Smart Manufacturing in the Semiconductor Industry - *Realizing the Digital Factory Vision*

Tim Hewitt, Global Services Director, Electronics & Semiconductor
Mega trends in the new era of Digital Transformation

1. Self optimizing energy systems
2. Autonomous operations
3. Electrification
4. Smart connected cities
Challenge of the Semiconductor IC Lifecycle

Current state of semiconductor value chain

Integrated-circuit design, process development, and factory setup

New-product introduction and ramp-up

Wafer manufacture

Assembly and functional testing

System integration and after-sales

End of life

50% increase in time in test and verification over the last few years

About 12–18 months of iterative debugging

80–90% utilization and 85–95% integrated yield

About 30% of capital expenditures relate to testing that does not add value

No end-to-end traceability at device level

Lack of feedback loop at end of life

McKinsey & Company
Semiconductor Shifts

Shifting Growth Segments

<table>
<thead>
<tr>
<th>2016</th>
<th>2025</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>IoT</strong></td>
<td><strong>$16B</strong></td>
</tr>
<tr>
<td>Semiconductor Value</td>
<td><strong>$62B</strong></td>
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<tr>
<td><strong>Automotive</strong></td>
<td><strong>$32B</strong></td>
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<tr>
<td>Semiconductor Value</td>
<td><strong>$51B</strong></td>
</tr>
<tr>
<td><strong>5G</strong></td>
<td><strong>$0B</strong></td>
</tr>
<tr>
<td>Networks/Devices</td>
<td><strong>$20B</strong></td>
</tr>
<tr>
<td><strong>AR/VR</strong></td>
<td><strong>$4B</strong></td>
</tr>
<tr>
<td>Market Size</td>
<td><strong>$131B</strong></td>
</tr>
<tr>
<td><strong>AI</strong></td>
<td><strong>$5B</strong></td>
</tr>
<tr>
<td>Market Size</td>
<td><strong>$50B</strong></td>
</tr>
</tbody>
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Current Trends

- Automotive Industry driving end-to-end traceability and higher quality requirements.
- Increasing Requirements to achieve zero level defects.

Impacts of the Trends

- Shorter technology innovation adoption.
- Inability to achieve zero defect will cause loss of revenue/market share.
- More difficult to enable collaboration across and through the Supply Chain.
- Manufacturing environment needs to be closed loop, intelligent and integrated.

Global Foundries presented the data at the ISS Summit Jan 2017 based on Gartner’s Actuals and their forecast data.
Advances in IC Technology are fueling Digital Transformation

### The cost of key technologies is falling

<table>
<thead>
<tr>
<th>Technology</th>
<th>2007</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>DRONES</td>
<td>$100,000</td>
<td>$700</td>
<td></td>
</tr>
<tr>
<td>3D PRINTING</td>
<td>$40,000</td>
<td>$100</td>
<td></td>
</tr>
<tr>
<td>INDUSTRIAL ROBOTS</td>
<td>$550,000</td>
<td>$20,000</td>
<td></td>
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<tr>
<td>SENSORS</td>
<td>$30,000</td>
<td>$80</td>
<td></td>
</tr>
<tr>
<td>SMART PHONES</td>
<td>$449</td>
<td>$10</td>
<td></td>
</tr>
</tbody>
</table>

Source: Accenture Technology Vision 2015

### Implications of Moore’s Law

- **Transistor density**
  - Source: Leading Technology Research Vendor

- **Cost of technology**
  - Source: Leading Technology Research Vendor
Digitalization
Sets the foundation and roadmap for the new era of digital transformation
“The IoT is being called the fourth industrial revolution, and is expected to have a value of over 10 trillion dollars by 2025.”

McKinsey Global Institute

“Digital is the main reason just over half of the companies on the Fortune 500 have disappeared since the year 2000.”

Pierre Nanterme, CEO Accenture
The Digital Thread and Digital Twin

The **Digital Thread** ties all of your data together, from requirements through design all the way to manufacturing and the field.

