SEMICONDUCTOR MANUFACTURING

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CAN THE U.S. BRING SEMICONDUCTOR MANUFACTURING BACK TO ITS SHORES (AND SHOULD IT)?

BY PAUL DICKSON

INTRODUCTION

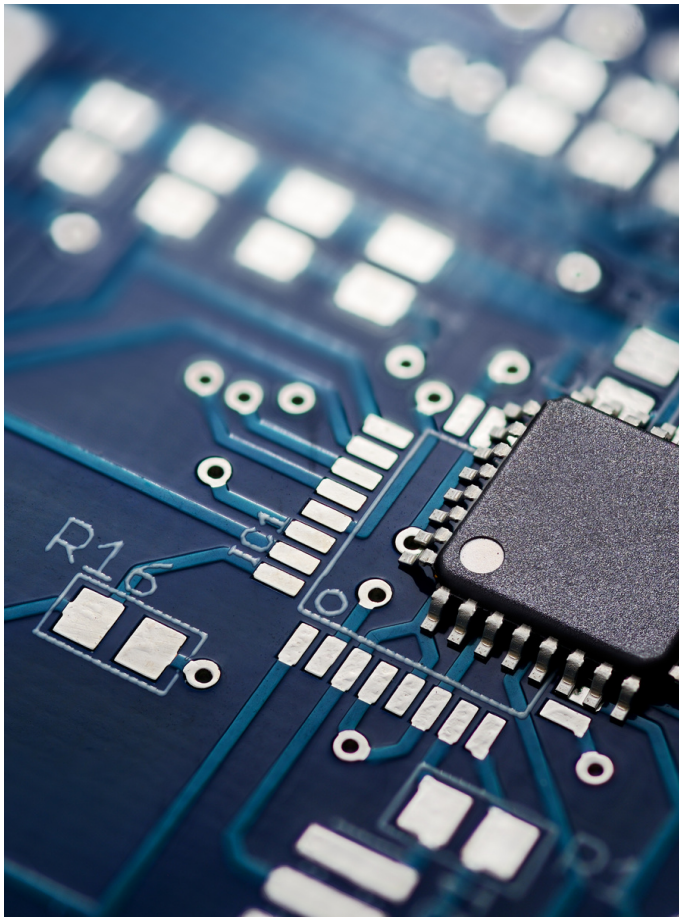
It's no secret that the U.S. has lost millions of manufacturing jobs over the last three decades, about five million jobs since 2000.

The U.S. used to dominate manufacturing of cars, electronics, textiles and other products. Both low and high tech manufacturing jobs have been relocating to mostly Asian countries, especially China. Although this has been an important issue for decades, it has taken on added importance recently due to three main events:

Chip Shortage:
The recent global semiconductor ("chip") shortage affecting virtually every industry. This highlights the U.S.'s dependence on a manufacturing supply chain located almost entirely outside the U.S.

Covid-19:
The Covid pandemic, which highlights the offshoring of critical drugs and medical equipment.

The Rise of China:
The U.S.'s increasing concern for its status as a major competitor and threat to the U.S.'s traditional role as the world leader.



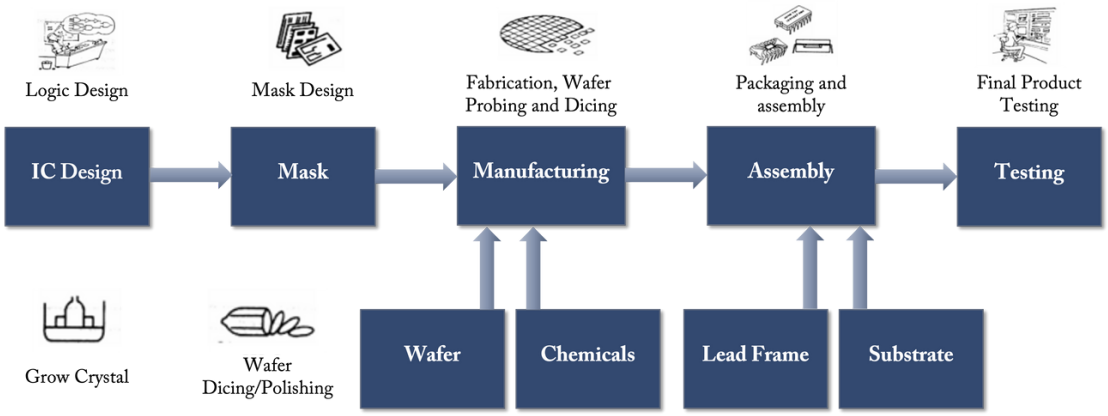
Source: https://money.cnn.com/2016/03/29/news/economy/us-manufacturing-jobs/

