300mm Prime Productivity Improvement

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Outline

• Provide overview of ISMI 300mmPrime pursuit, analysis and assessment activities
  
  – Show ISMI’s approach
  
  – Describe Next Generation Factory Vision and Guidelines
  
  – Describe analysis of 300mmPrime potential
    • Blue Diamond
  
  – Next Steps
300 mm Prime Definition

300mm Prime is an industry initiative aimed at improving factory manufacturing framework and operations

- May closely support some process-dependent issues (e.g., yield)
- Is not intended to directly support device process development (e.g., device shrinkage or node process development)
- Broadly applies to all potential future generations of factory improvements (e.g., 300mm retrofittable, 300mm green field, and 450mm)
Realization of 450mm is built upon coordinated improvements from 300 Prime and 450-only activities to efficiently utilize industry resources.

Collaboration is a critical success factor: Inside and Outside ISMI.
Benefits of the 300mmPrime / 450mm Path

• Target 300mmPrime designs to resolve biggest cost, productivity and cycle time limiters known from 300mm experience
  – Create upgrades to 300mm fab designs for a continuum of benefits and revenue

• Port 300mmPrime learnings to 450mm designs
  – Lower risk of major transitional changes
  – Lower developmental costs by demonstrating concepts at the 300mm wafer size
## Next Generation Factory Vision / Guidelines Development Progress

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<th>Result</th>
<th>Detail</th>
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<td>Q2’06</td>
<td>Define Program Targets</td>
<td>Cost Reduction, Productivity Improvement</td>
<td>300mmPrime ISMI Member Company survey results on desired NGF fab attributes and metrics.</td>
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<td>Q3’06</td>
<td>Define Problem Statement(s)</td>
<td>ISMI 300mm Productivity Detractors List</td>
<td>ISMI Member Company Consensus on 28 300mm Productivity Detractors</td>
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<td>Q1’07</td>
<td>High-Level Direction to Resolve Detractors</td>
<td>ISMI Rev.0 Factory Vision</td>
<td>Consolidation of 28 Detractors into 5 Vision “Themes”</td>
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<td>Q2’07</td>
<td>Methods to Realize Vision</td>
<td>ISMI Unified 450mm/300 Prime Guidelines</td>
<td>19 Guidelines to Realize Factory Vision and Re-use of Fundamental 300mm Concepts</td>
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Factory Guidelines – Definition

Factory Guidelines are
- Statements that aim to further define the Factory Vision.
- Explanations/directions for desirable capabilities to realize the Factory Vision
- Intended to make solutions more predictable and of higher quality
- Intended to be applicable to both 300mm and 450mm factories
- Consensus of ISMI member company inputs

Factory Guidelines are not
- Requirements - Requirements are defined by individual device makers
- Standards – Guidelines will provide direction for required standards where applicable
- Specific solutions
“19 Point” Guidelines to enable Next Generation Factory Vision

1. Maximum 450mm carrier capacity and specification for early prototypes
2. Front Opening 450mm wafer carriers
3. Carriers Designed for efficient Purging with standardized purge locations
4. MHS Design to assume infrequent, anomaly manual handling only
5. Design allowing Automated reticle transport
6. Standardized interfaces - equipment mainframe:process chambers
7. Standardized locations for low-cost buffers on tools (beyond loadports)
8. Equipment to be Predictive Maintenance friendly
9. Equipment maintenance and operation in parallel
10. “Smart Idle” mode for equipment
11. Facility adaptor plates
12. Equipment First wafer delay reduction
13. Single Wafer or Mini-batch (vs. Batch) processing tools
14. Equipment design for flexible capacity increments
15. Enable Continuous processing of material
16. Wafer-level instruction at any time before processing
17. Single Point of Control for factory system command/control
18. Equipment to provide data to enable external monitoring
19. Carrier:Slot integrity flexibility
300mm Legacy Guidelines

Use fundamentals of 300mm guidelines and standards to leverage learning where existing concepts are proven.
Guideline #4: Wafer and reticle storage, transport, and equipment physical interfaces should be optimized for 100% automated operations; equipment should be designed assuming that manual handling will be extremely infrequent and by exception only.

300mm: Pervasive AMHS was not proven; designs allowed for large-scale manual operation as a contingency.

450mm/300mmPrime: Pervasive AMHS is assumed; designs should assume minimal manual (e.g., PGV) handling.

Applicable safety standards will still apply.

Design assuming 100% automated operations
Guideline #5: Reticle carriers, AMHS, and equipment designs shall support cost effective reticle to equipment delivery using the same transport system(s) as the wafers without interruption of processing.

Common FOUP and reticle transport system
Guideline #6: Standards will be defined for the following interfaces: equipment load port to the EFEM (i.e., BOLTS), EFEM to loadlock or equipment mainframe, loadlock to equipment mainframe, equipment mainframe to process chambers/modules.

