A Fab-Wide Chamber Matching Solution for High-Mix Semiconductor Manufacturing Based on Equipment Fingerprinting

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The Tool Matching Problem

- Over the last couple years GLOBALFOUNDRIES has transitioned from a high-volume/low-mix IDM to a high-mix foundry

- As an IDM GLOBALFOUNDRIES (AMD):
  - Relied heavily on APC to compensate for tool differences
  - High product volume allowed us to leverage electrical data to easily identify rogue tools
  - Had fewer low-volume, high-value parts

- Now as a Foundry GLOBALFOUNDRIES:
  - Must ensure that the low-volume, high-value products yield on our entire fleet of tools
  - Does not have the product volume to easily “dial in” tool differences with APC
  - Cannot easily rely on electrical data to identify rogue tools

- To be the best foundry in the world we must have the best matched equipment
As a part of an overall manufacturing quality initiative, GLOBALFOUNDRIES is committed to tool matching.

Chamber matching at GLOBALFOUNDRIES includes:

- Electrical Matching
- Inline Matching
- Tool Sensor Matching
Trace Chamber Matching Approach

- A reference “Fingerprint” is created using trace sensor data
  - ARMA time series model represents the expected sensor trace signal
  - Confidence interval constructed around the ARMA model
- The distance between the reference Fingerprint and the new data is scored according to the ARMA confidence limits
Applications of Trace Chamber Matching

1. New Tool Qualification
   - When new tools are qualified, they must match the fleet of existing chambers at the sensor level
   - Example: New metal deposition tool (pressure sensor)

2. Tool Validation after PM
   - After a major PM does the tool match the fleet of tools?
   - Example: CVD tool following PM (electrical bias)
Applications of Trace Chamber Matching

3. Yield Analysis
- What is different about a poorly yielding tool or group of tools?
- Example: EPI temperature causing yield signature

4. Line Monitoring
- Fab-wide sensor level tool matching
- Regular, automated reporting to process and equipment engineers
- Business processes and action item tracking
Tool Cross Validation

- Line monitoring is accomplished through leave-one-out cross validation
  - A Fingerprint is constructed using all tools except one
  - The missing tool is scored against the Fingerprint
  - Repeated for all tools
Line Monitoring Approach

- Matching is owned by module engineers (process and equipment engineers)
  - Engineers specify tool matching families
    - Tools with identical hardware and software
    - Expected to run identically
  - Engineers specify “Golden Recipes” to be used to monitor the tools
    - Qual or production recipes
    - Recipes running on multiple tools
    - Recipes that run on key process steps and exercise the tool sensors

- Software enables regular notification of tool/sensor mismatches

- Business processes to assign ownership, track actions, and review mismatches
Regular Notification of Tool Matching

- Module engineers configure regular monitoring
- Regular reports highlight sensor mismatches
Business Process to Drive Sensor Matching

- Regular updates and Case Tracking System
  - Create chamber matching case for mismatched sensors
  - Assign ownership, actions, and review date
  - Case is closed when chamber matching is validated
GLOBALFOUNDRIES has deployed our sensor matching line monitoring solution throughout Fab1 and are ramping coverage in our other fabs.

Coverage:
- Etch, CVD, SNK, Implant, EPI, RTA, Metal deposition, Litho Tracks, Polish, Metal plating, Plasma Stripping, Furnace, …
- Dozens of tool platforms
- Hundreds of tools
- Thousands of chambers
Examples

Etch: MFC changed

Metal dep: water distributor unclogged

CVD: Confinement ring fixed

Plasma strip: RF generator fixed

EPI: pressure sensor fixed

RTA: pre-set pressure fixed
We are often asked the difference between trace chamber matching and fault detection (FDC)

- FDC and Trace chamber matching complement each other
  - Analogous to how SPC complements Inline Chamber Matching

<table>
<thead>
<tr>
<th>Category</th>
<th>FDC</th>
<th>Trace Chamber Matching</th>
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</thead>
<tbody>
<tr>
<td>Goal</td>
<td>Looking for <strong>sudden changes</strong> in chambers’ trace data</td>
<td>Looking for <strong>consistent differences</strong> between chambers’ trace data</td>
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<tr>
<td>Alarm action</td>
<td>Inhibit tool immediately</td>
<td>Typically maintenance at next PM</td>
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<tr>
<td>Model Data</td>
<td>Typically compare with data from tool itself</td>
<td>Compare with data only from other tools</td>
</tr>
<tr>
<td>Analysis Frequency</td>
<td>After every run</td>
<td>Regular scheduled job</td>
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FDC/ Chamber Matching Alarms

**Detected by FDC**
- Single wafer had a bad temperature measurement
  - Flagged by FDC
- Not a systematic, consistent tool difference
  - Not Flagged by Trace CM

**Detected by Trace CM**
- Consistent, systematic difference between tools
  - Flagged by Trace CM
- No sudden change in tool operation
  - Not Flagged by FDC
FDC models are typically tool/chamber specific

- Each tool is within historical operating range
- No FDC signal

FDC looks great!
Summary

- GLOBALFOUNDRIES is committed to chamber matching: Yield, Inline (SPC), and Trace Sensor Data
- Implemented a chamber matching solution based on trace sensor data
  - New tool qualification
  - Maintenance validation
  - Yield analysis
  - Fab-wide line monitoring
- Solution involves introducing business process that is driving continuous improvement in fleet matching
- Currently deployed on 100s of tools and 1000s of chambers
- Continuing to add both breadth and depth to our fleet matching coverage
- Continuous improvement in inherent in our approach
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