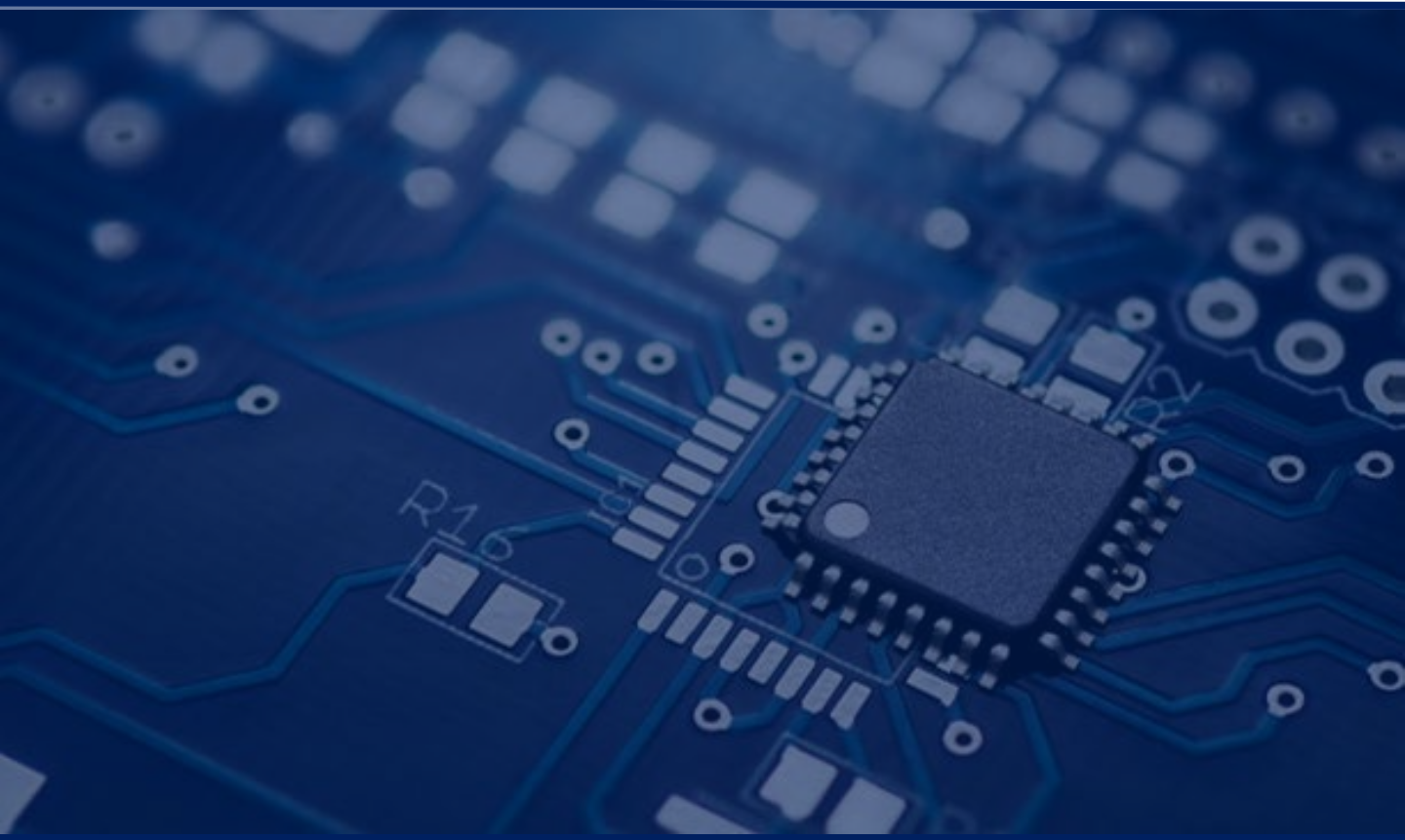


US SEMICONDUCTOR INDUSTRY

SEMI-PREPARED FOR THE FUTURE

The US semiconductor industry is on track to become a $522 billion industry by the end of 2021 with a high growth rate driven by the expanding digital economy. This industry interconnects emerging and developing concepts with applications in 5G, artificial intelligence, big data and industry 4.0.

Semiconductors power the world's infrastructure from healthcare and personal use to military and transportation. The recent COVID-19 pandemic has increased the demand for personal devices (phones, laptops, consoles, GPUs) in light of remote work as individuals crave increased connection to the digital world.

COVID-19 driven blockages and closures in the shipment and transportation industries have led to a worldwide chip shortage. This, inevitably, has effects on other industries that depend on this valuable commodity. The automotive industry, in particular, has been negatively impacted by forced factory closures and the lack of automated process, thus being unable to meet consumer demand.

The following report seeks to outline the growing demand from consumers with respect to semiconductors and its impact on related industries.

8 August 2021; Akshat Suri | Evan Higgins | Matthew Leung | Ryan Trainor | Vishnu Kurapati | Vyoma Shah | Zia Baig

Table of Contents

Introduction: Semiconductors Power the Future

Semiconductors: Integrated Circuits

As of 2020, the $439 billion semiconductor industry powers the modern-day digital economy and the future of work as humanity adopts technological innovations at an exponential pace. These semiconductors are integrated circuits layered on a thin semiconductor wafer, typically silicon, which undergo a complex production process consisting of hundreds of steps over a span of six to eight weeks. Semiconductors, more commonly referred to as "chips", can be categorized into three main use cases: logic chips which serve as the brains, memory chips which act as storage, and DAO (Discrete, Analog and Other) chips transmit, receive and transform data.

The COVID-19 pandemic led to global shutdowns across industries, which temporarily disrupted the semiconductor supply chain. Concurrently, demand for new PCs, mobile devices and data center upgrades skyrocketed in response to accelerating digitization from work-from-home trends.

Role of the US & China The Tech War

With the US and China, who account for 50% of global chip consumption, decoupling their supply chains in the race to absolve their foreign dependencies, the global supply of chips remains at risk of further shortages and higher consumer prices. Amidst national security concerns, the US levied sanctions against Chinese chip makers including SMIC, banning them from purchasing US made chips and exacerbating shortages in China. Caught in the crosshairs, the vital Dutch ASML Extreme Ultraviolet (EUV) lithography machine maker used for manufacturing advanced logic chips (<7 nm nodes), is forced to choose between serving either the US and EU or Chinese markets. With the Taiwan Semiconductor Manufacturing Company (TSMC) being perceived as an American ally, China is vigorously investing in domestic chipmakers to overcome its foreign overreliance. In parallel, Biden's $50 billion policy, the American Jobs Plan, is projected to incentivize the construction of 19 new semiconductor firms over the decade, carrying forward Trump's agenda in further bolstering the $208 billion US industry.

