Brief Number 1: History of Semiconductors

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We live among semiconductors. They are in our computers, cell phones, watches, cars, ovens, and even in LED lights. Semiconductors are important because no contemporary electronics can function without them. Powering up an electronic device to function happens through transistors and diodes, and these are made of semiconductors. All information in electronic system is transmitted or stored in the form of binary digits, 0s and 1s, and these digits are operated by switches in semiconductors to process the information when electric voltages are passed through the semiconductor. The more processing power the world needs, the greater need for semiconductors and for electric power.

The first transistor was made in the late 1940s by three American scientists at Bell Laboratories to replace earlier vacuum tube technology which was bulky, unreliable, and energy consuming. Employees of Texas Instruments then discovered new material, silicon, as a cost-effective option for mass production because the supply is abundant since silicon can be commonly found in sand. While material cost is cheap, high labour cost was incurred because manual workers needed to carefully place, mount each transistor, and connect them by soldering onto a circuit board. To placing semiconductors closer to each other so that as many transistors can be densely packed together to maximize output within a smaller space, an electrical engineer at Texas Instruments invented an integrated circuit which resembles the size of a fingernail, hence the name 'chip'. Around the same time, another engineer from Fairchild Semiconductor invented a new fabrication technique that creates a flat surface for interconnection between silicon layers (printed circuit board).

The defense industry first commissioned and funded the research and production for semiconductor companies, but the scale of orders was not sufficient to cover the research and development (R&D) cost for next level semiconductor technology. The hearing aid was the first commercial product that reached a wider consumer usage, and several employees of Fairchild immediately recognized the huge potential of the consumer market. They left Fairchild and founded Intel Corporation with initial focus on memory products. However, Intel initially lost to Japanese players who could make higher quality and lower price products due to larger scale and cheaper loans. The price war pushed Intel to carve out a niche and profitable market which was a higher quality, larger memory computer processor, the later famous 386 and 486 series of chips.

Intel co-founder Gordon Moore coined "Moore's Law[1]", which predicted that the number of transistors on a microchip doubled about every two years, though the cost of computers is halved. Smaller, cheaper and more powerful chips enabled the transition from bulky computers to smaller and later mobile devices, from mainframes to servers, PCs, then smart phones. The connectivity of these devices and the demand for real-time information processing drove the demand for higher and higher quality, specialized semiconductor chips.

The electronic industry therefore began to transform with the rise of the internet and increasing software sophistication into diversified product offerings. Apple, Qualcomm, NVIDIA, and

[1] https://en.wikipedia.org/wiki/Moore's_law

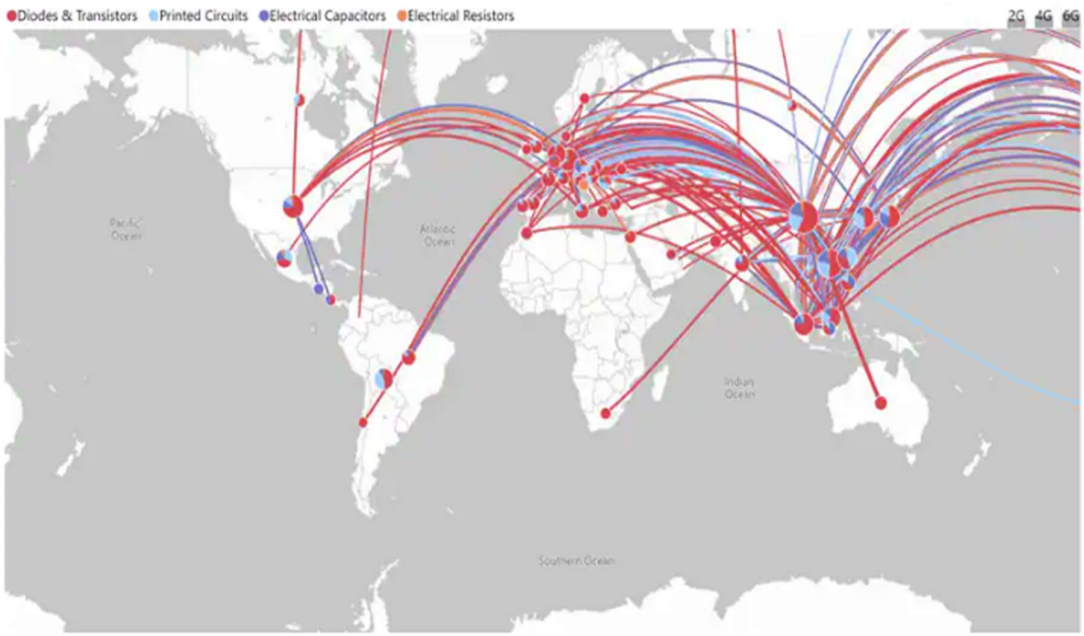
Advanced Micro Devices (AMD) emerged after the late 1990s, specialized in telecommunication and gaming products that eventually formed the electronic cluster in Silicon Valley. Initially, chip producers shifted labour intensive assembly operations to Taiwan, South Korea, Malaysia, and later China to remain cost competitive. For example, in 1969, following the end of Penang's free-port status, the Federal government engaged American consultancy firm Robert R. Nathan Associates, which advised Penang to adopt a tax-free industrial zone. Between 1972-75, National Semiconductor (NS), another spinoff from Fairchild, Advanced Micro Devices (AMD) and Intel, Osram, Hewlett Packard, Bosch, Hitachi, and Clarion were pioneer electronic companies called locally as the Eight Samurai".

