Accelerating China Semiconductor Industry with GlobalFoundries Smart Manufacture

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March 15, 2018
The GLOBALFOUNDRIES Story

Building an industry leader

- Largest privately held semiconductor company
- ~8X capacity increase since 2009

- GF created
- Acquires Chartered Semiconductor
- Fab 8 delivers initial silicon 1st time right
- Dresden ships 250,000th 32nm HKMG wafer
- Acquires IBM Microelectronics business
- Launches: 22FDX® Platform 14LPP ASIC offering
- Collaborates w/ Samsung on 14nm manufacturing
- Launches 14nm FinFET technology
- Launches 14LPP ASIC offering
- Announces 7nm FinFET & 12FDX™
- Launches: 8XP SiGe RF technology 22FDX®-MRAM technology FDXcelerator™ partner program
- Chengdu Fab 11 construction and FDX™ Ecosystem in China
- Launches 7nm FinFET (7LP)
Global Presence for Semiconductor Manufacturing

Local support for an expanding global customer base
Manufacturing – getting rid of Risk & Cost

Manufacturing
- Use your hands
- Execution of repetitive tasks
- High Cost, High Risk

What we really need (and partially have)
- Repetitive quality
- Manageable complexity
- Low Cost, No Risk
In 1990s and Early 2000s – driving full automation, reducing repetitive task & eliminating risk

- Human Tasks eliminated:
  - Process Start/Stop, Data Collection (20K each per day)
  - Material Transport (40K per day)

- Key Enabler
  - Load Ports
  - AMHS, FOUPs, Communication I/F

- Key Benefits
  - Error-free recipe selection
  - Better clean-room quality
  - More reliable task execution
Full Automation Prevents New Risks

- **Human Tasks eliminated:**
  - Process/Tool error detection
  - Process Tuning
- **Key Enablers**
  - Equipment Automation
  - System Theory
- **Key Benefits**
  - Stabilization of processes
  - Earlier detection of potential issues
How do we detect when something’s wrong?

**Driving a Car**

- Check
- Warning Lights
- Oil
- Brakes
- Engine
- Battery
- Fuel
- Wiper Fluid...

**Semiconductor HVM**

- Check
- Warning Lights
- Equipment Constants
- Recipe Control
- Fault Detection & Classification
- Inline SPC
- ET / WT SPC
Controls strategy is built for early identification of defects and sources of variation

Mean Time to Detect (MTTD) / Quantified Wafer Risk Exposure

<table>
<thead>
<tr>
<th>Inspection point</th>
<th>Real time process control</th>
<th>Wafer inspection at tool</th>
<th>Wafer inspection at sector</th>
<th>Scribe line test</th>
<th>Product test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical MTTD</td>
<td>Minutes</td>
<td>Hours</td>
<td>Days</td>
<td>Weeks</td>
<td>Months</td>
</tr>
</tbody>
</table>

Early identification is predicated on measuring and driving resolution based on Mean Time to Detection

LOD = Lines of Defense

Tool Alarms
RMS
ECC

SPC
R2R

CFM
Wafer E-Test

Sort Test

Data Mining
Tool Match

AND

LOD1
LOD2
LOD3
LOD4
Quantifying Wafer Risk Exposure

<table>
<thead>
<tr>
<th>Control</th>
<th>Time Delay</th>
<th>Wafer Risk</th>
<th>Cost Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sort Yield</td>
<td>8 weeks</td>
<td>11,200</td>
<td>$67,100,000</td>
</tr>
<tr>
<td>M1 Test</td>
<td>4 weeks</td>
<td>5,600</td>
<td>$33,600,000</td>
</tr>
<tr>
<td>CFM</td>
<td>2 days</td>
<td>800</td>
<td>$4,800,000</td>
</tr>
<tr>
<td>Inline SPC</td>
<td>6 hours</td>
<td>100</td>
<td>$600,000</td>
</tr>
<tr>
<td>FDC</td>
<td>Live</td>
<td>1 wafer</td>
<td>$6,000</td>
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</table>
HVM Challenges and Opportunities

• Signal Analysis is Labor Intensive and requires expert engineers:
  – Configure baseline set-up of process & equipment signals (FMEA driven)
  – Control old & new process & equipment signals (FMEA → Control Plans)
  – Acquire unambiguous trace data from tools for high risk process factors
    • Requires more 3rd party analog sensor signals embedded internally & installed externally to the equipment (OEMs are not the HVM control experts)

• Something(s) to Everything Correlation
  – Opportunity for more Artificial Intelligence to mitigate some labor dependency

HVM = High Volume Manufacture
Enable IOT Subsystem to Improve Planned Control

- Process & Equipment Control Gaps Assessed by SME’s
  - Different technologies drive different process & equipment control signal gaps at LOD1

- 3rd Party Sensor Evaluations
  - Benchmark information is combined with internal SME innovation to drive CIP projects
  - Information is shared across all sites via the FDC Global Domain Team

- Install 3rd party sensors if Fab ROI exists
  - Fab decides if the ROI justifies closing the control gaps

- Share BKM with all Fabs via GLOBAL forums
  - Sister sites decide if the ROI of the new signal is a value-add for processes, equipment, technologies & product portfolios
IOT at GLOBALFOUNDRIES for High Volume Manufacturing (HVM)

Smart Manufacturing with IoT is in-motion

Process

- **Classification → by risk level**
- **Detection → Sensors**
- **Controls Strategy**

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Outcomes

- **Mean Time to Detect (MTTD) / Quantified Wafer Risk** (Time Delay, Wafer Risk, Cost Impact) – Significantly increases from FEOL → MOL → BEOL
- Fab installs **3rd party sensors** if ROI justified for new signal control point. Sister sites replicate if valuable
- Improve **equipment health context** for automated fault classification for 1\textsuperscript{st} time Right Decisions
Implementing Industry 4.0 Smart Manufacturing in GLOBALFOUNDRIES

Key Benefits

- **Increased Manufacturing Throughput**: Longer Up-time for High Volume Manufacturing (HVM)
- **Higher Yield Management**: Reduce Wafer Risk (Time Delay, Cost)
- **Improved Efficiency**: Control at FEOL vs. MOL or BEOL
- **Reduced Downtime**: Equipment reports its health for Automatic fault classification
Exploiting Big Data Analysis in HVM and Integrating New Technologies

• **Classified Engineering Data is a Required Foundation**
  – Classified Engineering Data
  – 1st time Right OCAP & Engineering Decisions

• **Exploit Legacy & Nascent Instrumentation Techniques for:**
  – Atomic Scale Processing
  – Enable Automated Fault Classification for 1st Time Right Decisions

• **Introduce New Technologies, e.g. big data and artificial intelligence, to expedite the difficult issue solve.**
Broader Collaboration in China Semiconductors Industry
Summary

- Zero Defect
- Best Yield
- Full Support

GLOBALFOUNDRIES®
Thank You