ELECTRONIC MATERIALS

Semiconductor makers inspire chemical investments

Electronic chemical firms ramp up to supply billions of dollars in new chipmaking capacity

by ***Craig Bettenhausen***

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Credit: ASML

An ASML extreme ultraviolet lithography (EUV) tool is loaded onto a cargo jet for shipment to a customer. ASML is the market leader in EUV tools, which cost hundreds of millions of dollars each.

It's an exciting time to be a supplier to the US semiconductor industry. Since early 2021, chipmakers have announced more than $100 billion in investments to build new semiconductor manufacturing lines, often called fabs, over the next few years. The first chip-filled wafers from these fabs should ship to customers as early as 2024.

The new wafer volumes alone would be enough to spur investment by the chemical companies that supply raw materials to the semiconductor industry. But the new fabs will also require more material input per wafer than do older-generation fabs because they'll be cramming more features at smaller scales into each chip. After years of anemic investment in the US, materials makers will have to work hard to keep up.

The new fabs will be hungry for chemical raw materials because of the growing number of processes carried out on each wafer, says Mike Corbett, a managing partner at the electronic materials consultancy Linx Consulting. "It's the number of lithography steps, the number of cleaning steps, the number of deposition steps, the number of etches," he says. "As the steps increase, obviously, the consumables do too."

Corbett says the materials industry has some catching up to do in the US. "The industry is expected to grow like a hockey stick here, and the materials infrastructure isn't there for it." He says the US market for semiconductor raw materials is worth around $4.5 billion per year and will grow at 15% annually over the next few years.

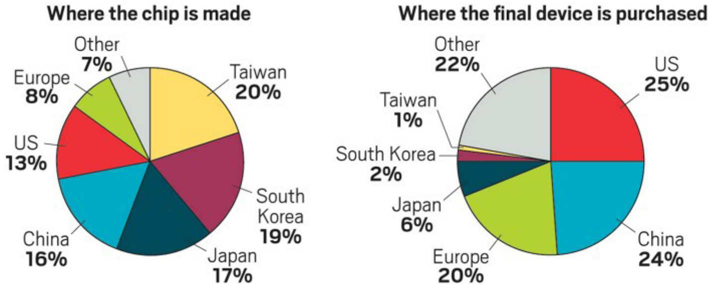
It wasn't always this way. Over the past decade, US fab capacity grew slowly relative to that in China, Taiwan, and South Korea. Semiconductor materials suppliers responded with textbook strategies for dealing with low structural growth, Corbett says, such as consolidating, finding efficiencies, and investing overseas. "People haven't been building chemical and material capacity in the US and Europe over the last 20 years, or they haven't been adding significant amounts," he says.

Then the pandemic lockdowns came, and the gradual digitalization of the economy leaped ahead by several years, Corbett says, spiking global semiconductor demand. At the same time, worldwide shipping disruptions led to calls to relocalize supply chains, especially for semiconductors and other products that are essential for 21st-century economies and national defense.

Now, the semiconductor makers Taiwan Semiconductor Manufacturing Company (TSMC) and Intel are both working on $20 billion fabs near Phoenix; Samsung is adding $17 billion of wafer capacity outside of Austin, Texas; and Intel is planning a new $20 billion site in Licking County, Ohio. Intel has said it may eventually quadruple the Ohio facility; TSMC and Samsung have similarly expressed interest in going well beyond their stated investments—if the local, state, and federal incentives look right.

SUPPLY IMBALANCE

The US uses more semiconductors than it produces.



Note: Data are from 2019. **Sources**: Semiconductor Industry Association, Boston Consulting Group.

Chemical firms have been responding with investments of their own. In September, Huntsman completed the first steps of an expansion in Texas of specialty amines for semiconductor use. In January, Taiwan's Sunlit Chemical broke ground in Phoenix on a $100 million plant to make hydrofluoric acid, which is used in etching and cleaning.

Merck KGaA said in December that it would spend about $1 billion on electronic materials R&D and capacity expansion in the US, part of a global investment of more than $3 billion. "The chip shortage needs industry-wide cooperation to resolve the supply chain issues consumers are currently facing. We are investing in the US to expand our production capacity and innovation footprint to support our customers' ambitious growth plans," the firm says in a press release.

On the acquisition front, one of the largest recent deals in the space is **Entegris's $6.5 billion purchase of the polishing slurry maker CMC Materials**. The slurries, which are usually aqueous suspensions of fine ceramic particles, are used with polishing pads in a process called chemical mechanical planarization. Together, the pads and slurries make up one of the larger-volume categories of consumable materials.

Entegris CEO Bertrand Loy says that buying CMC will bolster his firm's work around novel interconnect alloys, dopants, and other semiconductor materials. Developing slurry chemistry alongside the materials that the slurries polish will happen faster under one roof than if it was at two different firms, he says.

Moreover, CMC's 12 locations in North America and 9 in Southeast Asia add to Entegris's presence in the two regions that are receiving the most investment from semiconductor makers at a crucial time for the industry. "We have come to appreciate the fact that the world is changing and there is probably some value in trying to shorten the supply chains and localize supply chains," Loy says.

Any discussion of semiconductor manufacturing turns at some point to "node" size. The term generally refers to the physical size of the features, such as transistors, printed on the silicon of a chip. The smaller the node, the more transistors fit per square centimeter. Printing multiple layers of patterned components is another way to add feature density. More transistors mean more computing power and lower energy consumption. They also mean more chemical consumption.

