Wanted: More Fab Tool Part Standards

More complex equipment and advanced processes require higher reliability from thousands of parts.

AUGUST 15TH, 2019 - BY: **MARK LAPEDUS (HTTPS://SEMIENGINEERING.COM/AUTHOR/MARK-LAPEDUS/)**

As chipmakers ramp up the next wave of processes and grapple with how to reduce defect levels, they are encountering problems from an unlikely source—components inside of the fab equipment.

Defects are unwanted deviations in chips, which impact yields and device performance. Typically, they are caused by an unforeseen glitch during the process flow. But a lesser-known problem involves defects introduced by critical components and sub-systems in the fab equipment itself.

Generally, equipment vendors build systems with good components. But sometimes problems are caused by tool parts and faulty components, which can introduce unwanted defects on a wafer. That impacts chip yields and costs, and it can lead to excursions or unforeseen events in the fab.

Fab tool component issues have been lingering for years, but now there is an urgency to address the problem. Foundries, as well as logic and memory makers, are ramping up more advanced and costly processes in the fab. With costs rising and tolerances shrinking, device makers can't afford any major problems in the manufacturing flow, such as a glitch with the process or equipment.

If there is a glitch with a part in a system, it's not a simple matter to locate faulty components and fix the problems. For example, the more sophisticated fab tools incorporate more than 50,000 parts from dozens of suppliers. Other systems have fewer parts. Most tools incorporate chambers, pumps, RF generators, seals and valves.

Nonetheless, the issues with the fab tool components are sometimes problematic. "Foundries have repeatedly had quality excursions due to supplier variability and control gaps," said Glenn Colton, senior director and head of global capital equipment procurement at GlobalFoundries (https://semiengineering.com/entities/globalfoundries/), in a presentation at the recent Semicon West trade show. "We regularly investigate these quality excursions and almost always find out that we could have mitigated the risk if we had known there was a component quality issue before we installed that component into a tool. These lead to the need for more robust quality assurance and industry standards around these components."

The problem is that less than 1% of tool parts have quality assurance standards, according to Colton. "We really have little knowledge of the tolerance that those components are built in. When I give a component to the fab, how do I know it's going to work 100% of the time, first time right, and we are not impairing the equipment team's ability to achieve their targets," he said. "We also lack robust traceability. If we do have an excursion, most of our end clients want to know where this happened, how it happened, and what we are going to do to prevent this from happening again. We have difficulty going back into the supply chain and figuring out how exactly this occurred."

Other chipmakers have raised similar concerns. No one is blaming the problem on any particular company. What chipmakers and equipment vendors want are solutions. This involves more collaboration, as well as standards for fab tool components and subsystems.

In fact, a working group within SEMI has been hammering out new reliability, testing and traceability standards for select fab tool components, which could help address the issues. This industrywide effort is called the Semiconductor Components, Instruments, and Subsystems (SCIS) Special Interest Group.

SCIS has devised some standards, but so far it's been an arduous process. Generally, chipmakers and tool vendors have proprietary supply chains, and they find it difficult to share data, especially about proprietary tools and components. Going forward, though, some have issued a call to action to speed up the tool component standards process. Still to be seen, however, is if the industry can respond fast enough.

Sources of defects

Today's semiconductor fabs are automated facilities that process wafers using various equipment in a cleanroom. According to UC Berkeley, a theoretical 300mm fab with 50,000 wafer starts per month requires the following equipment:

- 50 scanners/steppers plus wafer tracks
- 10 high-current and 8 medium-current ion implanters
- 40 etch machines
- 30 CVD tools.

Fabs incorporate other equipment, as well. In operation, a batch of wafers is transported to one piece of equipment and then processed based on a given manufacturing flow. Then, the wafers are transported to the next equipment and processed, and so on.

It's a complex process. To make an advanced logic device, the wafer undergoes anywhere from 600 to 1,000 steps or more in the fab.

That's not the only challenge. Today's logic and memory devices are more complex. The equipment must process smaller and more exact features at each node. And the defects are becoming smaller and harder to find.

"The challenges that we face today are with scaling and with the fact that there are 3D structures," said Mohan Iyer, head of marketing for the E-beam division at KLA (https://semiengineering.com/entities/kla-tencor/). "And there are new architectures like gate-all-around (https://semiengineering.com/knowledge_centers/integrated-circuit/transistors/3d/gate-all-around-fet/), as well as new materials like cobalt (https://semiengineering.com/knowledge_centers/materials/cobalt/) and ruthenium."

