e-Manufacturing: There's still a long way to go

While chipmakers have set dead aim on achieving full e-Manufacturing, or totally automated processing plants, it was apparent at the recent AEC/APC Symposium (Colorado Springs, Sept. 15-18) that there is still a very long way to go. While automatic process control (APC) is now being widely used, especially in the new 300mm fabs, there is very little built-in or in-line metrology and today's tools fall far short in providing communications links and access to sensor data needed for full factory automation (see WaferNews, V10n41, October 13, 2003).

Speakers at the symposium cited failed process tool tests for providing even standard SECS/GEM outputs, and compared the crude approach to factory-wide data links in today's fabs to the more advanced systems common in other industries. Yet there were numerous reports of feverish activity to close the gap in work at organizations including SEMI, International Sematech, and Selete in Japan, by setting standards to enable sophisticated data handling and add flexibility and plug-and-play capabilities for tomorrow's process tools. Emphatic demands by major chipmakers, including Intel, AMD, IBM, and TSMC, for tools that meet emerging standards and provide better access to internal process data put an exclamation point on the push toward eventual e-Manufacturing.

A wide range of reports covered individual APC projects, most of them for lithography (especially CD and overlay control), etching (particularly gate trimming), and chemical mechanical planarization (CMP). They showed how both feedback (adjusting the processing recipe for the next wafer) and feedforward (compensating for variations in film thickness or other critical parameters in later processing) are being increasingly applied, often with remarkable improvements in yield and statistical measures such as Cpk. A typical example is the use of APC reported by June-Shien Lin of TSMC for more uniform wafer-to-wafer sheet resistance on copper wafers. Device delay in circuits is dominated by this parameter. Using conventional metrology to control Rsheet was very time consuming, so development of an advanced process control system made sense. Simple control of CMP could not fix the problem because too much of the variation was due to process steps prior to CMP. The contributors had to be identified and a model constructed that allowed a feed-forward, feedback loop to make needed recipe adjustments based on sensor inputs. This approach reduced wafer-to-wafer sheet resistance variation to less than 10%, 3s, according to Lin.

Fabs developing APC applications like this need to get good data from sensors monitoring tool processes. Brooks Automation's James Moyne pointed out that when human operators run a process, they can interpret the data and decide what needs to be done for the next run using implicit control models. But when computers run a process, they do the data filtering and decide on solutions, and they are not as adaptable as humans. "You don't want to disempower the user!" Moyne stated.

To test whether the latest 300mm process tools provide good data, experiments were run on current commercial versions of an etcher and CMP tool. Outputs were checked for conformance to SECS/GEM documents, and conformance results reports were developed by an International Sema-tech data quality task force, co-chaired by Moyne and John Pace of SI Automation and including Brad van Eck of Sematech. This reporting method is being used to help in communicating with tool OEMs.

The etcher reported all values in ASCII without any context, so a translation step was needed by the user to interpret the data. The tool manual did not include any information about minimum and maximum sensor values or the routes of gas flows. When asked for a flow rate, the tool did not deliver it even though it was listed in the manual. When the tool was off, sensor values were 2, indicating an unknown offset.

The CMP tool's manual simply numbered sensor outputs, so the user had to go through and define each one. Tests showed that sensor values were not exposed through the SECS/GEM port for end-point detection. When the tool was processing a wafer, a request for the states of all units returned all zeros.

The task force concluded that the present quality of tool interfaces is poor and insufficient to support e-Diagnostics. One problem, according to Moyne, is that the industry does not even agree on how to define key attributes such as time stamping. The task force is now gathering information so that it can move toward uniform definitions and data availability.

Harvey Wohlwend of International Sematech described work going on to enable e-Manufacturing, including a prototyping project with set-ups hosted by Sematech. The prototypes incorporate equipment engineering capabilities (EEC), plus integration with MES and other equipment and with automated materials handling systems (AMHS). The tool industry is currently being balloted on standard methods for data acquisition, so good data comes from the tool and there is no missing data, according to Wohlwend. A standard software interface for IC manufacturing, including extensive security and firewall protection, is being developed to link chipmakers, tool OEMs, and even component suppliers.

Engineers from Intel attending the sessions expressed frustration with steppers from a major vendor that collect internal data (not available to users) to help the company improve its design. In general, they complained, they cannot find out how sensor data is internally massaged inside their tools.

Contrasting the state of semiconductor manufacturing to other industries, James Moyne, with the University of Michigan as well as Brooks Automation, described the reconfigurable factory testbed (RFT), a project with an annual budget of about $5 million that started in 1994, with participation by General Motors, Rockwell, Schneider Electric, and other manufacturers. Funds come from NSF, the U. of Michigan, and the state of Michigan.