The **Digital Twin** allows us to simulate the entire supply chain, from requirements collection and design to factory layout, capacity, scheduling, processing, manufacturing and the field. **Shift-Left** and fail before committing physical assets.
Successful Industry 4.0 Electronic Factory Solution
The Digital Twin at Siemens

Amberg plant

Fast!
~1 Million monthly production of PLC products

Flexible!
60,000+ customers worldwide each year
24 hour lead time for new orders

Efficient!
~12 dpm means near perfect quality – every time

Siemens' state-of-the-art Electronic Works facility in Amberg, Germany integrates its manufacturing, production and automation systems to process 1.6 billion components from 250 suppliers with 99% reliability.
Siemens Investment in the Digital Enterprise

UGS acquisition establishes software foundation for product development

Acquisition of LMS expands strategy for verification and validation of systems

Siemens establishes leadership in product and process simulation to enable digitalization

>$6.5 Billion since 2013
Siemens Enables …
New Product Ideas to Become Volume Production Reality

Requirements
- Polarium ALS
  - Customer
  - Marketing
  - Product Data sheet
  - Embedded Software

Design
- Tanner EDA
  - AMS IC Design Flow
  - MEMS Design Flow
  - Schematic Capture
  - Analog Simulation
  - Layout
  - Physical Verification

Characterization
- Camstar MES and Process Automation Controller
  - Processing Model
  - Mask/Tool Management
  - Experiment Management
  - ERP Interface

Ramp
- Camstar Intelligence
  - Overall Equipment Efficiency

Volume Production
Yield & Quality Management
- Quantix Yield-Man
  - Correlation Studies
  - Spec Limit Adjust
  - Excursion Analysis

- Quantix ExaminatorPro
  - Multi-variable device characterization
  - Test program qualification

- Tessent Test Suite
  - Diagnosis – Classification
  - ScanPro

- Quantix PAT-Man
  - Parametric & geographic outlier detection.
  - Probe and FT

- Tessent Test Suite
  - TestKompress
  - BIST

Embedded Software
- Autonomous Driving Platform
- IoT Intelligent Gateway
- IoT Embedded Runtime
- IoT Cloud Services

Calibre Mask Flow
- Computational Lithography
- Mask Process Correction
- Mask Data Preparation

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Siemens PLM Software
Digitalization Ingredients
You need these “digital companions” to transform into a digital enterprise

Smart Innovation and Operation

Intelligence of Digital Twin + Connectivity of Digital Thread + Insight from Lifecycle Analytics
From Product Design to Manufacturing Operation Data Analytics

Semiconductor digital enterprise lifecycle solution

- **Ideation**
  - Product Design
  - Electromechanical Systems Design to Manufacturing
  - IC Design to Silicon
  - Software ALM
  - Model-based Analytics
- **Realization**
  - Digital Manufacturing
  - Manufacturing Operations Management
  - Lifecycle Analytics
  - Test and Validation
- **Utilization**
  - Collaboration and Lifecycle Management
  - Data-driven Analytics

Leading-edge systems companies are becoming the new system-on-chip designers.
Starting from Product Design to Manufacturing Operation Data Analytics: Some Examples

Verification Management:
Transform verification by bringing powerful engines and platforms together to deliver high performance verification from prototype to silicon.

Global MES:
Device level traceability across plants allowing for better Root Cause Analysis

Requirements Management:
Workflows integrated into the data model that give visibility for phase gate planning and interdependencies

SMT Line Planning:
Optimization for thousands of work orders across multiple vendor lines

Experiment Runs Modeled in MES:
20% reduction in NPI, faster Yield Increase

Schedule Optimization for Testers:
Yield analysis integrated to MES

Product Lifecycle Analytics:
Analytics on Tool, MES, Engineering, & Test data sets...leading to process and design improvement

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Digital Manufacturing
Leverage Integrated Factory Automation, MOM, PLM to build the solution
Factory Integration
Leverage Common Plant Model to build the solution

PLM
Common Plant Model

Run-Time Manufacturing
Operations Service Bus

Run-time process image

Real-time Data

BOP Execution
Production Screens
Manufacturing Intelligence

IOT Device
Auto-registration

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Siemens PLM Software
Smart Manufacturing
Leverage Digital Twin as The Vehicle to Realize Smart Manufacturing

- The virtual and the real worlds are linked by the Manufacturing Master Data Model and the Common Plant Model. Operations are simulated before any physical assets are involved.