No production flow is perfect, and process-induced defects can crop up in the fab due to impurities in the materials, device issues, and equipment glitches, among other reasons.

In the fab, chipmakers utilize various equipment to find and eliminate defects. Metrology (https://semiengineering.com/knowledge_centers/manufacturing/process/metrology/) tools, which are used to measure structures, are deployed after many process steps to pinpoint and fix the problems. In addition, inspection tools are also used to find killer defects on wafers.

"In general, as the process becomes more complex, the more you need to use these kind of tools," said Subodh Kulkarni, president and chief executive at CyberOptics (https://semiengineering.com/entities/cyberoptics/).

Fab tool part problems

Process-induced defects aren't the only problem. Defects in chips sometimes are linked to faulty components and subsystems inside the fab equipment.

"Defects introduced by process-critical components are actually part of the problem regarding lower yields and higher manufacturing costs," said Dalia Vernikovsky, chief executive and general manager at Applied Seals NA, a supplier of O-rings and seals, in a recent presentation. "More than 75% of yield losses actually come from the components. If you think about the many parts in the tool, it starts to become a relevant subject matter. Several yield excursions can really produce not just killer defects, but latent defects. Many times, you can't even find these defects until further in manufacturing, where it's costly and a hinderance to yields."

These issues are becoming more challenging at each node. "It's challenging from multiple aspects. We are requiring more from the technology itself, whether it's how fast does your RF system match or what are your acceptable particle levels," said Steve Johnston, director of supplier technology and industry development at Intel (https://semiengineering.com/entities/intel-corp/). "This trickles down to our engagements with equipment and materials OEMs. And then you have the cost challenges. They are becoming very significant compared to what the industry has dealt with in the past."

So what's the solution? Maintaining the status quo with some tweaks is one idea.

As before, for example, equipment makers are still responsible for the development of the fab tools and the component supply chain. Tool vendors can simply tighten up their supply chain vendor base and put more rigorous quality controls in place.

That's already taking place to a large degree. "If you sell anything in the semi industry right now, the first requirement is that it meets all the required standards. The list is fairly long. The amount of data being collected is staggering on all of that," CyberOptics' Kulkarni said.

As part of the solution, the industry needs more collaboration in the supply chain at all levels. That's also taking place to some degree. For example, chipmakers have been working more closely with component vendors. Some chipmakers even have invested in select vendors.

That might not be enough, however. What many chipmakers and even tool vendors want are fab tool component and traceability standards. They want testing methods and standards for select components, and the ability to trace the parts if a problem surfaces.

These issues have been lingering for years. But the industry began to take the problems more seriously in the early part of the decade when chipmakers moved to more advanced nodes.

So in 2013, SEMI as well as several foundries, tool vendors and component companies formed a new initiative called SCIS. The group, which resides within SEMI, began to look at issues and standards for fab tool components. Over time, SCIS formed seven working groups, which hoped to devise standards in the following fab tool component areas

—chambers, gas delivery, liquid delivery, pumps, RF delivery units, and seals and valves. Another group is working on a traceability component standard.