In this white paper, we discuss the pros and cons of bringing more semiconductor manufacturing back to the U.S.We also mention printed circuit board assembly (PCBA), in which semiconductor chips are inserted into boards, which in turn are inserted into systems such as computers, TVs and cars.That is a different, but related industry. Although we focus on the U.S., these issues apply to any and all countries and not specifically to semiconductors, although we believe chips are a special case. Economic globalization is on balance a good thing for most countries. We advocate that every country should maximize its key technology manufacturing bases, as those bases are becoming more and more important to the economic health of most countries. This issue has been exacerbated by the recent Covid-induced global supply chain disruptions, which have had negatively affected customers in many other countries. Finally, we also advocate that every country has the right and obligation to do all it legally can to protect itself economically and militarily.

So what can and should the U.S. do with respect to semiconductor manufacturing?

We are mindful of the harm that government policy can cause. We advocate for as much freedom as is practical for individual companies and industries to make their own decisions. However, when these decisions are short-sighted (i.e., the emphasis on quarterly profits) and affect the strategic political, economic and military interests of the U.S., the government should step in (as competitive governments such as Germany, Japan, Taiwan, Korea and China do) and help drive the bus.

Semiconductor Manufacturing Process

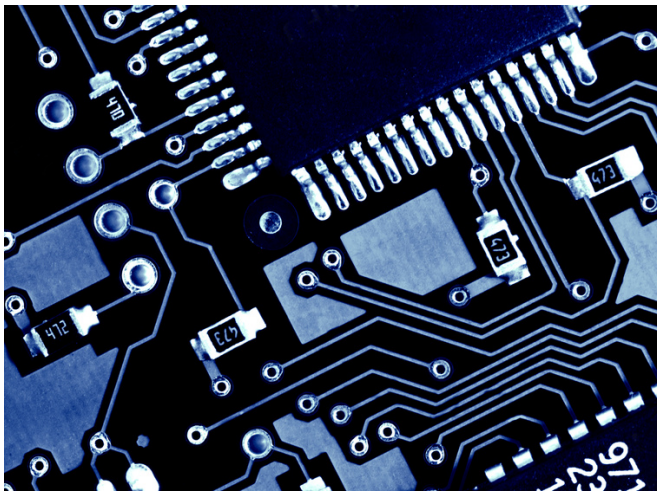


Source: Televisory's Research, Industrial Economics & Knoledge Center of Technology Research Institute (IEK/TRI

Where the U.S. comes up short

Semiconductor manufacturing consists of two main parts: front-end wafer fabrication ("fabs") and back-end packaging (see diagram below). The supply chain consists of equipment and materials (including the silicon wafers) used to manufacture chips. Further back in the chain is the design of the chips using sophisticated software. The U.S. is dominant in the design, equipment and materials stage of the process and currently well positioned for the future. It is less dominant in the manufacturing of the silicon wafers where the Germans (Wacker) and Japanese (SEH) dominate. It is the actual critical manufacturing of the chips (where the vast amount of technology is used and capital is spent) where the U.S. is woefully short, both in the front and back-end. That manufacturing deficiency will also harm the U.S. equipment and materials industries eventually, as more local vendors arise in countries such as Taiwan, Korea and China. In fact, that has already happened in the equipment and materials sector for back-end semiconductor assembly and packaging, where many equipment and materials companies have sprung up to take market share from their European and American predecessors.