Expand standardized interfaces to enable increased interoperability opportunities.
Guideline #7: Equipment shall be designed to include standardized locations and easements for integration with a low-cost, general purpose buffer (in addition to E15.x loadport buffers) that is physically independent of the tool and under the logical control of the AMHS.

Guideline #11: Equipment shall include standardized facility adapter plates to realize reductions in time required to install and qualify new toolsets.
Guideline #8: Equipment shall be designed to minimize unscheduled downtime through fundamental improvements and information-based predictive performance.

Guideline #18: Equipment shall be capable of providing (near) real-time data of high quality and integrity to enable external monitoring of equipment status such as process conditions, health, and reliability.

e.g., Wafer-Level Performance, Equipment Failure History, Parts History, etc.

OEM Scope

Improve equipment availability by improving availability and accuracy of critical equipment data
Guideline #9: Equipment shall be designed for maintainability to facilitate the predictive return of equipment to production-level performance levels. Equipment must support simultaneous operation and maintenance activities in a safe manner (i.e., degraded mode, rapid swapping of chambers)
Guideline #10: Equipment shall have a “smart idle” mode to enable automatic utilities shutoff control while maintaining quick startup for returning to production readiness, without added productivity penalties at equipment re-start.

* “Smart Idle” mode must not increase setups, first wafer delays, or chamber conditioning.
**Guideline #12:** Equipment shall be designed to eliminate waiting time between physical lot delivery and first wafer processing. This includes recipe-to-recipe delay, lot-to-lot change-over or job preparation time, cleaning, and conditioning requirements that prevent seamless cascading of lots with different processing requirements.

**Goals**
- Eliminate delays
- Seamless cascading

**Techniques**
- No recipe download → RaP
- Continuous calibration checks
- Active scheduling
- Design out stabilization delays
  - Conditioning
  - Warm-up, etc.

**Increasing impact of setup and FWD on cycle time and throughput**

**Greater impact on high-mix operations**

Design equipment to eliminate setup time and first wafer delay.
Guideline 13: Batch processing equipment should be replaced with single wafer or mini-batch processing equipment with equivalent process capability at competitive cost of ownership to reduce factory cycle time.

**300mm Classic Equipment**

**Next Generation Mini-batch Equipment Conceptual Examples**

-OR-

Batch Size (# of lots)

x6

x1

Conceptual Options –Examples Only

Example mini-batch tool concepts
Guideline #14: Equipment shall be designed to enable flexible capacity increments at competitive footprint and cost of ownership.

Flexible capacity increments and simpler equipment configurations are desirable.

> 300mm Classic Equipment

- High incremental cost
- Complex Equipment Configuration

> Next Generation Equipment

- Low incremental cost
- Simple Equipment Configuration

Conceptual Option – for Example Only

~X ft²

100 wph
**Guideline #15**: Material loading/unloading, factory system command execution and data collection shall not limit the equipment’s ability to process material continuously. To support requirements for some operational models, material handling systems will be required to have deterministic delivery times.
Guideline #16: Equipment shall be flexible enough to execute instructions and changes requested by the factory system down to the individual wafer and recipe parameter level at any time before or during a processing cycle.

E30 Methodology

- Recipe download
  - For every lot
  - Takes time
  - Some recipes are huge!
  - Shrinking download window
  - Tenuous parameter control

- PP-SELECT
  - Recipe exists on tool
  - Selected by host
  - Can cause misprocessing

RaP Methodology

- Recipe Download
  - Recipes guaranteed unique!
  - Only ever download ONCE
  - Publicly exposed parameters

- Recipe Select
  - Adjust parameters on-the-fly
  - Can be used between wafers
  - Standardized recipe editing
  - Ideal solution to shrinking download window problem
  - Eliminates operator-induced misprocessing

RaP is ideally suited for NGF – the time for RaP is now
Guideline #16: “… at any time before or during a processing cycle.”

- Caused great debate at IC makers
- Initial response was “it’s too complicated”

Why do IC makers want this level of control?

- Some tools go “PJ-Active” long before wafer actually processed
  - Excludes “late-breaking” APC feedback
  - Causes wider process variance
  - Wide process variance = $$$’s!

Solution space:
- “Boundary conditions” are the key to successful implementation
- Different for each tool type
- Equipment suppliers to define specific boundary conditions for each tool
- Specify when it is safe and unsafe to change parameters relative to start of Process Job and accept/reject requests accordingly

during a processing cycle is of high value to IC Makers
Guideline #17: There shall be a Single Point of Control for factory system command and control of equipment with standard messages and state models. All other data and file communication shall be handled via standardized supplemental communications port(s).
Guideline #19: Equipment shall be capable of material carrier slot integrity or redirecting material to any carrier/slot available to the equipment.

Current equipment and loadport designs are optimized to handle 25 wafer carriers without the need for empty carrier removal, hence 300mm “Slot Integrity” requirement.

Empty carriers waiting for their wafers to return block equipment loadports, causing material starvation on some tools, so empties need to be removed.