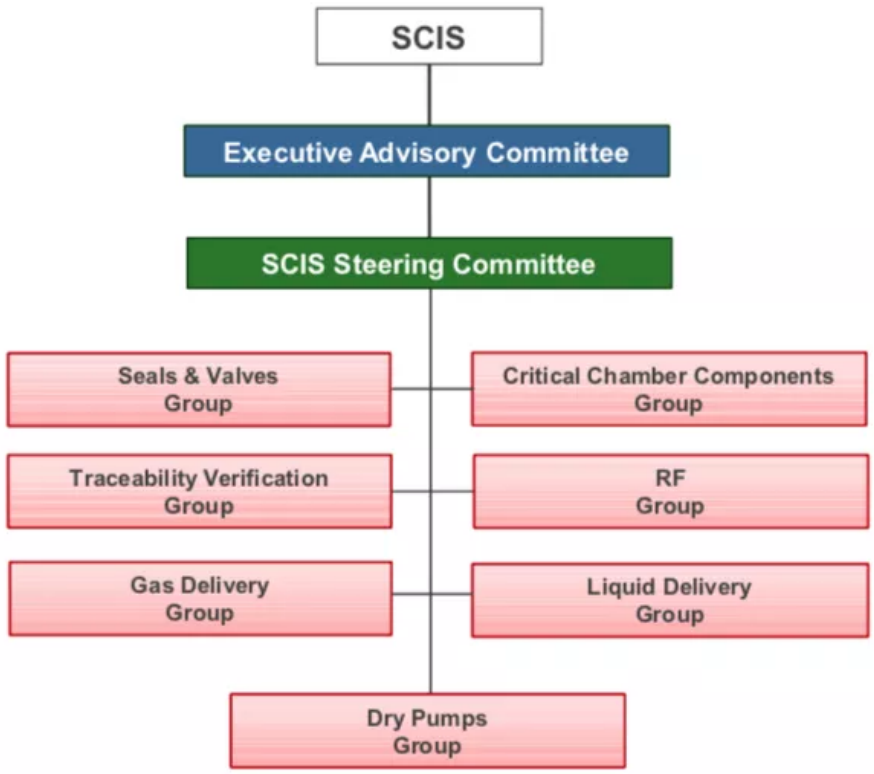

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Fig. 1: SCIS Organizational Structure Source: SEMI

Developing component standards is a challenging process and calls for more than just collaboration among various parties. It requires sharing proprietary data, which is somewhat foreign in the equipment industry.

Nonetheless, in 2015, the group published its first standard, SEMI F51, which is a guide for elastometric sealing technology. The standard is a basic guide for using seals in fab equipment.

Seals involve the use of O-rings, which are utilized at an interface. Each fab tool has several different seal types, including those for the lids, ports and windows.

Since then, SCIS has published other standards. The most recent was E135, which involves RF power generators used in thin-film processing equipment. Published in 2018, the standard determines the response of an RF generator operating in nominal-, high-, and low-impedance loads.

Other new standards are in the pipeline, including those for gas delivery, RF power generators, seals and shower heads. Each standard has its own issues. For example, the group is working on a test method to measure metal contaminates on chamber shower heads in fab tools.

“When you have seven working teams, they are all in different stages of gestation. There are many factors. One is the topic. Some topics are more challenging than others,” said Paul Trio, senior manager of strategic initiatives at SEMI. “On one end of the spectrum, you have seals. We have all of the major seal suppliers. They were able to gain traction pretty quickly. Traceability is more on the other side of the spectrum, where it’s still trying to gain traction.”