Cutting-edge fabs like the ones TSMC, Intel, and Samsung are planning can print patterns with feature node sizes smaller than 10 nm, generally using a technique called extreme ultraviolet lithography (EUV). EUV is growing fast, and chipmakers are constantly pushing to reach smaller nodes.

"If you think about what our customers are trying to do, they're trying to be first to market with 5 nm or 2 nm, or above 200 layers [of patterning] in 3D," Loy says. "Finding not just the right material or the right solution, but being able to come up with that in a shorter time frame, has tremendous value for our customers that translates into pricing power and market share."

Although tiny nodes grab the headlines, the larger sizes between 10 and 180 nm, often called mature nodes, make up more than 90% of chip manufacturing capacity today. And these nodes continue to get investment as well. Texas Instruments expects to spend $30 billion in its home state on capacity for mature-node chips by the mid-2030s.

"We can see that the market is going to remain strong, that the underlying fundamentals of our business remain strong," says Kevin Gorman, senior vice president for supply chain transformation at EMD Electronics, the North American electronic materials business of Merck.

Merck's $1 billion US investment will take place primarily at facilities in Arizona, California, Texas, and Pennsylvania. "The lion's share is going toward our specialty gases and thin films," Gorman says. Lithographic patterning materials are also getting investment.

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Semiconductor makers are increasingly looking to lock in long-term deals with their materials suppliers, Gorman says, including for the expansions they've proposed but are not yet fully committed to. "Customers are saying, 'We would like you to expand to be able to support this level of need, and we're willing to sign up for agreements if you're willing to put in the investments.' "

Long-term supply agreements can mitigate the risk of building new chemical capacity to meet projected future demand, but that approach assumes chemical companies can get enough of their own feedstocks. And that's not always the case.

For example, helium, a critical material for semiconductor manufacturing, has been under considerable strain recently. The inert gas has a thermal conductivity second only to hydrogen, so it is perfect for safely cooling down chips and tools during the patterning process. Helium is also used in some lasers, and ionized helium is a potent etchant. Many analysts describe helium as irreplaceable for semiconductor manufacturing, and the new nodes use more of it than ever.

Unfortunately, the global helium market is in a bad place. Several industrial accidents, most importantly at Gazprom's Amur gas processing plant in southeastern Russia and at the US Bureau of Land Management's Cliffside Helium Plant in Texas, have created a worldwide helium shortage. Russia's invasion of Ukraine further disrupted helium supplies by scrambling the natural gas market; most helium is extracted as a side product from natural gas wells. The current helium shortage is the fourth in recent history, according to helium consultant Phil Kornbluth, and it may be the worst yet.

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Linx's Corbett says helium demand from the US semiconductor industry will double over the next 5 years. But semiconductor fabs compete for helium with medical imaging, scientific uses such as nuclear magnetic resonance instruments, leak testing, and space exploration.

Although supply disruptions such as the helium shortage are creating headaches, they may make the industry more robust in the long term, Entegris's Loy says. Chipmakers have become more willing to qualify new sources of materials, he notes, rather than stick with their tried-and-true suppliers.

To that end, Entegris is similarly looking to diversify how it gets the helium it supplies to fabs. Loy says the company is now talking directly with some primary helium producers in North America to supplement its ongoing relationships with major industrial gas firms. Primary helium producers go after helium for its own sake, so they aren't exposed to the whims of the natural gas market. And because they're already in North America, they don't have to rely on clogged ports or hard-to-find oceangoing vessels.

The chips made by new fabs will consume a lot of chemicals, gases, and other materials, but building them will require materials as well. Bob Cates, who leads global marketing for fluoropolymers at Chemours, says each new fab will require hundreds of metric tons of the firm's perfluoroalkoxy (PFA) resins for tubing that pipes liquids, slurries, and gases around the facility. The resins are also used in gaskets and other fittings.

PFA is one of very few materials that is inert, stable, and impermeable enough to handle the aggressive chemicals used in fabs and to keep ultrapure chemicals—including water—free of particles and leachates, Cates says.

Credit: Intel

Intel CEO Pat Gelsinger broke ground in September on a $20 billion expansion at the firm's Arizona chip facility. The project will add two production lines by 2024 to the four already operating at the site. Intel is making a similar investment in a new facility in Ohio, set to open in 2025.

Semiconductor expansion in the US is great news for Chemours, according to Amber Wellman, the firm's sustainability director for fluoropolymers. "It's very exciting for us to hear about these investments," she says. "We're the only manufacturer of PFA in the US."

The US chip industry and its boosters have big plans. President Joe Biden calls semiconductors the "centerpiece" of his domestic supply chain security initiative and supports bills making their way through Congress that would provide more than $52 billion in subsidies to the industry. After a push from Loy and other chemistry advocates, the administration now plans to make chemical suppliers to the semiconductor industry eligible for some of those incentives.

Whether backed with public or private funds, electronic chemical capacity needs to grow quickly if the new fabs are going to turn out needed chips. "You have more process steps, and process steps drive the consumption of chemicals and gases," Loy says. "You have also the need for greater levels of purity, so you need to have greater cleaning steps. And then finally, a lot of the new architectures that are on the roadmaps of our customers are also going to rely on highly engineered materials."

There are a lot of challenges, Loy says, "which for companies like Entegris translates into a lot of opportunities—if you can put the pieces together."