Slot Integrity Mode

Material returned to same carrier/same slot after processing

Material Redirection Mode

Material may be returned to different carrier/different slot after processing

Material Redirection Mode is specified in SEMI Draft Doc. #4457 (E94) to be balloted at SEMICON West.
300mm Prime Productivity Potential
“Blue Diamond” target

Determine whether 300mm Prime has potential to deliver:

30% manufacturing cost reduction and 50% cycle time — “Blue Diamond target”

**IF** 300mm Prime deliver Target?

**YES**  => Delay 450mm wafer size transition

**NO**  => Begin active planning and pursuit of a 450mm wafer size transition
300mm Prime Productivity Potential - Analyses

300mm Prime analysis in past year

- > 130 full factory dynamic simulations for benefit analysis
- > 10000 hours of computer modeling time
- Static factory and economic modeling
Key Analyses Scenarios – 300mmPrime

- Sensitivity analysis of the following parameters were performed:

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<th>Factory Parameters</th>
<th>Low Mix (3 Process flows and 15 Products)</th>
<th>High Mix (5 Process Flows and 100 Products)</th>
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<tr>
<td>Carrier Capacity</td>
<td>25-Wafer, 12-Wafer,</td>
<td>25-Wafer, 12-Wafer,</td>
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<tr>
<td>First Wafer Delay and Setup Time</td>
<td>10%, 25% and 50% Reduction</td>
<td>25% and 50% Reduction</td>
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<tr>
<td>Equipment Availability</td>
<td>5%, 8%, and 10% Increase, limited by ITRS Targets</td>
<td>5% and 10% Increase, limited by ITRS Targets</td>
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<tr>
<td></td>
<td>• ITRS Yellow Cap Availability (Metrology 96%, Process Tools 92%)</td>
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<tr>
<td></td>
<td>• ITRS Red Cap Availability (Metrology 98%, Process Tools 95%)</td>
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<tr>
<td>Single Wafer Processing (SWP)</td>
<td>Normal Batching, Single Wafer Processing</td>
<td>Normal Batching, Single Wafer Processing</td>
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<tr>
<td>Combinations</td>
<td>• 5%, 8%, and 10% Yellow Availability + 25% Reduction in FWD and Setup</td>
<td>• 10% Yellow Availability + 25% Reduction in FWD and Setup</td>
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<tr>
<td></td>
<td>• 10% Red Availability + 50% Reduction in FWD and Setup (&quot;Extreme&quot; Case)</td>
<td>• SWP + 10% Yellow Availability + 25% Reduction in FWD and Setup</td>
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<tr>
<td></td>
<td>• SWP + 5% Yellow Availability + 25% Reduction in FWD and Setup</td>
<td></td>
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Scenarios Details - 300mmPrime

**Cycle Time vs. Wafer Cost**

- **Best Cycle Time Multi-factor Scenario**
  - Low-Mix Single Wafer Processing with [843 Tools]
  - High-Mix Single Wafer Processing [850 Tools]

- **Best Wafer Cost & Cycle Time Multi-factor Scenario**
  - Low Mix SWP w/ 5% Increase Equip Avail (Yellow Caps) & 25% FWD & SU [852 Tools] MQ=1 & 2
  - High-Mix SWP (Wet Only) [750 Tools]

- **Today's 300mm fab performance**
  - "Blue Diamond" Target

- **Scenarios Details - 300mmPrime**
  - Low Mix        with Single Wafer Processing        SWP (wet benches only)
  - High Mix       with Single Wafer Processing        SWP (wet benches only)
Best-case 300mmPrime wafer cost savings modeled are <10%
Cycle time reductions >50% modeled but may drive higher wafer cost
ISMI Next Steps on 300mmPrime

- ISMI targeting 300mm improvements that offer productivity benefits in cycle time and cost reduction
  - Realization of the Next Generation Factory Vision Guidelines in 300mm

- Initial focus areas from modeling are:
  - First Wafer Delay and Set-up reduction
  - Equipment Availability improvement
  - Advanced Factory Software Infrastructure
• Pursue 300mm improvements to achieve significant cycle time and cost reduction opportunities
  – Reduce FWD and set-ups at 300mm
  – Improve equipment availability and predictability at 300mm
  – Pursue productive and cost-effective 300mm SWP or mini-batch furnace tools with equivalent process performance to batch equipment
• Develop capabilities to ensure lots arrive in time at tools and maintain cascading benefits
  – AMHS and lot exchange times & variability
  – Advanced scheduling and dispatch
  – Minimum near-tool buffering (AMHS controlled) or additional loadports (without affecting tool footprint)

• Expectation from our members for suppliers to take proactive steps to propose and pursue productivity improvements and to meet guideline requirements
Summary

- 300mmPrime has cycle time opportunities but does not sufficiently address manufacturing cost reduction needs to replace a 450mm transition

- ISMI has developed common 300mmPrime / 450mm guidelines for productivity and cycle time improvement

- ISMI targeting 300mm improvements that offer productivity benefits in cycle time and cost reduction
  - Realization of the Next Generation Factory Vision Guidelines in 300mm
Thank You