Fig. 1: Global Semiconductor Sales by Chip Type | Fig. 2: Chip Application Markets

Fig. 1

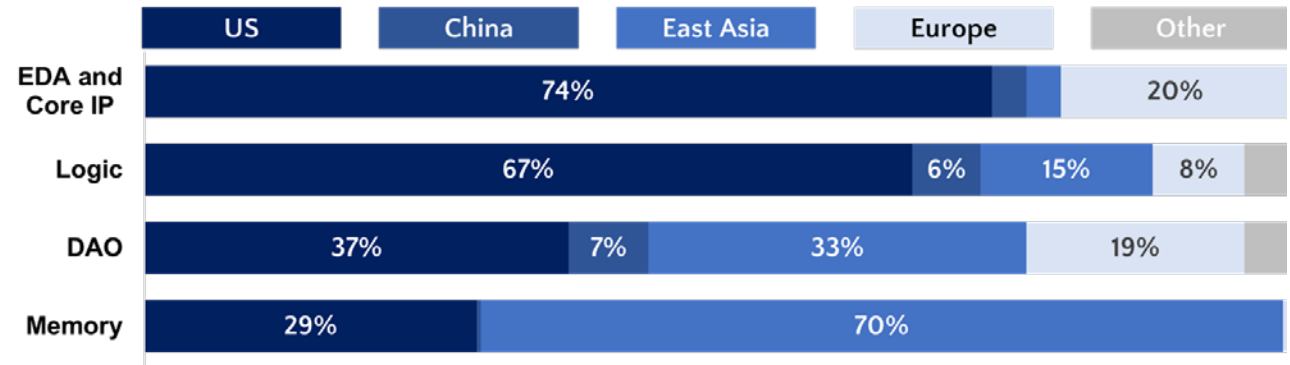
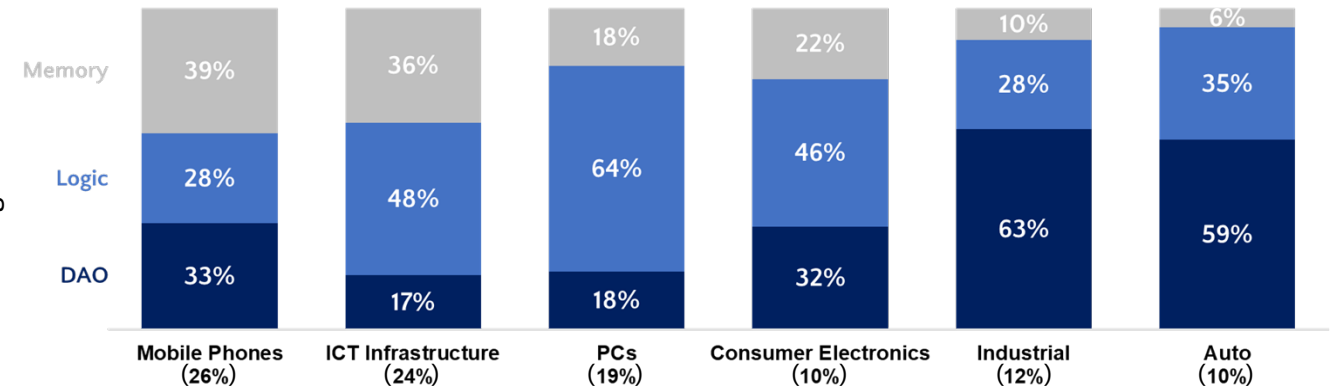


Fig. 2



Source(s): BCG, McKinsey, Semiconductor Industry Association, WSJ

Industry Dynamics

Business Models

Specialized layers of production have emerged due to the rapid increase in technological improvements for both chip design and manufacturing, emphasizing the reliance on a resilient global supply chain. As no single country or company is vertically integrated across the entire supply chain due to tens of billions in required capital expenditures and R&D costs, four specialized business models classified by their level of integration have emerged. The resulting $45 to $125 billion in annual cost efficiencies from the globally woven value chain have enabled a 35% to 65% reduction in semiconductor prices compared to a completely localized counterpart.

Integrated Device Manufacturers (IDMs)
IDMs are the largest players in the semiconductor industry as they are vertically integrated across several levels of the value chain from design and fabrication to packaging and testing. Notable players in the space, such as Samsung and Intel, have been investing billions in expanding their fabrication capabilities in response to the global shortage in chips driven by the pandemic.

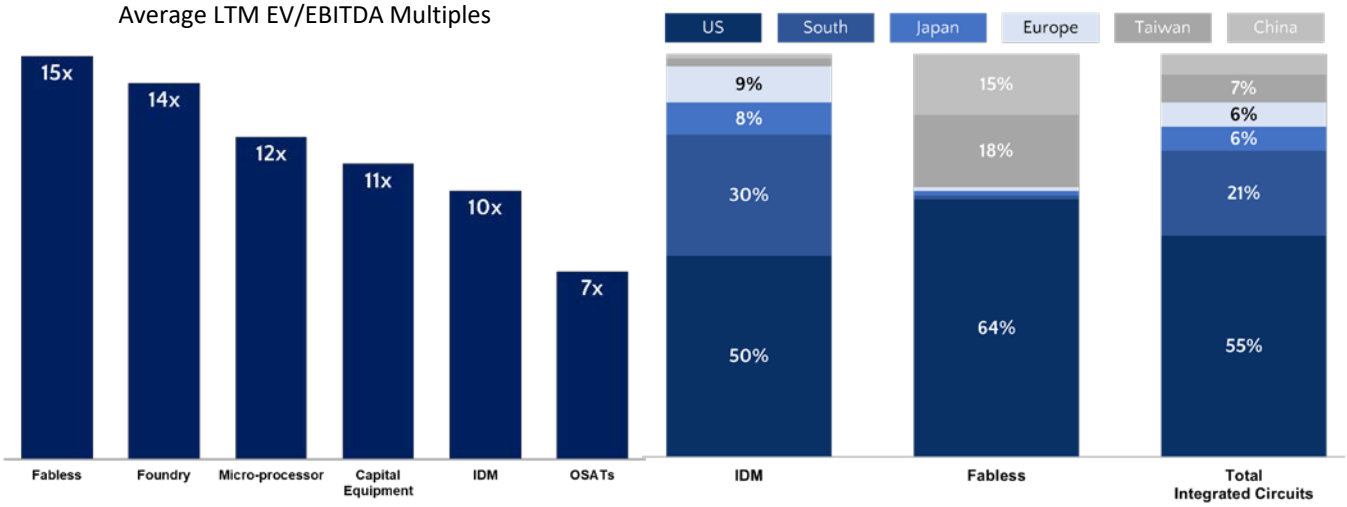
Fabless
Fabless firms solely focus on chip design. They outsource manufacturing to specialized foundries and packaging, assembly and testing to OSATs. This model proves financially beneficial as these firms can primarily focus on R&D while minimizing their capital expenditures.