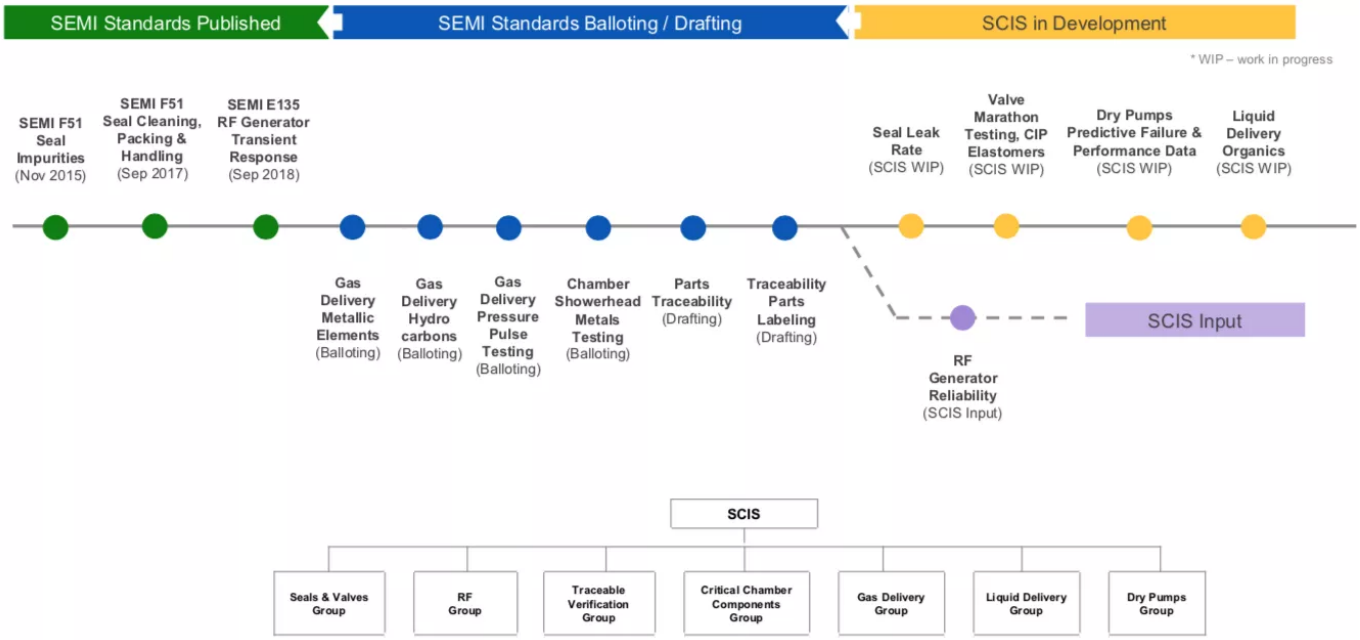

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Fig. 2: Status of SCIS Standardization Initiatives. Source: SEMI

Indeed, the next big hurdle is a traceability standard, which is underway within SCIS. If a part fails in a system, the idea is that you can track down and gain a better insight into the problem. At a minimum, chipmakers want the supplier information for a given part, the batch number and the production date.

A traceability part standard makes sense because the current methods are unworkable at times. "We'll end up spending a lot of time on the phone with different suppliers and vendors, and trying to call and identify what some of those problems are, what are the specifications for how things are manufactured, how things are cleaned, and the different cleanliness processes," said Eric Bruce, an equipment engineer at Samsung.

Ideally, traceability could help solve the problem. "When we have those types of problems, we need to identify what the component is inside the equipment. And then we need to identify the traceability of those components, where else we have those risks in our factory, and then find ways to correct those issues, as well," Bruce said.

In response, SEMI's SCIS group has developed a draft for one aspect of traceability, which involves a parts labeling specification. Other related standards are in the works.

That's just part of the puzzle. "You can create a data chain. Should something happen later on, then you can turn back to this data chain that you've created to help you with the excursion process. It's helps you figure out what was the root cause of the problem and why did this part fail," SEMI's Trio said.

Just how that is implemented in the fab remains unclear. At one time, SCIS wanted to incorporate traceability data via the Internet. But the industry has backtracked on those plans due to security concerns.

Now, the industry is looking at another model. Chipmakers, fab tool vendors and component vendors will develop their own methods to exchange traceability data.

Standards challenges

Going forward, chipmakers want more traceability and tool component standards sooner than later. But developing new and more standards presents some challenges.

For example, chipmakers are ramping up a multitude of processes. Each process type is different and requires a specific tool set. Each tool has different components. One part in a tool may come from different suppliers.

It's a complex supply chain. Tracing parts from every vendor is difficult, if not impossible. And formulating rigid metrics across the board for many, if not all tool parts, isn't feasible. "Driving toward a universal standard across the entire industry is going to be convoluted," said Patrick Martin, business development manager at Applied Materials (https://semiengineering.com/entities/applied-materials-inc/).

For years, meanwhile, intellectual-property (IP) issues have been the biggest hurdle in the arena. If sensitive IP is shared about a particular fab tool component, an equipment vendor runs the risk of losing its competitive edge. Others may adopt the component.

"On IP-related aspects, how much information do you put in the public domain so it's open for other people to see? There is always the risk of abuse, meaning you can commoditize a tool. It's a little easier to do this if everything is in the public domain," Martin said.

There are other issues. "Smaller companies and third parties that are trying to make their living on one or two tool parts don't have the resources," said Kevin Chasey, senior vice president and deputy general manager at TEL (https://semiengineering.com/entities/tel/). "We can apply the standards and put the standards out in the marketplace. But does each company have the engineering horsepower that's required to maintain that? I struggle with that one."

Conclusion

Those are among the many issues in the arena. All told, the industry sees a need for standards. Collaboration is an overused term, but the industry will need to cooperate more to solve the component issues and other challenges.

"We have to work together," Chasey said. "And then, we can finally get to the point where all the data is on the table. Let's start sharing the data. And then when you get to that collaborative point, then you can start collectively sorting this out."

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