« Back | Print

300 mm Moves into the Next Century

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As the world prepares to transition to the year 2000, the semiconductor industry is poised to transition to the next wafer size -- 300 mm. The new generation of fabs promises productivity gains that will support Moore's Law well into the next decade. Early on, it was recognized that the complexity of 300 mm factories would be compounded by new automation requirements. This, combined with the accelerated pace of technology advancement, would demand unusually large resource expenditures throughout the industry. Original estimates for the cost of the 300 mm transition ranged from $15B to $50B.

Based on lessons learned from previous wafer-size transitions, and to control costs, the 300 mm transition was planned as a cooperative effort. Therefore, in late 1995, 13 semiconductor manufacturers representing Asia, Europe and North America formed the International 300 mm Initiative (I300I). To jointly demonstrate and accelerate the availability of tools and infrastructure for 300 mm pilot lines, I300I has collaborated with SELETE (a consortium of 11 IC companies from Japan and Korea); J300 (an alliance of five Japanese trade groups); Semiconductor Equipment Assessment (SEA, a European community funded initiative); and worldwide suppliers of silicon wafers, process equipment, metrology and automation equipment. As of June 30, I300I formally concluded its mission.

While I300I's equipment demonstrations will end as a program at International SEMATECH (ISMT), 300 mm activity will not. Two essential program areas will continue: (1) maintaining a 300 mm tool set to support IC company and supplier development efforts and (2) continuing development, standardization and improvement of the 300 mm infrastructure.

A manufacturing technician places a 300 mm FOUP onto a load port. (Source: International SEMATECH)

Equipment demonstration methodology

Demonstrations identify the current state of 300 mm tool sets, including key areas that need improvement. Analysis of data from equipment demonstrations has indicated the main failure modes reside in the area of material handling and software.

Over the past three years, methodology for demonstrating 300 mm equipment has taken a significant step forward. The Demonstration Test Method (DTM)[1] is a framework for resource-optimized, staged testing. It was developed and ratified by member companies as the standard test method because it allows the reduction of sample sizes through test scaling based on rigorous statistical techniques (including Bayesian analysis) and provides for standardized, stylized report outputs.

A critical first step in the DTM is the equipment maturity assessment (EMA)[1] that is performed in a standardized way using an exhaustive checklist. The results were used to scale the demonstration targets and re-sources (wafers and time) to an appropriate level. The EMA also evaluates the compliance of the tool to I300I's guidelines.[2] The value of the EMA process is the immense database of results generated as well as the critical one-on-one education for suppliers on equipment requirements. Of the 36 tools assessed to be beta-level, only four failed to successfully complete the marathon portion of their demo. Running marathons only on sufficiently mature tools represented a huge saving to both suppliers and member companies at a time when 300 mm wafers and processing resources were at a premium.

Tool evaluation results

Fig. 1 *300 mm targets exceed 200 mm capabilities, and, in all but two cases, 300 mm results fall within the range of 200 mm performance.*

Fig. 2 *Forty-seven tools were evaluated with the process summary indicator, derived from the percent of process metrics satisfied.*

All tools are assessed with a standard, fixed set of COO parameters including throughput, MTBF, MTTR, capital cost, scheduled maintenance, footprint and cost of consumables.[3] Tests are designed to compare process performance, throughput, MTBF and COO to the performance metrics goals of the particular tool type. During the program, for example, to benchmark the EPM goals and evaluate results against 200 mm tool production-level performance, data from International SEMATECH member companies were used. Figure 1 shows a comparison of the normalized EPM goals for mean time between failure (MTBF) to the performance range of 200 mm production equipment and 300 mm individual demonstration results. In all areas compared, except etch, the 300 mm EPM targets for MTBF are higher than the best performing 200 mm equipment. Further, in all areas compared, except CMP, 300 mm tool MTBF is within the range of 200 mm performance. Figure 2 indicates 300 mm equipment has progressed to over 50% of EPM process targets. Overall, results indicate improvement over time, with growth in average throughput especially notable.

The EMA generates guideline compliance assessment data by the way of the factory integration maturity assessment (FIMA), which checks over 200 items in eight general areas. Through a simple roll-up calculation, a figure of merit (FOM) is calculated for each tool. The eight areas are Loadports, Interface for Material Delivery, Buffering, Tool Capability Requirements, Equipment Communication Interfaces, Facility Interface, Environmental Safety and Health, and Productivity. Figure 3 shows the growth of FOM over time. From the time these assessments began, it took suppliers approximately six months to make equipment available with steadily increasing levels of compliance.

Figure 4 shows the timeline for completion of tool demonstrations. From the beginning of 1997, I300I conducted 64 demonstrations and 12 gauge studies. During 1997, tools were tested to 250 nm capabilities. But, by the following year, the program quickly moved on to 180 nm targets. Figure 4 also shows the number of demonstrations in terms of tools in alpha phase (Phase II) and beta (Phase III).[4] By early this year, 79% (30 out of 38) of the tool types required for a 180 nm Cu/Low-k, logic process flow had been demonstrated. Excluding Cu/Low-k tools, the figure was 88% (29 out of 33 tool types, Fig. 5). Data from the tool types not covered are either available from the suppliers or are included in the set of demonstrations performed by SELETE. For example, Canon has an i-line stepper available with results from internal testing posted on their website.

Guidelines

Fig 3 A figure of merit for each tool, calculated from the factory integration maturity assessment, shows an increasing FOM over the past year.