The project involves a distributed testbed over the Internet, using networks and network control systems linking reconfigurable manufacturing systems (RMS). Software engineers use SOAP/XML for software interaction, along with DIME, a compressed form of XML. OPC is used for data collection, plus OLE for process control. The software engineers interact only through a database, not through scripts, according to Moyne, and user interfaces are tied into a database, not application software. The relational database includes control bus rules, applications models, current system data, and historical data. This links through middleware to various software engines, using XML for network optimization, a stream of variations, and e-health monitoring. Plug-and-play software engines are simply defined in the database. Middleware and all software modules are integrated as Web services on Apache Tomcat servers.

Currently a major focus is on where to draw the dividing line between sensor bus and Ethernet, according to Moyne. Ethernet was tried for real-time control, but failed. It is generally used for diagnostics, and for this, Moyne sees wireless as an attractive choice. At lower levels of control, Moyne suggests that sensor bus can play an important role. SOAP/XML requires much more data, perhaps 5-10x, to accomplish the same task. For example, Moyne said, it takes 1500 bytes to turn on the first bit, while sensor bus takes only 12 bytes.

Because of the magnitude of these efforts in industries such as auto manufacturing, some de-facto standards are appearing, and there is an opportunity for the semiconductor industry to leverage these efforts as it devises its own standards and approaches, Moyne concluded.

While several speakers painted visions of virtual factories of the future, a portrait of today's tough realities came from a presentation on crude attempts to implement e-Manufacturing with existing 200mm tools and networking by Cindy Petronis and others from STMicroelectronics' PF1 facility in Phoenix. They termed their project "APCeD Lite," for APC with little run-to-run control and e-Diagnostics without direct access to tool data.

There is also limited bandwidth for tool and process data, so the focus was on what the engineers termed "vital signs." Their on-line automatic fault detection (AFD) was univariate, with multivariate analysis used off-line to refine fault limits and to understand interactions.

While the exercise falls short of real e-Manufacturing, it did provide blueprints for what the STMicro engineers termed "the perfect tool." Because of a lack of budget, the exercise was conducted with existing tools and technology, so that, aside from people's time, Petronis explained, "almost nothing has been spent on e-Manufacturing efforts in PF1."

If chip markets take off again and margins improve, plans for new 300mm fabs may go into high gear, and chipmakers will be looking for tools that are far more "perfect" than those they have now. — B. H.

SEMI pushing tool interfaces for AEC/APC

Pieces are falling into place for major advances in real-time monitoring and control of process tools, according to Brad Van Eck, International Sematech's manufacturing methods project manager at the conclusion of the recent AEC/APC Symposium in Colorado Springs, CO, Sept. 15-18.

"All chipmakers are absolutely convinced that they need more real-time data for process and manufacturing equipment to improve fab productivity," according to Van Eck, even though industry acceptance has been slow in coming. He pointed out that Moore's Law is not just about shrinking features, "it's also about higher yields and higher equipment utilization to mitigate rising costs."

A trio of proposed SEMI standards specifying sophisticated in-tool software—Equipment Interfaces A, B, and C—will accelerate the introduction of AEC/APC into chip manufacturing, Van Eck explained. Interface A will enable in-fab productivity improvement and provide data for Interface C, which will allow off-site tool vendors to monitor their tools' performance over the Internet. Interface B will permit communications among tools and fab software applications, and potentially adjust processes while they are underway. Interface A should be an accepted standard by the end of this year, with commercial products available in 2004, with B and C being ready sometime next year, according to Van Eck.

"These interfaces will make it very easy for third-party vendors to install and maintain tool software, and for manufacturers to 'plug-and-play' them," Van Eck said. Such software should lead the way to scrap avoidance, preventive maintenance, run-to-run control, and fault detection and classification. The data-mining capabilities enabled by the standard interfaces, when coupled with interpretive programs that still need to be developed, could allow fabs to adjust tools and processes during production to maximize yield and productivity, Van Eck believes.

This would allow such improvements as adjusting CMP polishing time to compensate for film thickness variations, keep a tool running when it is within specs rather than shutting it down for unnecessary preventive maintenance, or prevent wafers from being sent to a tool that is out-of-spec. Tools might be requalified by comparison to the "fingerprints" of well-working systems, rather than using time-consuming punch lists.

Also, by building in more metrology, processing could be speeded greatly since, without APC, about 30% of all wafer moves involve metrology tools, according to Van Eck. — B. H.

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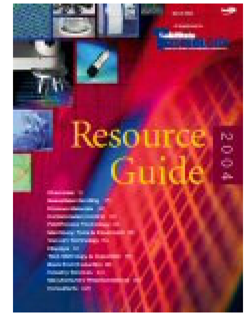

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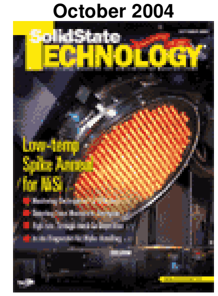

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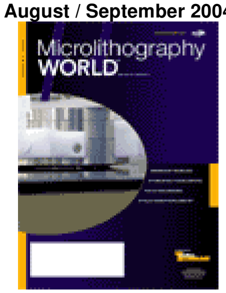

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