NANOCHIP FAB SOLUTIONS
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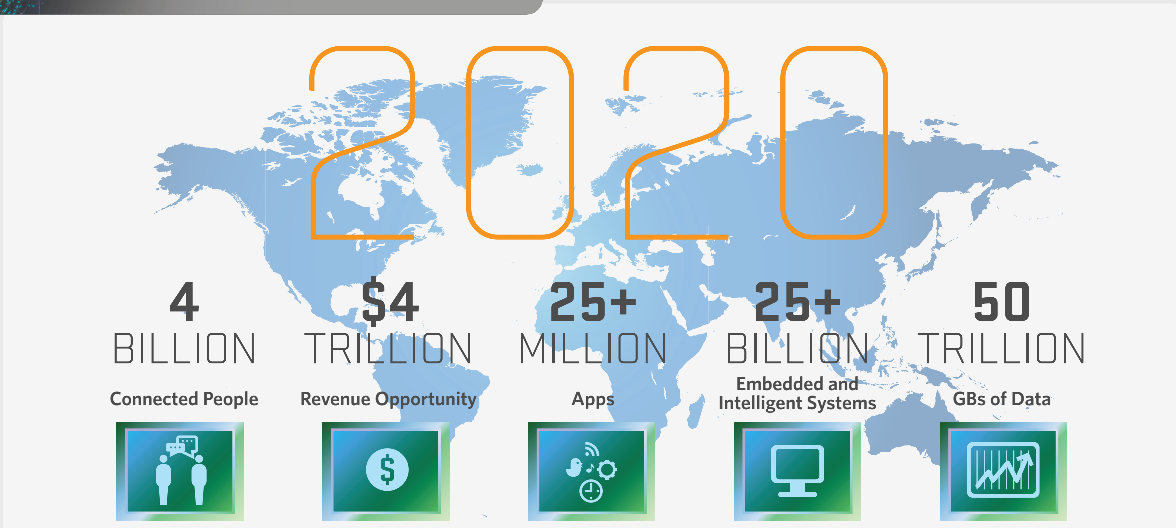
FABS IN THE INTERNET OF THINGS ERA

BY DAVID LAMMERS

As the wider society enters the Internet of Things era, semiconductor fabs are also benefiting from the analysis of data streaming from sensor-laden equipment. But the management of "big data," and the attendant security concerns, are among the biggest challenges facing chip makers and vendors as they seek to reap the benefits of a connected fab.



Source: Mario Morales, IDC

As PCs start to show revenue declines, the Internet of Things (IoT) is seen as the semiconductor industry's next big wave, following PCs, networking, and mobile systems. With its cloud-dependent, "everything is connected" promise, the IoT has a game-changing, futuristic aspect. While analysts agree security concerns and the productive management of data being generated need to be worked out before the IoT can develop fully, there is little doubt the long-range impact will be substantial.

Jeremie Bouchaud, principal MEMS and sensors analyst at market research firm IHS, estimates it will take about seven years before smart sensors and wireless networks begin to fully transform society into the connected cities and smart homes that hold so much promise.

Mario Morales, director of semiconductor research at IDC, describes a class of "intelligent systems"—defined as Internet-connected devices that analyze information collected in real time—and estimates there will be some 25 billion units out there in the next decade, larger than the *combined* number of PCs, phones and tablets.

Many of these intelligent systems will be in factories, "accurately monitoring conditions in real time," said Gareth Noyes, chief strategy and technology officer at Wind River. Noyes, speaking at an IDC seminar, said intelligent monitoring will support two overarching capabilities: predictive maintenance, and the "adaptive analysis of historical data, providing nuanced understanding" of what is going on inside factories.

Bill Morelli, an IHS analyst who tracks the IoT trend, said while some MEMS/sensors will be connected to the Internet, led by the obvious example of smartphones, others won't. A high-end car, for example, has hundreds of sensors monitoring its inner workings, but to avoid dangerous mischief from hackers, few of them will be connected to the Internet.

Morelli cautioned against irrational exuberance, noting that smart cities will require multiple businesses to agree on sharing data, some of which may be proprietary. "When we talk of smart cities, we have to get an awful lot of disparate organizations working together to make that happen. There are numerous security and business reasons why you might not want to do that. Getting people to buy into it is pretty challenging."

Individual companies are creating sophisticated networks inside and among their factories, but granting access beyond a firm's boundaries is a different story. "We are seeing a lot more automation in the factories, an increased use of sensors and machine vision. Machine-to-machine connections are a lot more prevalent, but many of those are not necessarily IP-connected sensors. The factory itself is the main outpoint of connectivity, and corporations don't want access to those externally" lest competitors engage in snooping, Morelli said.