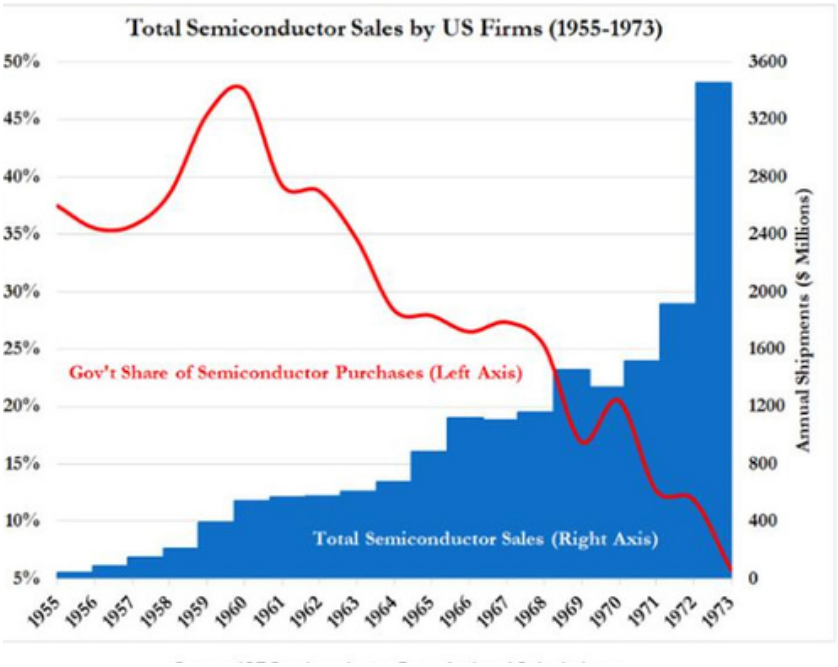
Why semiconductor manufacturing left the West for Asia



In a word: COSTS. Due to high costs (for land, labor, taxes, safety and environmental regulations, etc.), the U.S. became more and more expensive to manufacture relative to the rest of the world, especially Asia.

Concurrently, the U.S. government, specifically the Department of Defense (DOD), has dramatically reduced its financial support for the industry over the past few decades.[1] Total defense spending as a percentage of U.S. GDP is down. The DOD still buys chips from U.S. manufacturers and requires that most of the chips it uses are made in the U.S., but it hasn't made the contractual commitments that it used to in order to lower the high capital risk to chip makers. It also does not spend as much on R&D focused on manufacturing.

As the cost of decreasing the linewidths of advanced chips has grown (primarily due to increased capex costs), only the largest, best capitalized companies (ie Intel) can afford to build advanced chip manufacturing facilities called "fabs." The cost of the average advanced fab grew from $500 million in 1992 to over $10 billion today.[2] The rest of the advanced chip companies have had to contract with (mostly Taiwanese) offshore chip "foundries" for their products. (In this paper, we are primarily addressing leading edge semiconductor production. There exist industry niches such as power devices, some analog devices and sensors which can utilize older generation manufacturing equipment and be built in lower quantities in the U.S.).