Preeminent leaders like Apple and Qualcomm have found immense success in designing advanced logic chipsets and partnering with third-parties to power their mobile devices.

Foundries
Foundries fulfill the manufacturing needs of both IDMs and Fabless firms alike, effectively diversifying the risk stemming from the large upfront capital investments required to serve the exponentially growing demand for advanced chip sets. Accounting for 35% of global manufacturing capacity, advanced logic chips are almost exclusively produced by foundries like TSMC, further stressing the importance of their roles across current and future industrial applications alike.

Outsourced Assembly & Testing (OSATs)
OSAT firms are a relatively smaller component of the semiconductor industry, acting as the bowtie by performing some of the final stages in the production process – assembly, testing and packaging. Traditionally, large IDMs have performed these activities in-house, however specialized OSAT firms primarily concentrated in East Asia and Singapore, currently run contracts with foundries and IDMs to provide integral back-end services.

IDM, Fabless and Foundry Models Account for More than 50% of Industry Revenue



Source(s): BCG, McKinsey

Semiconductor Industry Trends & Impacts

COVID-19 Impact: Global Chip Shortage

With the advancement of the pandemic, semiconductor companies have primarily prioritized securing their supply chains through establishing business continuity plans with their vendors. Shortages resulting from temporary factory shutdowns and Chinese companies stockpiling chips due to US sanctions have proven detrimental mainly to the automotive industry, and also harming production of medical devices, electronics and networking equipment.

Foundries and fabless companies have struggled to catch up with the surge in demand arising from work from home trends given the complexity and lengthy timeline of the production process. However, customers of fabs who manufacture cutting edge nodes (≤10 nm) like TSMC do not have many alternatives, thus simply delaying revenue instead of losing it altogether. Unfortunately, IDMs like Intel and Samsung who serve the industrial and automotive industries are taking the brunt due to their vertically integrated nature and the operational strain involved in managing the end-to-end supply chain.

PC and Smartphone

PC sales soared as the world hurried to adjust to working and attending school from home as a result of COVID-19, according to research firm IDC. After roughly 13% YoY growth of PC sales in 2020, sales volumes are expected to increase by 18% YoY in 2021, with 357.4 million global shipments.

Smartphones are also being affected by the supply deficit. Qualcomm Inc. a major supplier, has stated that if not for supply constraints, they would have sold substantially more inventory, Thus, allowing PC market to soar compared to smartphone market, as the need for PC outgrew smartphones

Automotive Industry

The chip shortage that has practically crippled the auto sector exemplifies the worst repercussions of the problem, as critical parts needed to construct finished automobiles and trucks are in limited supply, forcing automakers to cease production. This has led to an estimated $110 billion decline in global auto sales (-15% from 2019 to 2020). The demand is high for integral parts of new EV and hybrid vehicles, governments around the world are increasing funding and resources towards the electric vehicle market. There is also high demand for integrated circuits for EV-based vehicles, which urge semiconductor vendors to develop industry specific devices.

Significant Growth in Asia-Pacific Markets

Asia-Pacific is expected to continue dominating the global power semiconductor market, as the region's current prominence coupled with highly supportive government policies and increased demand predicts continued growth of 13.2% YoY. Moreover, the region’s semiconductor industry is driven by China, Japan, Taiwan, and South Korea, which together constitute around 65% of the global discrete semiconductor market. Others in the region like Vietnam, Thailand, Malaysia, and Singapore also contribute significantly to Asia-Pacific dominance in the market.

Cyclicality of Semiconductor Industry

On average, semiconductors have a shelf life of a minimum of 2 years, and an average of 5 years. Due to high product demand and low shelf life, it is imperative the devices are delivered and added to the product as soon as possible, to allow the product to perform the best of its ability. This creates a large disparity in the demand and supply ratio for semiconductors given that as demand increases, it hard to keep up with supply due to backorders and other factors. During periods of low demand, overproduction will cause chip prices to drop creating an influx of purchases by companies looking to leverage the cost saving opportunities. Rapid demand increases for products has drastically called for innovation to help control the cyclicality of the market.

Source(s): BCG, CNBC, McKinsey, Statista

Industry Dynamics

M&A Activity

Acquirer Name	Target Name	Announcement Date	Transaction EV (US$M)	Valuation EV/LTM Revenue	Valuation EV/LTM EBITDA	Valuation 1-Month Deal Premium
Skyworks Solutions, Inc.	Infrastructure & Automotive (I&A)	Apr 22, 2021	2,750.0	7.3 x	N/A	N/A
Marvell Technology Group	Inphi Corp.	Oct 29, 2020	9,498.9	15.5 x	87.1 x	39.7%
Advanced Micro Devices Incorporated	Xilinx Corporation	Oct 27, 2020	36,788.9	11.3 x	35.4 x	41.2%
SK Hynix Incorporated	Intel NAND SSD, Wafer Business & Memory Factory	Oct 20, 2020	9,000.0	N/A	N/A	N/A
NVIDIA Corporation	ARM Limited	Sep 14, 2020	38,587.6	N/A	N/A	N/A
Analog Devices, Inc.	Maxim Integrated Products Incorporation	Jul 13, 2020	22,844.0	9.7 x	26.1 x	37.2%
Infineon Technologies AG	Cypress Semiconductor	Jun 03, 2019	10,352.3	4.1 x	20.4 x	35.7%
NVIDIA Corporation	Mellanox Technologies, Ltd.	Mar 11, 2019	7,339.0	6.3 x	28.7 x	28.7%
Renesas Electronics Corporation	Integrated Device Technology, Inc.	Sep 10, 2018	7,581.8	8.3 x	33.7 x	36.9%
Microchip Technology Incorporated	Microsemi Corporation	Mar 01, 2018	10,244.9	5.5 x	18.1 x	11.1%
Marvell Technology, Inc.	Cavium, Inc.	Nov 20, 2017	6,843.3	7.0 x	37.1 x	22.1%
Renesas Electronics Corporation	Intersil Corporation	Sep 12, 2016	3,225.7	5.7 x	31.4 x	47.5%
Analog Devices, Inc.	Linear Technology Corporation	Jul 26, 2016	14,764.0	9.4 x	19.4 x	31.9%
Intel Corporation	Altera Corporation	Jun 01, 2015	18,216.2	8.3 x	27.4 x	18.0%
	Maximum		38,587.6	15.5 x	87.1 x	47.5%
	75th Percentile		17,353.1	9.5 x	34.6 x	38.5%
	Median		**$ 9,871.9**	**7.8 x**	**28.7 x**	**35.7%**
	25th Percentile		7,399.7	6.2 x	23.3 x	25.4%
	Minimum		2,750.0	4.1 x	18.1 x	11.1%