- Feeding back all relevant information from production execution creates a nearly real-time image of the digital twin of product, process and resources.

- Decisions can be made based on real-time data – What’s the next best step to take?

- Analyze the engineering and manufacturing big data with a machine learning model.
How do I get ALL my Data?

MindSphere
The cloud-based, open IoT operating system
The cloud will become the IoT operating system

MindSphere
The cloud-based, open IoT operating system

- Global Siemens installed base of millions of devices (30 million automation systems, 70 million contracted smart meters, 800 thousand connected products, e.g., trains)
- Transfer of domain know-how into vertical-specific analytical apps
- Integrate operational data with model-based analytics to optimize simulation and engineering
Cross-Functional - Why did this fail?
Business Use Case Definition

Provide Product Insights

| Identify Patterns | Suggest Root-causes | Access Production defect modes | Trace IP | … … … |

**Description:**
Identify patterns, which were unknown or would require huge effort to uncover, by analyzing all available data / parameters related to a specific lot.

**BUC Objective(s):**
- Reduce time-to-resolution which will avoid prolonged containment times, avoid scrap / rework and avoid production disruption

**Source system(s)**
- Test Specs
- Testing raw data
- Manufacturing Execution System (MES)
- Process Equipment Sensors

**Example:** All the in-process test are in Specs, but at final tests some items fail: Why? A pattern is discovered showing, that when test 5 & 7 are in the bottom range of the spec, it ends up with fail at final test
Cross-Functional – Intellectual Property Defect Traceability

Business Use Case Definition

Provide Product Insights

| Identify Patterns | Suggest Root-causes | Access Production defect modes | Trace IP | ... ... |

**Description:**
Identify dependencies between manufacturing defects and IPs, to support the problem solving process.

**BUC Objective(s):**
- Identify root cause related to the IP definition

**Source system(s)**
- Issue Lifecycle Management (ILM) System
- PLM System
- Manufacturing Execution System (MES)

**Example:** From a particular issue, be able to trace the material involved, and therefore the related IPs. Or from a particular IP, be able to trace up to the impacted issues.
Predictive Learning – Matching Golden Equipment

Business Use Case Definition

**Description:**
Predict issues during production ramp-up based on data (chemical used, test raw data, temperature, pressure, etc...) gather during pre-launch production orders.

**BUC Objective(s):**
- Accelerate production ramp-up by proactively solve issues, even before they appear

**Source system(s):**
- Issue Lifecycle Management (ILM) System
- Manufacturing Execution System (MES)
- Test data
- PLM System
- Equipment Sensors
- … … …

**Example:** Production is ok for “golden equipment” used for pre-launch, but fails with volume equipment: why? → identify the major variation of internal equipment component, between “pre-launch” and “post-launch” equipment.
Classification
Too Much Data, Not Enough Information

- When did we have problems in the line?
- Without classification, one may draw a wrong conclusion
- If there was a 30 min planned changeover at 10:00 AM, then the target utilization should only be half of the usual target

Without Classification

With Classification

Seems to be the problem

Shows the actual problem

Target utilization

Based on a planned 30 min changeover, utilization was actually very high
Accelerating the Innovation Velocity
Leveraging Analytics to Transform Your Business

Descriptive
What happened?

Diagnostic
Why did it happen?

Predictive
What happens next and when?

Prescriptive
When this happens, take these steps.

- Fast Contextual Search
- Performance Analytics
- Advanced Data Visualization

- Fast Contextual Search
- Performance Analytics
- Advanced Data Visualization
- Discovery

- Performance Analytics
- Advanced Data Visualization
- Predictive Learning
In Summary

- Complexity of the Supply Chain means Design Anywhere, Build Anywhere is today’s reality.
- Big Data Analytics is not just a data lake, but requires deep domain knowledge and data contextualization to be of value.
- Analytics extends through the entire Digital Enterprise and encompasses Descriptive, Diagnostic, Predictive and Prescriptive results.
Thanks for Your Attention

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