Siegfried Dais, deputy chairman of the board at Stuttgart, Germany-based engineering and electronics company Robert Bosch GmbH, predicts that "a piece of metal or raw material will say, 'I am the block that will be made into product X for customer Y.' This unfinished material already knows for which customer it is intended and carries with it all the information about where and when it will be processed."

In the macro view, there is debate over how quickly the worldwide IoT will mature, but the impact is almost certain to be huge. Dean Freeman, semiconductor manufacturing analyst at Gartner, Inc., noted the various predictions that—perhaps by the end of this decade—the world may be home to a trillion sensors. Eventually, a trillion sensors a year could be consumed. Freeman notes that about two-hundred ninety 200mm fabs would be required to process the 1.7 million wafers necessary to meet that trillion unit sensors figure. "It may not reach the full 290 fabs, but the main point to keep in mind is that there is very healthy growth ahead for legacy silicon," Freeman said.

For chipmakers, producing all those wafers, while adding speed and functionality to devices and keeping a tight rein on costs, is a significant challenge. As sensors, processors, and wireless links become faster and less costly, the connected fab will transform fab productivity. Increasingly connected tools will help the chip industry reduce variability by monitoring each tool's "health." Semiconductor companies will be able to optimize a fab line for chip performance, yields or high throughput, said Alex Schwarm, senior product manager in the Applied Global Services (AGS) group.

BIG DATA, BIG CHALLENGE

Consultant Tom Sonderman, who pioneered the adoption of advanced process control (APC) techniques while at AMD, said the IoT in the semiconductor industry brings both challenges and opportunities. Key among them is dealing with the big data that sensors and other automation technologies gather (see www.appliedmaterials.com/intelligence-connected-fab).

"All of this information is like a sunken treasure," Sonderman said. "You have to figure out how to get it into the boat."

A leading-edge fab might contain >1,000 tools, with several dozen key sensors on each tool, and each wafer may see as many as ~1,400 process steps. Huge streams of information are coming from fab tools, wafers, GDS (design) files, and facility systems such as chillers.

A fab will generate 140 TB per year at 20nm design rules, three times as much as at the 45nm node, according to John Scoville, senior director of application engineering at AGS.

WHAT DOES THE DATA MEAN?

"There will be a lot more data coming in as we instrument our tools to much greater levels and take subcomponent tracking much further. The challenge is: what does the data mean?" said Jeremy Read, vice president of automation products at Applied Materials.

Data analysis is moving beyond fault detection and classification (FDC) and other techniques aimed at figuring out what might have gone awry. "Now companies are pushing data analysis down to the manufacturing technician level," Read said. Data analysis techniques previously used by test and yield engineering groups are now being employed by the technicians engaged in daily manufacturing. "A module manufacturing group may not have had access to analysis systems before; it wasn't necessarily part of their daily work flow. Now they need access to the data so they can more quickly ramp and manufacture the process," he said.

Read noted that sensors and other data-gathering tools are propelling the industry to move toward a more efficient, predictable manufacturing model. "Big data is allowing customers to get beyond reactive, beyond even proactive, to predictive. We can take a more holistic view of the tool and its behavior," he said.

"We will see a lot more equipment monitors providing data that give a general indication of the health of the tool: parts that are beginning to wear, erratic performance indicators, and so forth. We will be able to catch the vast majority of general efficiencies as the tool is in use, and will know, 'Will the tool be working at its best?' And if it not, we'll know that now we have to fix something."

The industry also will move to tackle chamber matching on a broad scale. Read said this has always been a topic of interest, but so far, solid automated techniques to achieve and maintain it have been lacking. "Now, as tools move and are repurposed from product to product and factory to factory, chamber matching is more important than ever. It's the quickest way to ramp production. A tool may be working perfectly well in this factory or on this device design, but how can I get it working in the next fab or the next production batch? This isn't a new concept, but the data will help us achieve that," he said.

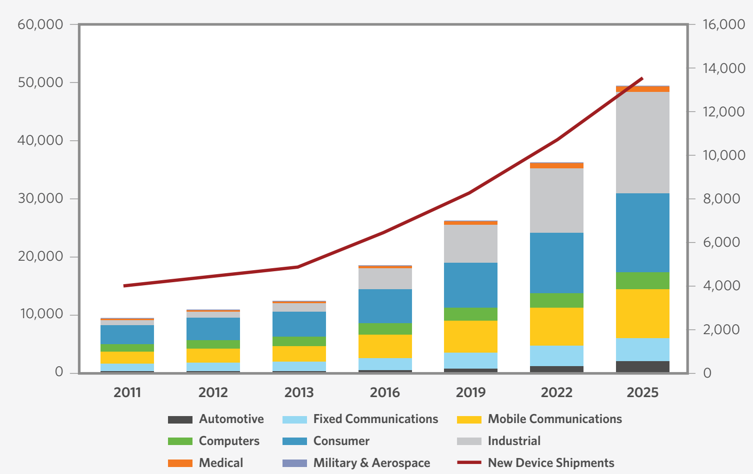
PARTNER, OR GO IT ALONE

For leading-edge companies, the need to move faster to the 20nm node and beyond coincides with the new emphasis on the predictive analysis techniques that rely on production tool data. Read was asked if the largest semiconductor companies prefer to develop data analysis and predictive techniques in-house.