Consolidation Trend

Growing demand for technology and the escalated costs of operating in the semiconductor industry have led to increased industry consolidation. Global capital expenditures have risen 102% since 2010 highlighting the continuous nature of capital reinvestment in the industry. In addition to increased capital expenditures, the number of global semiconductor companies has decreased by 50% since 2010. The number of companies larger than $30 billion in market cap have increased from three to 14 as the giants of the industry are expanding across geographies to capture flourishing global demand. The influx in deal flow over the past decade has led to a drastic increase in valuations. This is seen by the ~530% rise in the PHLX Semiconductor Index since its inception in 2014. The semiconductor industry is highly acquisitive, and acquisitions are likely to continue and drive value creation as the industry evolves with technological advancements.

Headline Deals

Despite the jaws of the pandemic, the second half of 2020 has proven to be a near record breaking year with over $110 billion in deals as industry leaders explore new avenues.

Nvidia's acquisition of Arm levels the competitive playing field against Samsung and Intel by allowing Nvidia to create chip designs and licenses prevalent in personal devices and appliances as part of the IoT ecosystem, including your phone and smartwatch.

AMD's acquisition of Xilinx Corp. provides access to industry-leading FPGA technology – user-programmable chips – useful for bolstering telecommunication networks ahead of the upcoming 5G network race. Additionally, this $36.8 billion deal not only rivals Intel's Altera in the FPGA space, but catalyzes AMD's expansion into the profitable and primarily Intel Corp dominated data-center computer components industry.

Ahead of the US-based Analog Devices (ADI) $22.8 billion acquisition of Maxim Integrated, the firm will boost its market share in the 5G and automotive chipmaking sectors to better compete with larger competitors like Texas Instruments.

Source(s): Accenture, Capital IQ, Company Filings, Statista

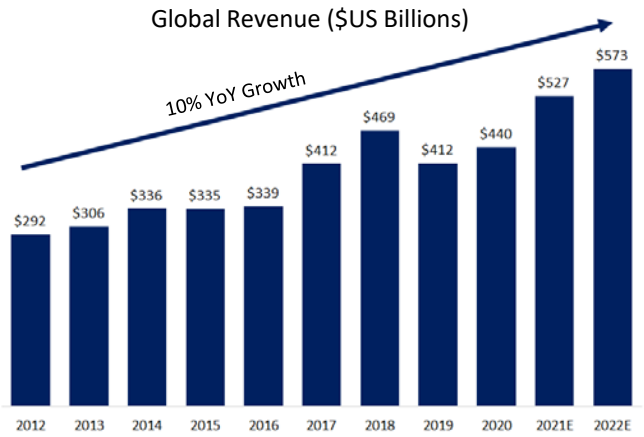
Industry Outlook

Key Drivers of Industry Growth

With the remote workplace becoming the new normal, semiconductors will shape the future of how we work, shop and connect with one another. Accounting for the following catalysts driving growth, the semiconductor market is forecasted to grow at a ~6% CAGR from 2021 to 2025.

AI and Big Data
According to IBM, over 90% of the world's data has been created in the last two years and the future of corporate productivity depends on how companies collect, filter and use information. Semiconductors are not only integral to the collection, but more importantly, the processing of data through algorithms leveraging Artificial Intelligence (AI) and Machine Learning (ML) technology. As US based semiconductor firms lead AI investments, they will be able to capture the surge in demand resulting from the increased applications in cloud computing, healthcare, manufacturing and smartphones.

Industry 4.0 and Smart Factories
Contrary to the industrial revolution, industrial automation, powered by semiconductors, enables smart machines to adapt to worker needs. The e-commerce giant, Amazon, has invested billions in creating smart warehouses where robots transport the high volume of goods while streamlining the use of floor space and reducing operating costs. By utilizing AI and ML enabled by advanced logic chipsets, industrial automation is key to serving the growing demand of the global e-commerce industry on track to reach $5.4 trillion in market size by 2022.



Automotive
In light of the ongoing pandemic, global auto sales have declined an estimated $110 billion (-15% from 2019 to 2020) due to disruptions including chip supply shortages, temporary factory shutdowns, transportation delays and reduced demand. However, by 2022, vehicles are forecasted to require up to 50% more semiconductor components as autonomous vehicle production increases. With the Asia Pacific region driving global demand, the automotive semiconductor segment is on track to reaching $60 billion in revenue by 2022.

IoT Solutions
With 39 billion connected devices powered by semiconductors, each person connects with 7.25x as many devices today as ten years ago, from our toaster and coffee maker to our laptop and smartwatch. Innovations breaching new frontiers in chip design will be integral in boosting interconnectedness and poses game changing solutions in enabling smart cities, remote healthcare, autonomous driving (ADAS) and efficient supply chain management. During the next decade, opportunities created by rising demand for memory, connectivity and sensors can be capitalized by IDMs like Samsung who specialize in memory and discrete, analog and other (DAO).

5G Networks
The reliability and rapid data transfer speeds promised by 5G technology relies upon advanced semiconductors and is instrumental to unlocking the path forward for smart factories, vehicles and cities as part of the broader IoT ecosystem. For example, 5G will be especially helpful in processing the vast amounts of data produced by the increasingly interconnected people worldwide. As the global currency in the digital economy is data, increased communication speeds provide applications with virtual reality, robotics, energy and private networks which can improve how we work and connect with one another.