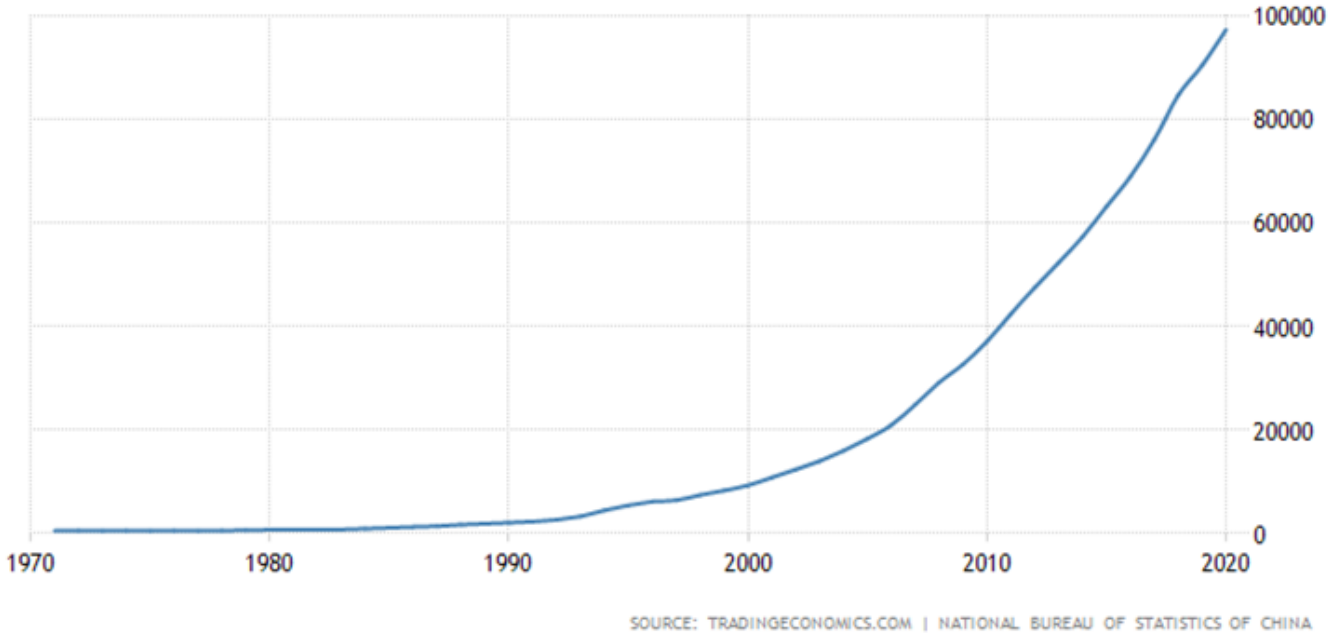


Also, the world has been metaphorically "shrinking," due primarily to improvements in transportation, communications and the growth of global capitalism, making it easier to manufacture in Asia and ship goods back to the U.S. In the semiconductor industry, this began in the 1980s with back-end chip packaging, which has historically been less complex, less automated and less costly than front-end wafer fabrication. It has morphed into the entire manufacturing process moving offshore.

[1]https://employamerica.medium.com/a-brief-history-of-semiconductors-how-the-us-cut-costs-and-lost-the-leading-edge-c21b96707cd2
[2]https://www.princeton.edu/~ota/disk1/1993/9315/931505.PDF

China

China was one of the world's poorest countries only 30 years ago, until Deng Xiaoping began to open up the economy very slowly and in a controlled fashion in the 1980s. In the 90s, the Communist government presented their people with a deal: We'll let you make lots of money (capitalism) if you let us continue to rule the country with an iron fist (communism). The country has been running this way ever since, and the results so far have been mind-blowing.



See above chart, which shows the growth of annual wages in China in CNY the past 50 years. For reference, 100,000 CNY is about $16,000 USD.

The Chinese government has staked out key strategic industries for investment and protection.Semiconductors is one of these industries. So far, the U.S. has managed through diplomatic and economic arm twisting to prevent the most advanced production equipment and processes (mostly photolithography from Holland (ASML) and Japan (Nikon and Cannon)) to go to China, so it remains a generation or two behind us. However, China plans on catching up quickly, by hook or by crook.

Why should the U.S. desire to bring back more semiconductor manufacturing?

You cannot transfer semiconductor manufacturing to countries with smart, ambitious people without also transferring your know-how and intellectual property (IP), i.e., your crown jewels, no matter how hard you try not to. (This typically happens organically, but with China it has been accelerated by IP theft.)

Know-how transfer is what has happened in the global semiconductor manufacturing arena over the last four decades. What started as basic low-value-add chip assembly services in Asia has blossomed into much higher value-add design, R&D, and the most complex electronics manufacturing. Supply chains have also grown up in those countries; the disruptions in which can cause serious consequences in the U.S. economy.[3] The loss of higher value-add, complex manufacturing has resulted in the loss of many high-paying jobs in the U.S. As will be discussed below, it is also of strategic importance to the U.S.

