing metals	China	78%	Russia	6.40%	USA	4.90%
Minerals	Beryllium	used as an alloying agent in aerospace and defense industries	USA	65.40%	China	26.00%	Mozambique	3.00%
Minerals	Ruthenium	used as catalysts as well as electrical contacts and chip resistors in computers	South Africa	91%	Russia	4.00%	Zimbabwe	2.00%
Minerals	Iridium	used as coating of anodes for electrochemical processes and as a chemical catalyst	South Africa	?	Russia	?	Zimbabwe	?
Minerals	Tin	used as protective coatings and alloys for steel	China	27%	Indonesia	25.80%	Myanmar	17.40%
Minerals	Scandium	used for alloys, ceramics and fuel cells	China	99.00%				
Minerals	Ytterbium	used for catalysts, scintillometers, lasers and metallurgy	China	99%				
Minerals	Yttrium	used for ceramic, catalysts, lasers metallurgy and phosphors	China	99.00%				
Minerals	Germanium	used for fiber optics and night vision applications	China	68%	Russia	4.30%	USA	2.10%
Minerals	Gallium	used for integrated circuits and optical devices like LEDs	China	95.00%				
Minerals	Hafnium	used for nuclear control rods, alloys and high-temperature ceramics	France	45%	USA	41.00%	Ukraine	8.00%
Minerals	Rubidium	used for research and development in electronics	Namibia	?	Zimbabwe	?	Canada	?
Minerals	Cerium	used in catalytic converters ,ceramics, glass, metallurgy and polishing compounds	China	?				
Minerals	Tantalum	used in electronic components, mostly capacitors and in superalloys	DRC	37.70%	Brazil	25.30%	Rwanda	14.50%
Minerals	Erbium	used in fiber optics, optical amplifiers, lasers and glass colorants	China	?	Russia	?	Malaysia	?
Minerals	Barite	used in hydrocarbon production	China	34.00%	India	19.40%		
Minerals	Antimony	used in lead-acid batteries and flame retardants	China	54%	Russia	?	Tajikistan	?
Minerals	Indium	used in liquid crystal display screens	China	57.60%	South Korea	21.70%	Canada	6.50%
Minerals	Bismuth	used in medical and atomic research	China	73%	Laos	16.00%	South Korea	5.00%
Minerals	Gadolinium	used in medical imaging, permanent magnets and steelmaking	China	?	Russia	?	Malaysia	?
Minerals	Samarium	used in permanent magnets, as an absorber in nuclear reactors and in cancer treatments	China	?	USA	?	Brazil	?
Minerals	Praseodymium	used in permanent magnets, batteries, aerospace alloys ceramics and colorants	China	67.00%	Myanmar	12.00%	Australia	10.00%
Minerals	Dysprosium	used in permanent magnets, data storage devices and lasers	China	99%				

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Minerals	Terbium	used in permanent magnets, fiber optics, lasers and solid-state devices	China	?	USA	?	India	?
Minerals	Holmium	used in permanent magnets, nuclear control rods and lasers	China	?	Russia	?	Malaysia	?
Minerals	Neodymium	used in permanent magnets, rubber catalysts and in medical and industrial lasers	China	80.00%				
Minerals	Europium	used in phosphors and nuclear control rods	USA	?	China	?	Russia	?
Minerals	Cesium	used in research and development	Canada	?	Zimbabwe	?	Namibia	?
Minerals	Lutetium	used in scintillators for medical imaging, electronics and some cancer therapies	China	?	Russia	?	Malaysia	?
Minerals	Arsenic	used in semi-conductors	China	42.40%	Chile	19.50%	Morocco	11.90%
Minerals	Tellurium	used in solar cells, thermoelectric devices and as alloying additive	Russia	12%	Sweden	11.60%	Japan	10.60%
Minerals	Zirconium	used in the high-temperature ceramics and corrosion-resistant alloys.	Australia	43.00%	South Africa	28.70%	Senegal	9.50%
Minerals	Fluorspar	used in the manufacture of aluminum, cement, steel, gasoline and fluorine chemicals	China	63%	Mexico	11.60%	Mongolia	9.40%
Minerals	Thulium	used in various metal alloys and in lasers	China	97.00%				
Minerals	Niobium	used mostly in steel and superalloys	Nbrazil	88%	Canada	9.90%		
Minerals	Chromium	used primarily in stainless steel and other alloys	South Africa	44.00%	Kazakhstan	17.00%	Turkey	17.00%
Minerals	Lanthanum	used to produce catalysts, ceramics, glass, polishing compounds, metallurgy, and batteries	USA	?	Brazil	?	India	?
Wood	Lumber	Buildings, furniture (industrial roundwood)	USA	18.00%	Russia	11.00%	China	9.00%

Source: USGS.gov, Statista, MMTA, OPEC, multiple other sources

The semiconductor research and analyses have been prepared by James Iwi, who has been our summer intern in June 2023

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