Source(s): Globe Newswire, Statista

Industry Outlook

Challenges

Why Can't We Just Make More?
The global semiconductor shortage has severely disrupted the supply chain and constrained the production of many electronic devices. The world's leading suppliers are pushing to ramp up production and overcome the prolonged chip shortage, however, these small gains are not likely to remedy the issue due to the prolonged capital realization period of semiconductor companies.

The obvious response to any shortage is to simply ramp up supply. Indeed, semiconductor manufacturers have already announced investments in foundry expansions and new factories that will increase supply. Taiwan Semiconductor Manufacturing Company (TSMC), the world's largest semiconductor manufacturer, has increased its 2021 capital spending budget to $28 billion, a 58% increase from its 2020 capital spending of $17 billion. Unfortunately, the supply crunch does not appear to be easing up in the near term.

Despite billions of dollars in investments, semiconductor fabrication facilities take over two years to build and be equipped with the necessary machinery. The extended build-out times will result in delayed production capabilities and returns for investors and semiconductor companies which indicate that heavy immediate investment will not solve short-term supply chain constraints. In addition, the production of the single chip often takes more than three months and involves sophisticated machinery, extreme precision and high capital expenditures, barring all unprecedented events that may disrupt the process.

Long-term, consistent investments are critical to securing the resiliency of the US semiconductor market, however, making the US self-sufficient will require more than $1.4 trillion in investments and government incentives over a decade. These funds will largely be directed towards Foundries to increase the US' ability to compete on a global scale with China and other semiconductor powerhouses.

Paving The Path Forward
Considering the complexity of the semiconductor manufacturing process, as well as the advanced facilities needed to produce them, it is now clear that the semiconductor shortage is not as simple as simply scaling capacity. It is critical that global foundries increase capacities in the long-term while also making structural changes to increase transparency with buyers, in turn providing more predictability for the supplier.

Winners and Losers

Semiconductors have performed extremely strongly throughout the COVID-19 pandemic. Below we have identified potential winners and losers in the space as we emerge out of the pandemic.

Potential Winners
Global semiconductor equipment manufacturers such as Applied Materials, Lam Research, Tokyo Electron and KLA Corp will massively benefit from the surge in demand for semiconductors and the increased focus on domestic production. As governments direct funds towards developing domestic foundries, equipment manufacturers will benefit.

Consumers have been negatively impacted by disruptions in the semiconductor supply chain. As supply catches up to demand, the massive global investment in semiconductors will continue to accelerate technological trends in innovation across the consumer tech and manufacturing space resulting in higher quality, cheaper goods.

Potential Losers
COVID-19 has exposed the flaws of the global semiconductor supply chain and as countries focus on more domestic production, foundries may be susceptible to political tensions. Global foundries may be negatively impacted by trade wars between the US and China as the US is looking to levy sanctions on foundries which would stop firms from conducting business with China. Additionally, increasing geopolitical tensions in Southeast Asia raise concerns as threats of a military invasion by China into Taiwan may possibly impact TSMC, UMC and VIS, three of the world's largest semiconductor foundries.

There has been a heavy investment into fabless firms to combat the massive demand heightened by the recent chip shortage. However, if long-term demand is not as strong as perceived, this could be highly costly for fabs and foundries alike.

Source(s):CNBC, Financial Times, Harvard Business Review

Business Models: Foundries

Foundries

Pure play foundries or semiconductor fabrication plants (fabs) are factories that do not produce their own designs and only manufacture circuits for other companies.

Over the years, pure play foundries have become more popular and are expected to experience their highest growth this year. The reason for this being the semiconductor shortage, as well as the increase in 5G telecom devices globally from 20M to 200M.

Top Pure Play Foundries
Some of the most prominent pure play foundries globally are TSMC, Micron, UMC, SMIC and SK hynix. The largest one by far is TSMC as they are one of the pioneers of the industry and has capacity for 13 million 300mm wafers/year.

Pure Play Model Company: TSMC

- Taiwan-based company that is considered the revolutionary leader in the $500 billion semiconductor industry
- The most well known pure-play semiconductor foundry
- Serves many companies globally like Apple (responsible for 20% of TSMC's revenue) and Huawei
- Plans to spend $100 billion in next three years

Impact of US-China Trade War
Of the 5 largest pure play foundries, three (TSMC, UMC, and SMIC) trade with China. The implications of this is that despite the tailwinds from 5G becoming more heavily used and increased volume of sales, there will be long-term headwinds as a result of the political tension and tariffs.

Comps Set and Financials Snapshot

Valuation Statistics	Equity	Enterprise	EV/Revenue		EV/EBITDA		P/E	
Company Name	Value	Value	LTM	FY21	LTM	FY21	LTM	FY21
Micron Technology, Inc.	$ 87,339.6	$ 84,873.6	3.3 x	2.4 x	7.6 x	4.3 x	21.4 x	7.2 x
Taiwan Semiconductor Manufacturing Company Limited	$ 538,055.8	$ 521,696.8	10.0 x	8.8 x	14.7 x	13.2 x	27.3 x	25.0 x
United Microelectronics Corporation	$ 25,682.9	$ 23,037.8	3.4 x	2.9 x	8.5 x	6.7 x	18.8 x	12.9 x
SK hynix Inc.	$ 66,799.4	$ 74,933.5	2.6 x	1.7 x	5.9 x	2.9 x	15.0 x	6.0 x
Semiconductor Manufacturing International Corporation	$ 27,574.8	$ 28,457.2	6.9 x	5.6 x	20.8 x	12.0 x	31.7 x	43.6 x
Maximum	$ 538,055.8	$ 521,696.8	10.0 x	8.8 x	20.8 x	13.2 x	31.7 x	43.6 x
75th Percentile	$ 87,339.6	$ 84,873.6	6.9 x	5.6 x	14.7 x	12.0 x	27.3 x	25.0 x
Median	**$ 66,799.4**	**$ 74,933.5**	**3.4 x**	**2.9 x**	**8.5 x**	**6.7 x**	**21.4 x**	**12.9 x**
25th Percentile	$ 27,574.8	$ 28,457.2	3.3 x	2.4 x	7.6 x	4.3 x	18.8 x	7.2 x
Minimum	$ 25,682.9	$ 23,037.8	2.6 x	1.7 x	5.9 x	2.9 x	15.0 x	6.0 x

Foundries being the most capital intensive of all semiconductor companies represent more of a value play compared to the rest of the industry. This can be seen by pure-play foundries having much lower EBITDA multiples than Fabless firms, due to a significantly higher CapEx on average.