[3] https://www.forbes.com/sites/arthurherman/2021/05/03/the-global-chip-shortage-is-americas-wakeup-call/?sh=6995789928fd

In today's world, with competitor countries using strategic economic initiatives to support industries they consider vital to their very survival (as should the U.S.), we believe the U.S. has to institute government-sponsored industrial policy, although not nearly as much as many of its competitors. In fact, too much government strategic intervention hurts the very companies and economies it is modeled to help, as it drives up costs and results in inefficient use of resources. Helping the steel industry for instance, can hurt the auto and computer industries which use steel. Another example is the U.S. funding of a semiconductor consortium, called Sematech, to manufacture memory chips in the 1980s. This was in response to Japan's government-sponsored dominance of that then-critical industry. Within a decade, however, the memory chip industry became commoditized, and the need for Sematech subsided.

We believe the factors the U.S. government should consider in intervening in markets with subsidies and tariffs are:

1. **Strategic political importance:**
   The ability to relate to and negotiate with other countries. Politics infects virtually every interaction between countries. It is really intangible. But it is critical to maximizing any country's place in the global community. The perception of being on the "cutting edge" is important to geopolitical dynamics.
2. **Strategic economic importance:**
   The ability to drive increases in standard of living. Some industries inarguably are more economically important than others. (As economic advisor, Michael Boskin, memorably quipped, "Potato chips, computer chips, what's the difference? A hundred dollars of one or a hundred dollars of the other is still a hundred dollars."[4]) As we point out in this paper, that is absolutely not true. Some industries (such as semiconductors and energy) can act as "chokepoints" which affect industries further downstream.
3. **Strategic military importance:**
   The ability to protect a country against enemies. This should be self-evident. Most people agree that this is critical for any country, and they should spend whatever is necessary.

These criteria are not mutually exclusive and in fact overlap more often than not.

In the below chart, we rank the strategic importance of the two main components of the semiconductor manufacturing industry from low to high. We include the PCBA industry as it is very closely linked to the back end semiconductor industry and is becoming more so with leading edge packaging solutions:

	Political	Economic	Military	Risk to US
"Front end" Semiconductors, equipment, and materials	High	High	High	High
"Back end" Semiconductor packaging and PCBA (printed circuit board assembly)	Med High	Med High	High	Med High

We could rank many other manufacturing industries, such as computers, airplanes, automobiles, consumer electronics, oil and gas, textiles and others. Suffice to say that none of them (except arguably oil and gas) would score as high as the two areas of semiconductor manufacturing above. Let's discuss each of the two in more detail:

1. **Semiconductors, equipment and materials**
2. **Semiconductor packaging and PCBs**

[4] https://www.jstor.org/stable/1149161?seq=1

Semiconductors, equipment and materials:

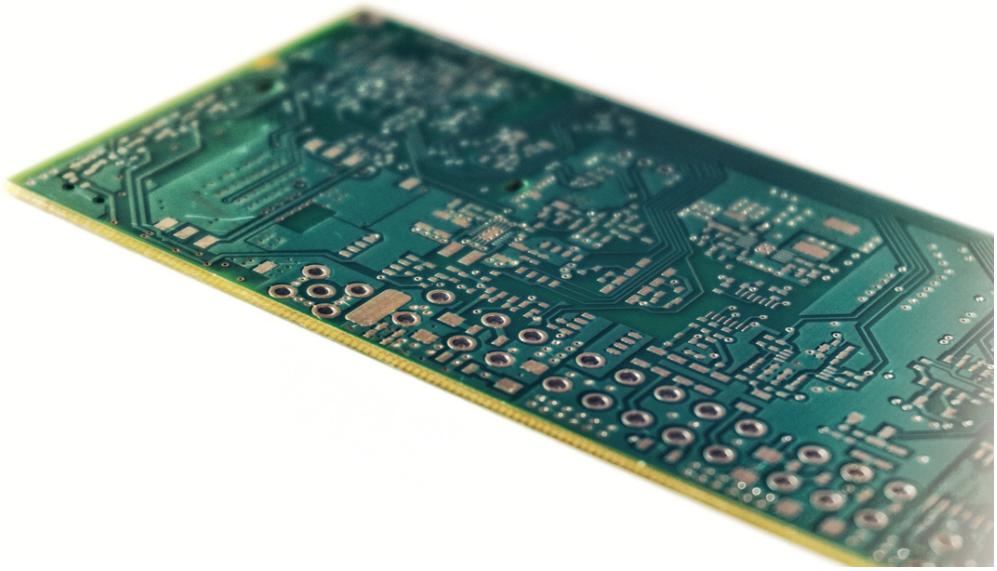
No manufacturing industry is more important in all four categories than the nearly half trillion dollar semiconductor industry. Why? Simply because semiconductors are the building blocks of the modern economy. Virtually everything today runs on them, including many industries which China and other countries consider critical, such as artificial intelligence, advanced computing, 5G telecommunications, advanced manufacturing, and robotics, to name a few. The U.S. semiconductor industry provides over 240,000 direct jobs and each job supports nearly five other jobs for a total of over one million direct and indirect jobs.[5] Millions of other current and future jobs in some of the industries mentioned are dependent on a strong semiconductor supply chain.

