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Accelerating Advanced Backend Automation through Smart Application of Frontend GEM 300 Standards

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We must also credit developers of the software tools highlighted herein...

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Outline

- Background and motivation
- Solution approach and key innovations
- Current status
- Conclusions and next steps







Background and motivation

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Background and motivation

- Increasing emphasis on quality and productivity by OSATs and IDM backend facilities
- Tighter integration of wafer fab and backend as number and complexity of product form factors increase
- Requirements for single device traceability in several critical market segments
- Specific drivers include
 - Demands by consumer product customers for equipment data to support quality and supply chain optimization initiatives
 - Need better event/status data to support automated calculation of OEE and other KPIs
 - Broader deployment of multivariate FDC, which requires more trace data parameters than operational monitoring
 - Actual feedback control based on backend metrology (e.g., saw performance optimization using kerf data) and inspection data



Backend automation challenges In contrast to wafer fabrication

- Multiple material transformations
- Flow shop manufacturing operations
- High product variety and velocity
- Significant manual intervention
- Complex unit product traceability
- Low equipment cost and automation budget
- Supplier un-familiarity with SEMI Standards
- Handling multiple data source types/protocols





Backend material/carrier forms and related processes

- Incoming wafer
 - Wafer mounting
- Mounted wafer
 - Saw
- Strip (lead frame)
 - Die bond
 - Wire bond
 - Mold
 - Cure
 - Trim and form
 - Plating
 - Mark
 - Individual packages
 - Final test and burn-in
 - Pack and ship













Related backend automation topics

- Handling multiple carrier types
 - FOUPs, magazines, trays, carts
 - And carriers of carriers of ...
- Augmenting equipment data with human input
 - Equipment fault codes, operator actions, settings selection
- Managing WIP buffers in "open corrals"
- Consumable/durable handling and management
- Cost-effective integration of "simple" equipment
- Compliance testing for non-standard requirements
- Educating the supplier base





Solution approach and key innovations

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Key innovation #1

Explicit backend operational scenarios

- Several backend equipment purchase specs already list applicable GEM 300 automation standards, but provide little additional guidance
- Infineon has gone well beyond this to define a "Target Equipment Integration Sequence" in its latest Tool Operation Specification for Backend (TOS BE)
- Scope includes detailed interactions among system elements using the following GEM 300 standards:
 - Object services (E39)
 - Job creation, execution, and tracking (E40, E94)
 - Carrier placement, verification, and removal (E87)
 - Substrate processing and tracking (E90)
 - Substrate mapping and full traceability support (E142)
 - Consumable and durable handling (New!)
- Also enables automated validation by standard GEM protocol test software





Target Equipment Integration Sequence

Expression: Ladder diagram of system communication partners

- Operator/robot/AGV
 - Load/unload material
 - [Occasionally] provide input
- Equipment
 - Perform process operations
 - Communicate principally with EAF component
- EAF Equipment Automation Framework
 - Implement SEMI Standards and Integration Sequence
 - Provide bridge to generic Backend Factory Host
 - May include site-specific automation logic
- FA/EA Factory/Equipment Automation
 - Backend Factory Host system(s)
 - Provide MES, OEE, APC, and other application functions





Integration Sequence diagram/spec excerpts FOUP, MultiDimensional and Nested Carriers

- Backend material transformations require different carrier types
- This complicates content verification AND device traceability
- Equipment handling all carrier types must support E87 Carrier Management, including content (slotmap, etc.) verification
- FOUPs have the familiar list of slot IDs
- Multidimensional carriers include a location spec for each substrate (x, y, z position)
- Nested carriers (and their content maps) have inner carriers at specified locations, which in turn have their own content maps
- The number of slots, positions, and inner carriers varies by product type and must be configurable

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ProceedWithCarrier #2 Nested Content Map



Integration Sequence diagram/spec excerpts Process/Control Job creation and execution tracking

- Required Process/Control Job states and transitions are specified
- However, some equipment types have no concept of a "job"
 - They merely execute a fixed operation sequence, perhaps with some settings selected by product type
 - Regardless, these processes still require full automation support in the Integration Sequence



Process Job States

Control and Process Job Setup



Integration Sequence diagram/spec excerpts Consumable/durable handling

- New traceability requirements now include keeping track of consumable materials and durable components used for each device
 - Manual record keeping is too error prone to satisfy this requirement
- Consumables are materials that are consumed during manufacturing of a product, and which are directly identified with that product
 - Examples include glue, mold compounds, wires, etc.
- Durables are tools or parts which are mounted on the equipment and used in the manufacturing process
 - Examples include feeders, grippers, adapters, etc.
- Mounting, Verification, Consumption, and Unmounting must be supported
- Required variables, events, and commands are described in the appendices



Consumable Mounting and Verification



Integration Sequence diagram/spec excerpts Substrate map download/upload (E142)