Foundries are able to diversify risk as they manufacture chips for Fabless companies and IDMs that exceed their manufacturing capacity. This diversification is incredibly important given the heavy, continuous investment in upgrading technology and refining practices.

Foundries have experienced less significant growth due to their area of specialization. Foundries typically produce DAO chips which represent only 32% of global chip sales compared to logic chip sales at 42%. DAO chips are mainly found in mobile phones, industrial machinery and automobiles

Source(s): CNBC, Statista, Comps as of July 31, 2021

Business Models: Integrated Device Manufacturers (IDMs)

Capitalizing Upon Vertical Integration

The core philosophy behind IDMs is to capitalize upon the synergies that arise via vertical integration across numerous stages of the production cycle. In practice, modern firms adopt a "fab-lite" model, outsourcing some assembly and production, given the sheer need for both scale (CapEx) and specialization (R&D) in light of today's rapid pace of innovation.

Risks of Vertical Integration

IDMs primarily produce and sell memory and DAO chipsets, accounting for more than 90% of the industry's capacity and revenue. Vertical integration can further streamline and standardize production, increasing revenue and reducing production costs if done correctly. However, excessive integration through constructing foundries can run the risk of creating a surplus of chips as IDMs can't meet consumer demands of exponentially faster processing capabilities in time. For perspective, TSMC manufactures advanced chips in the 5 to 7 nm range, whereas IDMs like Intel are still in the 10 to 14 nm era – years behind specialized foundries who have established practices, talented workers and bleeding edge machinery.

Compensation for the tens of billions in setup costs (CapEx and R&D) translates to hiked-up prices which reduces the overall competitiveness of these firms. Consequently, a recent trend has been a shift towards the fabless-foundry model, where design and fabrication are handled by separate entities instead of one firm taking the reins.

General Overview

IDMs primarily develop and manufacture general purpose components that are largely scalable, thus accounting for a majority of the memory (98%) and DAO chips (94%) in terms of both industry capacity and sales (98% and 75% respectively). The US and South Korea hold a combined 80% of the IDM market with successful giants like Intel, Texas Instruments, Micron, NXP and Samsung taking the throne.

In general, IDMs experience moderately high costs for both R&D and CapEx at around 15 and 20% of their annual revenues respectively due to their vertically-integrated structure. As IDMs bring the entire value-chain in-house, they generally cut down on costs and benefit from a slightly higher gross margin.

Comps Set and Financials Snapshot

Valuation Statistics	Equity	Enterprise	EV/Revenue		EV/EBITDA		P/E	
Company Name	Value	Value	LTM	FY21	LTM	FY21	LTM	FY21
Intel Corporation	$ 217,942.0	$ 226,879.0	2.9 x	3.2 x	6.5 x	7.9 x	12.0 x	12.9 x
Infineon Technologies AG	$ 49,605.6	$ 52,931.5	4.5 x	3.9 x	20.2 x	18.4 x	105.9 x	25.4 x
Texas Instruments Incorporated	$ 175,980.4	$ 174,841.4	10.4 x	9.7 x	21.1 x	18.7 x	26.6 x	24.1 x
Micron Technology, Inc.	$ 87,339.6	$ 84,873.6	3.3 x	2.4 x	7.6 x	4.3 x	21.4 x	7.2 x
NXP Semiconductors N.V.	$ 56,922.4	$ 62,886.4	5.3 x	4.6 x	24.0 x	21.8 x	573.3 x	137.6 x
Maximum	$ 217,942.0	$ 226,879.0	10.4 x	9.7 x	24.0 x	21.8 x	573.3 x	137.6 x
75th Percentile	$ 175,980.4	$ 174,841.4	5.3 x	4.6 x	21.1 x	18.7 x	105.9 x	25.4 x
Median	**$ 87,339.6**	**$ 84,873.6**	**4.5 x**	**3.9 x**	**20.2 x**	**18.4 x**	**26.6 x**	**24.1 x**
25th Percentile	$ 56,922.4	$ 62,886.4	3.3 x	3.2 x	7.6 x	7.9 x	21.4 x	12.9 x
Minimum	$ 49,605.6	$ 52,931.5	2.9 x	2.4 x	6.5 x	4.3 x	12.0 x	7.2 x

In 2019, IDMs accounted for approximately 70% of global semiconductor revenues with industry giants, Intel and TI, dwarfing the competition as their chips are prominent in a vast majority of laptops, calculators and wearables. Given their vertically-integrated nature, these firms experience high R&D costs and Capital Expenditures at an average of 14% and 20% of annual revenues respectively. However, their vertical integration yields the highest gross margins in the industry at around 52%. High gross margins and strong cash flow conversion have resulted in IDMs trading strongly on cash flow and earnings-based multiples as they trade at the highest EV/EBITDA and P/E multiples in the entire semiconductor industry.

Source(s): BCG, McKinsey, Comps as of July 31, 2021

Business Models: Integrated Device Manufacturers (IDMs)

Case Study: Intel Corporation (INTC)

Company Profile
Since 1992, Intel has taken the throne for being the largest chipmaker in the world by revenue, only being momentarily overtaken by Samsung in 2018. The company is famous for its x86 chip architecture and its founders who co-invented the integrated circuit – the foundation of modern-day semiconductors.

Investing in the Future
With TSMC being two years ahead of the innovation curve, Intel invested $20 billion in two new Arizona-based foundries while Samsung has pledged to invest $151 billion over the decade to dethrone TSMC by 2030. Unfortunately, investments in cutting-edge foundries can become obsolete within 5 years and must make substantial profits in short time frames to sustain operations in the long run.

The Loss of Apple
In light of Apple's shift from Intel's (x86) chips to Apple Silicon (ARM technology) breaking a 15-year long partnership, Intel will lose 2-4% of its annual sales. This, coupled with the negative press garnered by the CEO's response, is detrimental to Intel's innovative, top-dog image as Apple outpaces the IDM with cheaper, more efficient and more powerful technology.

Losing Market Share to AMD and NVIDIA
Over the past 5 years, Intel's weakening grasp on the crown can be quantified by a drop in datacenter market share from 98% to 68% due to AMD and NVIDIA's adaptation of ARM CPUs. Although Intel still boasts strong financials, perceived weakness in important segments drives investor sentiment downwards.