In addition to executing dozens of demonstrations, I300I charted new waters by publishing nearly 1000 pages of specific, member company consensus guidelines for suppliers, including factory hardware and software interface guidelines for equipment, performance metrics, specifications and test methods for equipment and materials.[5] As part of the continuing dialogue within the 300 mm industry community, International SEMATECH also publishes a quarterly newsletter, *The 300 mm Transition*.

Worldwide guidelines for factory interfaces, backend equipment and computer integrated manufacturing (CIM) have been published jointly as part of a collaborative effort with J300.[6] Finally, unified equipment performance metrics for 250 nm and 180 nm equipment have been developed by I300I and SELETE. 300 mm guidance will continue to be developed and will remain permanently available to the industry at large via the International SEMATECH website.

Productivity and infrastructure

Ergonomic requirements made total automation a prerequisite for 300 mm factories. In this new area of automation, I300I's Productivity and Infrastructure Group worked with suppliers and a member company working group to create metrics and test methods for automation equipment demonstrations (Table 1). Guidelines and standards for automation allow a new era of equipment configuration uniformity, resulting in cost reductions that augment the productivity increase expected from the 300 mm transition (Fig 6). In addition, automated factories support new manufacturing paradigms that are being investigated through factory simulation modeling.

Automation standards must be accepted worldwide to ensure transport safety and efficiency needed for a cost-effective 300 mm transition. By the end of August 1999, International SEMATECH will have supported the passage of nearly 40 international standards related to 300 mm materials, equipment and factory integration. It remains committed to continuing progress in guideline and standards development.

Table 1 AMHS Demonstration Summary

Technology Demonstrations	**Total**
FOUP characterization	4
FOUP cleaner	6
Sorter characterization	4
Loadport characterization	5
Interbay Trans. System Characterizaton	4
Interbay Trans. System Characterizaton	3
Stocker characterization	4
Wafer alignment fixture	2
Automation/material handling TAP's	2
Buffer characterization	1

Environment, Safety and Health (ESH) program activities emphasize the importance of inclusion of safety, environmental impact and ergonomics consideration at the tool design stage. A detailed ESH assessment is part of every I300I demonstration, and a detailed assessment on the compliance is included in the final report for the demonstrations. This cooperative effort with suppliers has been very successful, as seen by increasing compliance to S2, S8 and CE mark.

Lessons learned

PGV characterization 4

A number of valuable lessons have been learned. From economics and device shrinks to the need for a change in philosophy, they warrant passing on.

The transition has been hard for 300 mm suppliers. The opening of 300 mm fabs has continued to slip due to the economic downturn and over-capacity caused by technology acceleration. Although technical challenges can be met, business conditions are the main drivers for wafer size transitions. International SEMATECH is working with suppliers to develop a common understanding of industry economics and a permanent dialogue to ensure better communications in the future.

The feature sizes of IC devices continue to shrink per Moore's law. I300I demonstrations began at 250 nm and advanced to 180 nm in 1998. It is now clear that some production fabs will come up at 130 nm and beyond. As a result, suppliers must offer tools different from those demonstrated. Global industry discussions must identify the tool architectures necessary to support the evolution of tools to the next wafer size while dealing with the rapid pace of technology change (which is much faster than wafer size change). Bridge tools, those capable of both 200 mm and 300 mm operation, were another approach to the 300 mm transition, but they were not needed when the transition was perceived to be imminent.[7]

Fig 4 *More than half of all tool demonstrations were done on beta-level (tool phase 3) equipment.*

Fig 5 *Of the tools required for 180 nm logic process flow, 88% were covered by at least one I300I demonstration.*

Fig 6 *Of the SEMI standards endorsed by I300I, 76% have been published and 11% are in progress.*

The industry faces redundancy issues because suppliers develop many key components of a tool in-house. In the future, such costs should be shared in a supplier-based, pre-competitive consortium. As engines of innovations are spread across universities, national labs, consortia and hundreds of small and large suppliers, a mechanism must exist for sharing pre-competitive knowledge.

Concluding remarks

The transition to 300 mm is not optional. Current economic and capacity analysis indicates 2001-2002 is the likely timeframe for starting the ramp of 300 mm volume factories. 300 mm equipment is ready for pilot lines, though some performance gaps remain before 300 mm volume manufacturing will be cost-effective. Siemens and Motorola (SC300) have announced production of 64Mbit DRAMs on 300 mm wafers, and others are publicly announcing 300 mm plans.[5] The transition into the next century sees the natural evolution of 300 mm into mainstream. Looking forward, armed with the lessons learned from 300 mm, the industry will be ready when the next wafer size transition to 450 mm takes place.

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References

1. 'Demonstration Test Method' - Revision 1, 1997, available at www.sematech.org programs.
2. 'I300I Factory Guideline Compliance: Factory Integration Maturity Assessment for 300 mm Production Equipment,' 1998, available at www.sematech.org programs.
3. 'Cost of Ownership for 300 mm Tools,' *Semiconductor Process Analysis Characterization and Control*, January 24-27, 1999, San Antonio, Texas, USA.
4. '300mm Transition,' Derek Youngson, Randy Goodall and Vivek Bakshi, *Strategic Business Conference*, April 26-28, 1999, Welches, Oregon, USA.
5. *300 mm Transition Newsletter*, Issue 2, March 1999, published by I300I at www.sematech.org programs.
6. GJG documents jointly produced by I300I and J300 (available at www.sematech.org programs).
7. 'Impact of the 300mm Scale-Up on IC Fab Process Metrology, and Automation Equipment,' *Proceedings of Electrochemical Society*, 1998.

« Back | **Print**