The U.S. is still a leader in chip design, with 65% of global market share for "fabless" chip companies. It still owns 40% of the global equipment market.[6] Unfortunately, the U.S. chip industry has been very short-sighted (like many other industries) in transfering too much critical leading-edge manufacturing to other countries such as Taiwan. The U.S. has gone from producing 70% of global chips in 1979, to 37% in 1990, to 12% today. That 12% consists of Intel's "standard" IC microprocessors; a very small amount of contract manufacturing ("foundry") capacity at primarily two companies, Skywater and Global Foundries (which may itself sell to Intel); as well as many other small volume "specialized" applications. The vast majority of the rest of the leading-edge, high volume manufacturing is in Asia. Chip design is great, but if you can't make them, design is useless.

If anything was to happen to the Taiwanese semiconductor supply chain (as China is currently sabre rattling about "reunifying" Taiwan), the U.S. would find itself in a world of hurt in many critical industries, such as computers, artificial intelligence (AI), telecommunication systems, the internet, automobiles, transportation and weapons systems.

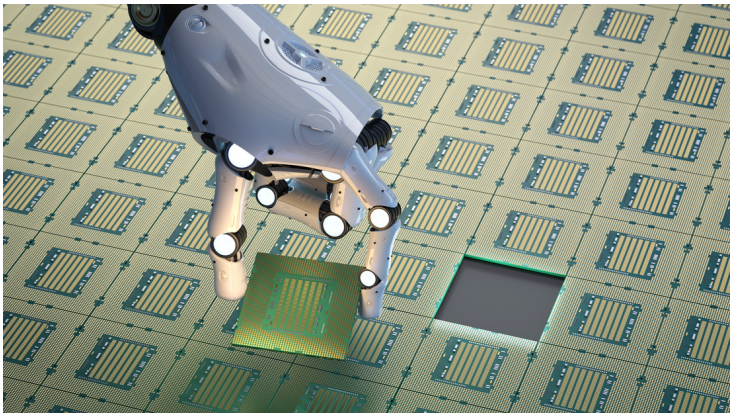
Many believe that the multi-trillion dollar industry of the future will be AI and machine learning. These technologies of tomorrow will need increasingly specialized chips to run efficiently, said Brendan Burke, an emerging tech analyst at PitchBook. China and the U.S. are in an arms race to build the chips to power that industry. In recent years, China has launched semiconductor-focused funds reportedly totaling around $50 billion.[7]

Even our military is at risk, despite the vast majority of components it uses having to be made in the U.S. Why? If the U.S. falls further behind in chip development and manufacturing, American manufacturers of those chips will also fall behind. We could find ourselves with planes, ships and tanks with inferior computer and weapons systems.