South Korea, Taiwan and Malaysia pioneered the global semiconductor supply chain, in which each country carved out different business models for themselves. As Western companies shifted their production in order to globalize, Korean Samsung and Hynix bought Phillips technology and decided to concentrate on memory chips, whereas Taiwan Semiconductor Manufacturing Corporation (TSMC) under Morris Chang, formerly from Texas Instruments, began to seize the manufacturing market by establishing itself as a pure fabrication company. Such specialized production enabled "fabless" companies like Qualcomm, Nvidia to emerge, designing chips whilst leaving the fabrication to contract (fab) manufacturers in Asia like TSMC, Samsung and United Microelectronics Corporation (UMC) to produce. Fabless tech companies were asset-light but software design heavy. British companies like ARM gave up manufacturing and focused on design, selling intellectual property (IP) through license fees. The Dutch Philips electronic giant spun off their semiconductor manufacturing company ASML in 1995 and today ASML competes with Japanese Nikon and Canon as the dominant semiconductor manufacturing machines in the world.

Clearly, smart electronics require more processing power, which meant that R&D became the driving force for innovation, commercialization and profits. Global semiconductor annual revenue grew five times from roughly $100 billion in the early 1990s to $500 billion by 2021. Silicon Valley created a successful R&D model between academia and high-tech firms, specializing in design and cutting edge technology, leaving production on a global supply chain. China was a latecomer to the semiconductor industry. After the Asian financial crisis of 1997, cheap labour assembly and production shifted to China by Western companies to secure local market share for electronics. As the Chinese economy grew in size and sophistication, with scale in manufacturing, Apple, Samsung and other major electronic manufacturers shifted production there, whilst importing all the necessary chips and IP technology. At the same time, Chinese domestic brands, such as Huawei, Oppo, and Xiaomi emerged to compete with foreign brands on better pricing and features. With the announcement of Made in China 2025[2] in 2015, the Chinese also encouraged local fab Semiconductor Manufacturing International Corporation (SMIC) to domestically manufacture processors and increase domestic value added and content. These measures triggered US-China trade tariffs and sanctions, which meant that today, Chinese companies increasingly face difficulties in sourcing sensitive technology and access to key equipment from US allies, such as Japan, Netherlands, UK and Korea. These have huge implications on possible bifurcation of the global semiconductor supply chains. The complexity and concentration of the supply chain is shown in the following figure.

[2] https://en.wikipedia.org/wiki/Made_in_China_2025

Global trade in electronic components (Q2 2021)



Source: IHS Markit Global Trade Atlas(GTA). Flows above USD 25 million in Q2 2021.

After cheap assembly was shifted out of Malaysia, the multinational companies retained in Malaysia their design, testing and packaging facilities. This has been a source of strength for Malaysia since Penang (Bayan Lepas and Batu Kawan) and Kedah (Kulim) have developed an ecosystem for both multinational and local tech companies involved in different parts of the semiconductor supply chain.

The semiconductor industry is in a critical stage of change, as all key players, especially China and the US, are accelerating their R&D and innovation, including on process engineering and production. The geopolitical sensitive economy of Taiwan has become crucial in the next phase of semiconductor development, as TSMC factories are being built in the US, Europe, and Japan. The implications of such geopolitical developments will be discussed in further briefs.

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