Inside the global battle over chip manufacturing

A few weeks ago, President Joe Biden was in the Netherlands, where he asked the Dutch government to restrict export from a company called ASML to China. ASML is the only company in the world that makes a specific machine needed to make the most advanced chips. Apple couldn't make iPhone chips without this one machine from the Netherlands' biggest company. ASML doesn't just shape the Dutch economy — it shapes the entire *world* economy. How did that happen?

Chris Miller, Tufts professor and author of *Chip War: The Fight For The World's Most Critical Technology* walked me through a lot of this, along with some deep dives into geopolitics and the absolutely fascinating chip manufacturing process. This one has everything: foreign policy, high-powered lasers, hotshot executives, monopolies, the fundamental limits of physics, and, of course, Texas. Here we go.

The following excerpt has been lightly edited for clarity. The full transcript is coming soon.

Can you walk us through the basics of EUV lithography and how that makes chips?

So first off: what is lithography? If you want to make patterns on silicon wafers, you do so by shining light through masks. The masks will block light in certain areas and let it through in others, and that is how you get a pattern in a miniaturized version on a chip. Advanced chips today have millions, or often billions, of tiny circuits carved into them. They are often the size of a virus or even smaller, so you really need ultra-precise carbon capabilities. EUV

lithography uses light at a wavelength of 13.5 nanometers, an ultrasmall light far smaller than the wavelength of visible light. You need really small wavelength light because the circuits you're carving are very, very tiny and often measure just a couple of nanometers in dimension. Producing this type of light is really hard because it's right next to the X-ray spectrum. The production of it is complicated, and the development of mirrors to reflect it is also very difficult.

Here's how the process works. A ball of tin falls at a rate of several hundred miles an hour through a vacuum and measures around 30 millionths of a meter in diameter. It is pulverized by two shots from one of the most powerful lasers ever deployed in a commercial device and explodes into a plasma measuring several times hotter than the surface of the Sun — that is, several hundred thousand degrees Fahrenheit. This plasma emits EUV light at exactly the right wavelength of 13.5 nanometers and is then collected via a series of about a dozen mirrors, which themselves are the flattest mirrors humans have ever produced. The mirrors reflect the light at just the right angle so that it hits the silicon wafer and carves the circuits on the chips that make your iPhone possible.

That's how you get to an A13 chip in the iPhone, right?

That's right.

TSMC has to buy this machine from ASML, which has to assemble all these components from the flattest mirrors ever produced to the most powerful lasers ever deployed in a commercial setting to balls of tin. I imagine the balls of tin are somewhat easy to acquire. It has to make that machine, then it sells it to TSMC, which then uses it to make iPhone chips or whatever else. Does ASML just wash its hands of this machine when it sells it to TSMC? This sounds like a very complicated thing to operate.

"Just shipping the machine alone takes multiple [Boeing] 747s

to move, and they cost $150 million apiece.”

It’s extraordinarily complicated. Just shipping the machine alone takes multiple [Boeing] 747s to move, and they cost $150 million apiece. There is also ASML staff on-site next to the machine for the entire lifespan of these tools. ASML is the only company that knows how to service them when something goes wrong, and they are the only company with the spare parts in case something breaks. You just can’t operate them without ASML staff.

They’re so sophisticated and precise that learning how to operate them in a mass-production facility requires not only the semiconductor companies like TSMC to have done a lot of research into using them but also a deep partnership with ASML because they have really unique knowledge about how the optics work and how the light reflects and refracts in different contexts. You need to partner very, very deeply with ASML to understand how to actually use these machines in mass manufacturing.

It sounds like ASML has a monopoly on this fab equipment. Do they sell to other vendors? Can Intel buy these machines? Can other foundries? Can Samsung buy these machines?

Yes. ASML sells to customers all over the world — except in China, which we can discuss — but there are only a couple of companies that can really plausibly use an EUV machine. It’s TSMC, Samsung, Intel, and a couple of memory chip makers as well, like SK Hynix and Micron. There are very few other potential customers out there because the price tag is so high and the level of precision manufacturing skill needed to actually make use of them is really so niche and unique that ASML knows it will only ever have a customer base measuring a half dozen or maybe, at most, a dozen firms.

Why doesn’t ASML just make the chips itself?

Well, ASML has no idea how to make chips. They’re an

extraordinary firm, but one company can only do so much. This machine is just one of multiple ultra-complex machines needed to make chips. In addition to shining light at exactly the right wavelength through this really complicated optics, you also need different machines that can lay down thin films of material just a couple of atoms thick or etch canyons in the silicon just a couple of atoms wide. These machines are produced by different companies that have unique capabilities, about which ASML knows nothing. The chipmakers themselves also have unique capabilities. TSMC is better than anyone, including its suppliers, at using the machines to actually effectively make chips. We really need a partnership of all of these different firms, the toolmakers like ASML and the chipmakers like TSMC, to actually produce effective semiconductors.

Yeah. People can argue about whether Milwaukee or DeWalt make the best power tools, but that doesn't make you a carpenter. Is that the vibe here — that you can buy the tool, but you have to actually know how to use it?

That's absolutely right. Knowing how to use it, as a process, not only requires starting with a PhD in electrical engineering or material science but really requires years of working with the tools. The process of developing an EUV tool took 30 years. That just gives you a sense of the scale of precision that was needed to actually harness it.

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