"There certainly is no barrier to the customer doing it themselves," Read said. "However, if Applied already has the models and algorithms, and is prepared to engage with the customer in a performance-level contract based on our capabilities, then the customer has to ask, 'Why am I reinventing the wheel? Is that truly core to my value?'"

Given the time pressures involved in getting to advanced

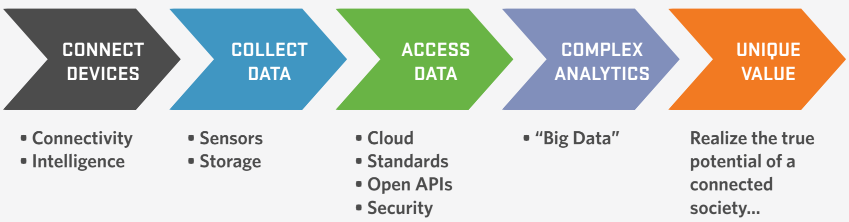
INTERNET OF THINGS, WORLD, 2011–2025



Source: IHS 2013

INTERNET OF EVERYTHING EVOLUTION

Internet of Everything (IoE): Represents the open access to data from one or more monitoring and control systems by third-party applications to provide unique, additional value to stakeholders.



Source: IHS 2013

nodes, device makers are increasingly likely to depend on suppliers for modeling, sensor prioritization, predictive maintenance algorithms, and other analytics. That being the case, "if Applied Materials has a solution, why spend six months or more trying to do it on my own, at a risk of not getting there in time?" Read said. Applied also has sought to understand "the broader context" of the data coming from individual tools, he added. "We work with the customer to address process challenges on tools and we also look at data holistically, from the viewpoint of the entire fab."

Schwarm said Applied's technology-enabled services go beyond the maintenance-driven relationships Applied has with chipmakers. Most large manufacturers, he said, are already collaborating with the company on data-driven analysis projects, drawing upon Applied's E3 performance-tracking and data-mining software, as well as libraries and models.

Applied engineers record vibration data, wafer placement images, optical emissions, and other sets of information to help enrich analysis models. For instance, the company has done some very high speed analysis, collecting data at 1000 Hz, to detect potentially damaging arcs in a plasma system. "We want to take the data we have now, along with the new sources of data, and combine them to create specialized analysis techniques," Schwarm said. "These technology service relationships are much more interactive and integrated than a typical maintenance service relationship. You are now an extension of the customer's team for these device- and film-oriented problems."

HANDLE WITH CARE

While the benefits of cooperative data analysis can provide a competitive edge, overcoming security concerns in the hypersensitive semiconductor industry is a major challenge. "Without a doubt, security and IP-related issues are the biggest obstacles to effective collaboration between vendors and manufacturers," Schwarm noted.

One approach Applied takes is using servers within the fab's firewall that are connected to the process tools only and with tightly controlled access to data.

"Applied has many layers of security, and we have to adapt to varying customer needs," Schwarm said. "Some customers use our remote service access via secure VPN to allow Applied Materials engineers anywhere in the world to help diagnose issues. Others are more conservative and invest in having us install a server behind their firewall with access that they define."

Schwarm noted that Applied's analysis systems and procedures are designed with the protection of the customer's IP in mind. "Our customers are investing to develop the most advanced processes, and we understand and respect that," he added.

Sonderman said the connected fab, including big data analysis, is a fast-moving field. Fabs must become more efficient to supply the world with low-cost processors and sensors, and foundries must be able to protect the IP of multiple customers, who guard their design- and yield data closely.

Data analysis is bringing huge returns to forward-thinking companies with the resources to embark on the journey. Schwarm said some are already figuring out how to "dial in their factory" to align it with production goals such as optimized device performance, higher yields, faster throughputs and lower costs.

"Now that we have less expensive compute power and storage, there are systems that allow you to do this kind of analysis. For example, we can take a process tool data set and extract from it an understanding of what is driving variation. Some companies are doing that, but many are not," Schwarm said, citing a lack of resources as a major reason.

To achieve that heightened level of "nuanced understanding" that Wind Rivers' Noyes predicts, chipmakers will need to deal with security concerns and lack of in-house resources, which may hinder progress toward the connected fab. Read summed up the challenge as tools begin to provide more data: "We need to get better at providing the context to the information coming off of the tool. What's needed are more personnel resources and analysis systems to be able to figure out 'what is that data telling me?'"

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