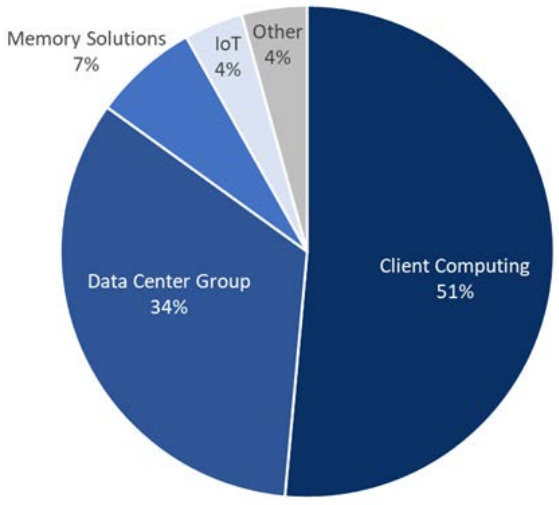
Persistent Supply Chain Delays
Even prior to the pandemic, Intel faced setbacks in upgrading their manufacturing capabilities from the dated 10nm nodes to the more current 7nm counterparts. Coupled with the pandemic's shortage issues, the defect in their manufacturing process means production of 7nm nodes do not commence until 2022. Meanwhile, TSMC is mass producing 5nm nodes that will power the future.

$9 Billion Sale to SK hynix
Given Intel's onslaught of problems and shareholder pressure, the divestiture of the NAND SSD memory business enables the firm to focus on fortifying its Data Center solutions.

Overall, Intel Corp will face a difficult couple of years due to rapidly intensifying competition with its upside being limited due to manufacturing delays and further adoption of ARM by Apple.

Financial Breakdown

Financial Metrics	
Market Cap	US$217 billion
52wk High/Low	$68.49/$43.61
P/E	11.95x
EV/EBITDA	6.50x
3-year Revenue Growth	6%
Operating Margins	31%
CapEx to Revenue	23%
ROE	30%



Source(s): Market Cap as of July 31, 2021

Business Models: Fabless Firms

Designing for the Future

Fabless chip makers are companies that design and sell the hardware and semiconductor chips whilst outsourcing the fabrication of silicon wafers and chips used in these products to a foundry or manufacturer. The fabless business model works by leveraging the design, R&D and distribution networks of the fabless companies, while relying on chip foundries for all manufacturing requirements.

Fabless/fab-lite business models have become popular mainly due to their financial benefits. By outsourcing production, firms can allocate the majority of their resources towards designing new chips. These companies also use their operational foundation to minimize overhead and labor costs.

Top Fabless Chip Makers
U.S. companies: Qualcomm, Broadcom & Nvidia
Taiwan: MediaTek

The ability to outsource manufacturing and rely on Instruction Set Architecture (ISAs) for compatibility has created an incredibly diverse field as fabless companies can focus exclusively on design, and have all other processes taken care of externally. As a result, over the past decade, almost every company that uses specialized chips have started designing their own, including Apple, Google, Samsung and Huawei for their phones as well as Microsoft and Amazon for their data centers.

Impact of US-China Trade War
The trade war led to new tariffs being added to components moving between the two countries. Products designed by fabless chip makers have become difficult to obtain and more costly in the end-market.

Comps Set and Financials Snapshot

Valuation Statistics	Equity	Enterprise	EV/Revenue		EV/EBITDA		P/E	
Company Name	Value	Value	LTM	FY21	LTM	FY21	LTM	FY21
NVIDIA Corporation	$ 485,915.1	$ 480,986.1	25.0 x	18.9 x	69.0 x	48.6 x	92.4 x	48.4 x
QUALCOMM Incorporated	$ 168,974.4	$ 171,807.4	5.3 x	4.8 x	14.5 x	11.8 x	18.7 x	16.7 x
Advanced Micro Devices, Inc.	$ 128,808.5	$ 125,568.5	9.4 x	7.5 x	43.3 x	30.9 x	37.4 x	40.4 x
MediaTek Inc.	$ 51,538.8	$ 45,033.1	3.4 x	2.5 x	18.8 x	11.1 x	23.8 x	14.9 x
Broadcom Inc.	$ 199,159.6	$ 230,106.6	9.0 x	8.2 x	17.6 x	13.8 x	45.1 x	16.8 x
Maximum	$ 485,915.1	$ 480,986.1	25.0 x	18.9 x	69.0 x	48.6 x	92.4 x	48.4 x
75th Percentile	$ 199,159.6	$ 230,106.6	9.4 x	8.2 x	43.3 x	30.9 x	45.1 x	40.4 x
Median	**$ 168,974.4**	**$ 171,807.4**	**9.0 x**	**7.5 x**	**18.8 x**	**13.8 x**	**37.4 x**	**16.8 x**
25th Percentile	$ 128,808.5	$ 125,568.5	5.3 x	4.8 x	17.6 x	11.8 x	23.8 x	16.7 x
Minimum	$ 51,538.8	$ 45,033.1	3.4 x	2.5 x	14.5 x	11.1 x	18.7 x	14.9 x

The less capital-intensive nature of Fabless companies is reflected in modest cash flow-based valuation multiples relative to their peers in the semiconductor industry. Having the lowest Capex as a percent of revenue at 4% and the highest R&D as a percent of revenue at 20%, Fabless companies trade largely based on their growth potential which is represented by the highest median EV/Revenue multiples as investors are excited by the top line capabilities, especially given the recent investment in the Fabless space. Fabless firms will benefit greatly from increased overall investment in the industry as historically Fabless companies have grown at accelerated rates during times of increased investment. In 2000, Fabless companies made up around 10% of the total semiconductor industry revenue whereas now they represent approximately 30% of industry revenue. This growth is largely due to the influx in demand for logic chips, which Fabless companies predominately design. Logic chips can be found in consumer electronics, PCs and infrastructure innovation.

Source(s): Comps as of July 31, 2021

Business Models: Outsourced Semiconductor Assembly & Test Providers (OSATs)

OSATs

Outsourced Semiconductor Assembly and Test (OSATs) Providers are third party companies offering IC packaging and test services. These companies mainly package and test silicone-based devices made by foundries. OSATs play a critical role in the semiconductor value chain as they are responsible for distributing the chips throughout the global markets.

As of 2020, the OSAT market is valued at $31.6 billion, and it is expected to reach $49.7 billion by 2026, with a CAGR of 7.3% from 2021 - 2026. OSATs are largely expected to grow alongside the Fabless-Foundry model as companies producing chips through this model need to outsource testing and distribution. With such heavy investments in both Fabless firms and Foundries it is natural that OSATs will grow alongside the two.