- For equipment types that have substrate mapping functionality, the map download and upload sequence is required
- Substrate types in this context may include wafer, strip, or tray
- Specific data items that must be included in the map are detailed in the appendices
- Note that the E142 schema has recently been updated to accommodate much more traceability information



Substrate Map Download and Upload



Key innovation #2

Adaptation of mature GEM/GEM 300 automation standards

- Specific messages/objects from the GEM/GEM 300 are woven together in the Target Equipment Integration Sequence
- This concept was a major success factor in the definition and use of SEMI's automation standards at the 300mm wafer size transition in the mid-90s
- This results in significant reuse of existing factory and equipment connectivity software
- This also enables equipment suppliers unfamiliar with SEMI Standards to implement a subset of GEM 300
- The <u>only</u> modifications made to the standard GEM 300 message set were those needed to support carrier/tray ID and content verification



Synchronized View of Multiple GEM 300 State Machines



Key innovation #3

Reference implementation and validation test software

Entire Target Equipment Integration Sequence is realized in a sample application suite

- Equipment simulator, communication partner utility (Robot, EAF, FA/EA), validation tester plug-ins
- Brings the specification to life
- Accelerates equipment supplier development process to incorporate the sequence in their products





Backend equipment simulator and sample factory host Incorporate GEM 300 libraries to fully implement Integration Sequence

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Backend Equipment Simulator



Backend equipment simulator

Carrier management (FOUP style, MultiDimensional, Nested)

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Backend equipment simulator Job control

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Backend equipment simulator Consumable handling

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Backend equipment simulator Durable handling

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Validation tester plug-in

Extends GEM 300 compliance tests to include Integration Sequence items

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	Aut	oFill Parameters	
Access Mode Violation			
Consumables			
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 E40 Process Job 			
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/ LP1 Foup			
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 LP3 Nested Carrier 			
 Manual Carrier Placement 			
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Scope of Integration Sequence Plug-in (Configuration Settings Screen)

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	LCAS Report Id	Inner Carrier Id:	Inner Carrier Location:
	Usage	CARRIERS	001
	LTS ReportID ID#	Add Substrate	Remove Substrate
	O CIDS Report Id	Substrate Id: TRAY2.01	Lot-ld: lot1 Location: 010
	CSMS Report Id	Substrate Id: TRAY2.02	Lot-1d: lot2 Location: 0.2.0
0	ProcessJob Report Id	Substrate Id: TRAY2.03	Lot-ld: Jot1 Location: 0.0.2
	Control Job Report Id	Substrate Id: TRAY2.04	Lot-ld: lot1 Location: 0.0.3
	Substrate Location Rep	Substrate Id: TRAY2.05	Lot-ld: lot1 Location: 0.0.4
	Substrate State Model I		Save and Close
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Nested Carrier Content Map Verification Sequence Tests



Validation tester plug-in Consumable handling example

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		Parameters >	0 0	CC123.1	FAIL 🔻	MaterialStatusMap ClassA
		Output	0 0	CC123.2	PASS *	MaterialStatusMap ClassA
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Consumable Handling Sequence Tests



Key innovation #4



Integration Sequence document transfer to SEMI Standards community

Advanced Backend Factory Integration Task Force (ABFI TF)

Charter

- "To explore, evaluate, discuss, and formulate consensus-based specifications that, through voluntary compliance, will enhance assembly and test for semiconductor manufacturing"
- Operating principle: ensure that any new backend standards are consistent with the existing body of connectivity standards and leverage as much of the current SEMI standards as possible, especially GEM / GEM 300
- Focus to date
 - Updating E142 (Substrate Mapping) to support single device traceability (tracking raw materials and process materials, adding new substrate types)
 - Identifying needed updates in existing standards (GEM, GEM 300, EPT, etc.)
- Members (companies)
 - Energetic mix of major device makers, equipment and software suppliers





Current status, Conclusions, Next steps

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Current status

Target Equipment Integration Sequence fully defined

- And included in latest Tool Operation Specification for Backend (TOS BE V 2.4.4)
- First equipment simulator reference implementation complete
 - Including matching host utility application and Validation Tester plug-ins
- Stakeholder training material development underway
- Technology transfer process has now begun (this public presentation!)



Conclusions

- Wherever possible use proven standards don't invent new ones
- It is encouraging to see that with minimal interpretation and adaptation many of the GEM 300 operational scenario elements can be used for backend equipment
- Several companies are already taking this approach, so the stage is set for deeper collaboration
- This is low-hanging fruit if we truly want to accelerate the pace of cost-effective backend automation, adopting GEM-based technology is the best way to go



Next steps

- Prepare technology transfer package for SEMI Standards (in process)
- Present material to SEMI Advanced Backend Integration Task Force (done)
- Present at major industry events (e.g., SEMICON West !)
- Host webinars to demonstrate reference implementation software
- Gather, review, and incorporate feedback into key artifacts
- Update ABFI standards roadmap
- Incorporate new features into our standard equipment, factory, and validation commercial products
- Promote to backend equipment/system suppliers





Questions and Answers

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Thank You

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