[5] https://www.semiconductors.org/wp-content/uploads/2020/06/2020-SIA-State-of-the-Industry-Report.pdf
[6] https://www.semiconductors.org/wp-content/uploads/2020/06/2020-SIA-State-of-the-Industry-Report.pdf
[7] https://pitchbook.com/news/articles/US-China-semiconductor-chipmakers-venture-capital

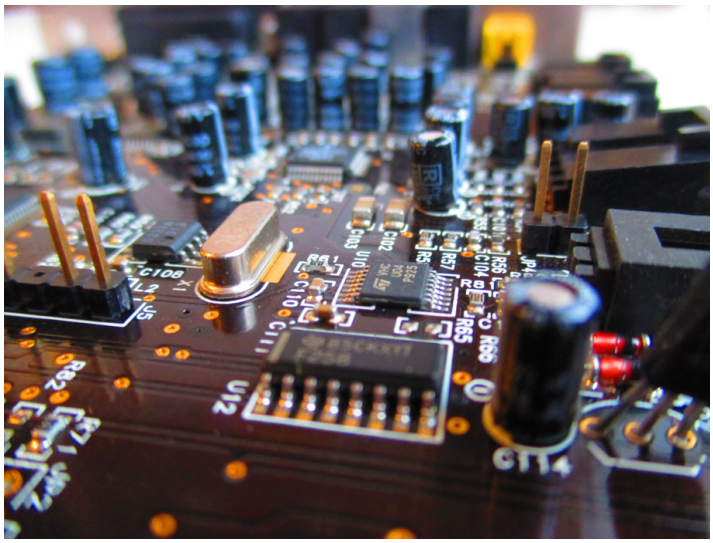
The U.S.'s long-time global lead in microprocessor development and "linewidth" shrinkage (leading to faster and more efficient transistors) has disappeared in the past five years, moving from Intel to Taiwan's TSMC. The fact that the U.S. semiconductor manufacturing industry's technological advancement has been so dependent upon one company, Intel, is staggering and scary for the U.S. That development is so dire that President Joe Biden's infrastructure proposal, the American Jobs Plan, would allocate $50 billion in new spending to the U.S. semiconductor industry to win back global technology and manufacturing leadership. (Frankly, we believe that is probably only a fraction of what is really needed, as the cost of new chip plants can run $10 billion to $20 billion each).



Seeing the handwriting on the wall (that the U.S. may finally be getting serious about requiring more onshore semiconductor manufacturing), just in the past few months three global semiconductor leaders—Intel, Samsung and TSMC—have announced plans to invest over $100 billion combined in new fabs in the Phoenix area. (Why Phoenix? Low taxes, competitive labor costs and a generally friendly business environment, of course). That number will certainly increase substantially. This is obviously a good sign for the U.S. However, in the past, foreign semiconductor manufacturers such as Hyundai, Fujitsu, TSMC, Samsung and others have "announced" plans for multiple fab developments, only to build one such fab and then cut and run, as they realize the exorbitant cost of running them in the U.S. Any government-sponsored developments this time would have to have real "teeth," i.e., penalties built in, if those companies again decided to back out.

Semiconductor packaging and PCBs:

The semiconductor "back end", where the wafer is diced up and placed into individual packages, then placed on printed circuit boards to be incorporated into electronic systems, is not nearly so complex and expensive as "front end" semiconductor wafer development and production. Over 95% of this manufacturing is done in Asia and has been for over four decades, transferring there well before the front end fabs did. Frankly, this portion of microelectronics manufacturing has been treated as an afterthought by chip makers in the past. However, with modern chip development, the need to be able to package these increasingly small and powerful devices and integrate them into the real world becomes more critical.[8] Just as chip design needs wafer fabrication, so does fabrication need packaging to function. We believe that a reasonable level of advanced semiconductor and PCB packaging technologies such as "3D" packaging and "flex" boards, especially for the military, will increasingly have to be manufactured in the U.S.



[8] https://mule.substack.com/p/semicap-primer-packaging-history

Conclusion

Every advanced country needs advanced manufacturing to function as its backbone. Without it, good paying jobs disappear and families get decimated. This negative process ripples throughout society, resulting in many of the problems the U.S. has today: divorce, drug dependency, homelessness and inequality.