Companies in the OSAT market are actively innovating ways to offer packaging and testing solutions for semiconductor companies. OSATs are involved in the communications, consumer & computing markets, while also recently entering automotive markets and wearable devices.

OSATs Segment Economics
(% of annual revenue, 2016-2019)

Gross Margin	17%
Research & Development	4%
Capital Expenditures	16%
Operating Cash Flow	2%

Drivers

Pent up demand in the automotive industry for integration of more high-powered semiconductors and the growth of the EV market is expected to have the highest impact on short-term OSAT growth. The sector is shifting into using devices from the semiconductor industry, especially due to increasing usage of the ADAS system.

The government of China has made a pledge in that it recognizes OSAT as a potential market for growth. The country mentioned that it will continue to provide incentives and support for OSAT providers in its “Made in China 2025” plan. With the proposed $150 billion investment in Foundries by the Chinese government, OSATs will be crucial in supporting the evolution of Chinese semiconductors to meet strong regional demand

Comps Set and Financials Snapshot

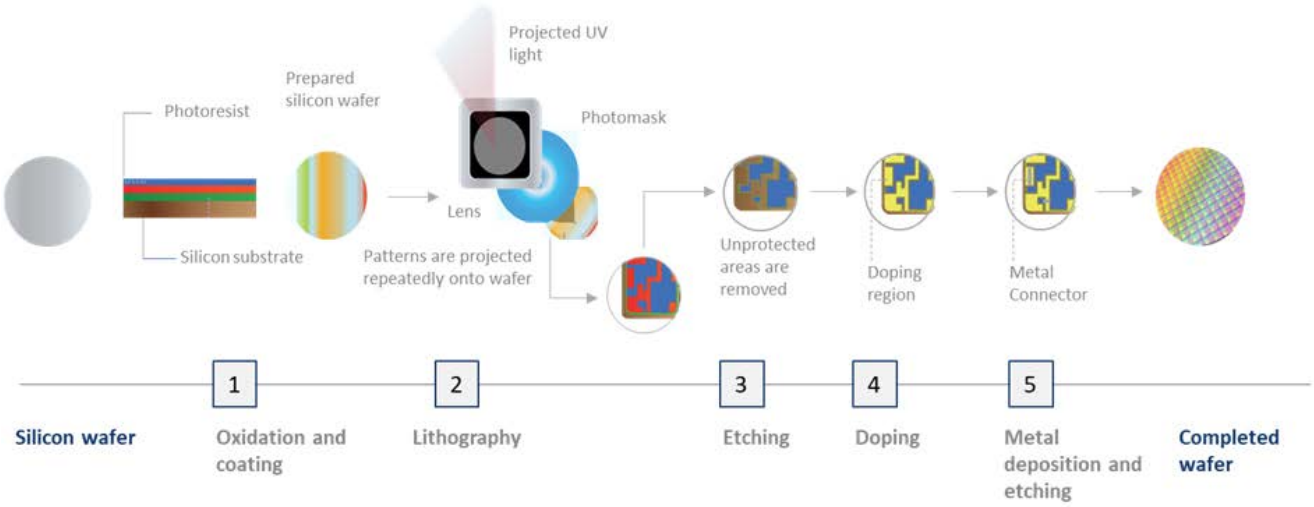
Valuation Statistics	Equity	Enterprise	EV/Revenue		EV/EBITDA		P/E	
Company Name	Value	Value	LTM	FY21	LTM	FY21	LTM	FY21
Amkor Technology, Inc.	$ 6,017.1	$ 6,289.5	1.2 x	1.0 x	5.5 x	5.5 x	12.9 x	9.9 x
ASE Technology Holding Co., Ltd.	$ 18,877.8	$ 24,661.9	1.3 x	1.2 x	7.3 x	5.9 x	15.1 x	11.0 x
JCET Group Co., Ltd.	$ 10,784.4	$ 12,265.9	2.9 x	2.5 x	15.0 x	12.5 x	40.4 x	31.9 x
Tongfu Microelectronics Co.,Ltd	$ 4,763.2	$ 5,299.0	2.9 x	1.9 x	15.3 x	11.5 x	51.4 x	36.0 x
Powertech Technology Inc.	$ 3,053.4	$ 3,831.1	1.4 x	1.2 x	4.3 x	9.8 x	12.7 x	9.2 x
Maximum	$ 18,877.8	$ 24,661.9	2.9 x	2.5 x	15.3 x	12.5 x	51.4 x	36.0 x
75th Percentile	$ 10,784.4	$ 12,265.9	2.9 x	1.9 x	15.0 x	11.5 x	40.4 x	31.9 x
Median	**$ 6,017.1**	**$ 6,289.5**	**1.4 x**	**1.2 x**	**7.3 x**	**9.8 x**	**15.1 x**	**11.0 x**
25th Percentile	$ 4,763.2	$ 5,299.0	1.3 x	1.2 x	5.5 x	5.9 x	12.9 x	9.9 x
Minimum	$ 3,053.4	$ 3,831.1	1.2 x	1.0 x	4.3 x	5.5 x	12.7 x	9.2 x

OSATs typically trade at the lowest multiples due to their operating model. As they only assemble, package and test chips they share a much smaller portion of the profits as chips are passed down the value chain. OSATs earn gross margins of 17% with cash flow conversion of around 2% representing a less attractive investing opportunity relative to their peers in the industry as investors are typically not willing to pay large multiples for low cash flows. However, due to the less capital-intensive nature and lower-skilled work required to operate an OSAT they are emerging quickly alongside the Fabless-Foundry model. As investment has increased in Fabless and Foundries this has led to an increased demand and quick scale up of OSATs to compliment this demand spike.

Source(s): Forbes, Globe Newswire, Insider, Comps as of July 31, 2021

Appendix

Production Process



Process	Description
Oxidation and Coating	Oxidation is the process of adding oxygen to a material. Coating is the process of applying a thin layer of material to a surface.
Lithography	Lithography is a process used to create circuit boards with Extreme Ultraviolet (EUV) lasers printing patterns that will later form the billions of transistors.
Etching	Etching is a process used to create a design on a surface by removing material.
Doping	Doping is the deliberate introduction of impurities into a semiconductor in order to change its electrical, optical, and structural characteristics.
Metal Deposition & Etching	Metal deposition is the process of adding a thin layer of metal onto a substrate. Metal etching is the process of removing a thin layer of metal from a substrate.