The U.S. invented semiconductors. Semiconductors are arguably the most important manufacturing industry for the U.S. The U.S. was once the semiconductor manufacturing envy of the world, with dozens of leading edge fabs. We've discussed the imperative in bringing leading edge semi manufacturing back to the U.S. But is it realistic to expect that it can do so in a reasonable amount of time and at reasonable cost? The answer is that the U.S. must, no matter what. There's no question that semiconductor manufacturing left the U.S. in the first place because it was and is just too expensive in labor, land and regulations compared to Asian countries, and its public companies have been focused on short-term profits. That's why the semiconductor industry will need government carrots and sticks to bring back, we believe.

Both the carrots and sticks have to be tax and regulatory incentives. The U.S. should positively incentivize semiconductor companies with tax credits, and accelerated depreciation for the expensive capex needed (a single leading-edge photolithography tool now costs over $150 million). It has to make sure there is plenty of reasonably priced land available. It has to make sure its environmental and safety regulations are competitive with Asian countries, and don't force semiconductor companies to produce in other countries to remain competitive.

Those positive incentives should be balanced with negative ones, too, arguably starting with the dreaded "T" word: Tariffs. We believe that tariffs are usually an evil to be avoided. They often result in increased costs for consumers.However, the U.S. must look at all alternatives with respect to deterring China and other countries from "dumping": making chips at below cost, flooding the market, grabbing market share, then driving out U.S. competitors. Also from extorting U.S. companies out of key intellectual property and believe it or not, making counterfeit chips, which are increasing in number, especially in today's current shortage. The U.S. government must encourage Science, Technology, Engineering and Math (STEM) education at all levels so it can increase its homegrown pool of talent.The government must increase its investment in semiconductor R&D, to ensure it remains on the competitive edge.

Vis a vis China, there must also be a national security component. The U.S. needs to take China's intellectual property theft (increasingly perpetrated by Chinese spies in U.S. universities and companies) much more seriously, with serious penalties for such behavior. The China issue may extend to the world-leading Taiwan semiconductor industry before we know it, as China continues to rattle its sabre about "reunification" with Taiwan. If China were to take over Taiwan's advanced fabs, it would control the world's supply of advanced chips. Another stick the U.S. has is its political and economic relationship with Holland and Japan, where the most advanced photolithography machines are made. So far, it has been successful at preventing those companies from selling their most advanced machines to China. China is still several technology nodes behind the global leaders in Taiwan, and the U.S.[9] On the other hand, China is as we speak, continuing to steal advanced chip technology from wherever it can, as well as spending billions of dollars to develop its own advanced photolithography technology. It is probably just a matter of time before it catches up.

This process won't be easy, as the U.S. propensity to outsource semiconductor manufacturing in the past couple of decades has resulted in the loss of know-how and increased global competition. This issue was raised before, in the 1980s, to fight back against "Japan, Inc.", with meager governmental support. The stakes today, however, are much higher, as more and more of the world's economy (and our military) is comprised of semiconductor-run technology, and China has made clear its desire to dominate the world, economically at least. At this point the U.S. really has no choice but for the government to contribute to onshore semiconductor supply chain manufacturing if it doesn't want to find itself falling farther and farther behind other countries, especially China, in critical technological development. This development is crucial for the U.S. politically, economically and militarily. Finally, we would argue that U.S. success in the semiconductor manufacturing industry is good for the free world economically and militarily.A strong U.S. is a large contributing factor for a stable, free world.

[9] https://www.reuters.com/technology/chinas-smic-invest-887-bln-new-chip-plant-shanghai-2021-09-03/

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About the Author

Paul Dickson has over 15 years in investment banking and is a Managing Director in the Advanced Manufacturing Team at FOCUS Investment Banking. With nearly 25 years of experience in the Semiconductor industry, he has worked for Fortune 500 companies such as AMAT, KLA, and Varian. He has also worked with global companies such as Intel, Samsung, NEC, TSMC, and others. His extensive experience in leadership, sales, marketing, operations, law, and finance led him to start up his own manufacturing software company which he built from the ground up and later sold to a large public company at a significant multiple. After selling his business in 2006, Mr. Dickson decided he wanted to utilize his experiences and successes to help other entrepreneurs and companies grow, build value and exit. He has helped dozens of companies in multiple industries on their journey, culminating in highly profitable M&A events.

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