Prognostics and Health Management (PHM)

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Agenda

• What is Prognostics and Health Management (PHM)?
• What is ISMI doing in the PHM arena?
  – ISMI Predictive Preventive Maintenance Project (PPM)
  – Project Scope
  – Project History
  – Project Status
  – Project Look-Ahead
  – PPM resources
• Why should JPWG care?
• Q&A
What is Prognostics and Health Management?

- Prognostics & Health Management (PHM) — The discipline that links studies of failure mechanisms to system lifecycle management. PHM uses information to allow early detection of impending or incipient faults, remaining useful life calculations, and logistical decision-making based on predictions.

- The objective of PHM is to maximize equipment return on investment. A PHM system will optimize scheduled maintenance, predictive condition-based maintenance, and non-predictive condition-based maintenance to an operational objective.
  - Scheduled maintenance is performed on a fixed, calendar-based schedule.
  - Non-predictive condition-based maintenance is accomplished by instantaneous monitoring of equipment and by performing maintenance when an equipment health indicator reaches a predetermined threshold.
  - Predictive condition based maintenance is accomplished through acquiring relevant equipment and factory data and applying an equipment degradation model to predict the equipment’s RUL.

- A PHM system will combine scheduled maintenance, condition-based maintenance, and predictive maintenance to enable effective cost versus performance decisions.
Who is already doing PHM? (in other industries)

- **PHM is famous in**
  - Automotive industry
    - in the modern automobile, especially the engine
    - Toyota in the car/truck assembly line
  - Aeronautics
    - GE & Rolls Royce aircraft engines
  - Defense and Space programs
    - Advanced fighter jet
    - NASA and International Space Station
  - Heavy Industry
    - John Deere, Komatsu in earth moving equipment
    - Power plant generators

*How can we leverage their >20 years of learning?*
PHM for the Semiconductor Industry

- PHM for semiconductor factories will apply mathematical models to equipment and factory data to predict tool failure and then act on those predictions to optimize factory productivity
  - PHM will be developed for key equipment where
    - Technically possible, and
    - Adequate business value exists
    - This is NOT every tool
  - At/near the Equipment level, the system will monitor tools and predict failures
  - At the Factory level, the system will make business rule based decisions about scheduling PM, parts, personnel, and WIP
PHM Integration

**Fabrication Information & Control Data**
- Parts Inventory
- WIP
- Factory Schedule
- Staffing

**Equipment Data**
- Equipment Raw Data
- OEM defined Health Indicators

**Decision Application**
- Functions
- Libraries

**Scheduled PM Application**
- Functions
- Libraries

**Predictive CBM System**
- Functions
- Libraries

**Non-Predictive CBM System**
- Functions
- Libraries

**Factory/Metrology Data**
- MES Process Data
- Defects
- Parametric
- Yield Parameter

**DCP Or Collect All Data**

**Process Equipment**

**Metrology Equipment**

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Health Dashboard View

• **Interpretation**
  - The tool is performing OK with an Health at 0.7
  - The EFEM and PM1 are in great shape – Health 0.9
  - The PM3 is starting to perform worse with Health 0.65
  - The PM2 is failing with Health 0.4
  - Drill down on PM2 shows the problem is in RF subsystem, and specifically the RF Generator needs replacement
  - The RF Generator is the lowest level as the RF Generator is the FRU – the thing you change as a unit when the failure occurs
PHM Data to Information to Decision

- Equipment
- Raw Data - Features
- PCA, Fisher - Feature Importance
- &Metrology Data
- &Maintenance Record
- Prediction Models - Planning Info
- Health Models - Actionable Info
- Optimization - WIP & Maint
- Select tools
- Scheduler - WIP, PM Resources
- $$$
- PM
- WIP
IC Industry PHM Status & Issues

• Current state of implementation of this capability in volume manufacturing
  – IDM FDC spot solution using commercial application and framework & OEM custom non-standardized on-board equipment diagnostics, unconnected
  – Predictive Maintenance efforts are gaining momentum at OEMs internal programs, but are not yet commercial, and are not standardized
  – Prognostic modeling has not been successfully demonstrated in IC production
  – ISMI PPM project will provide proof of concept on a few key tools
  – Integration with factory planning systems for WIP and PMs is difficult

• Requirements needed to support this capability
  – Standards and/or guidelines are needed for this capability
    • Some guidelines have been produced by ISMI (see Resources slide)
  – Data completeness, availability, data standardization (e.g. EDA)
  – Proven predictive algorithms, mathematical models

• Known issues that impede implementation of this capability
  – OEM IP and IDM IP concerns about data for PHM
  – Commercialization and implementation paths for PHM
  – Factory architectures are customized
PHM Benefits & Effects

- Optimization scenarios can be written to maximize equipment availability, reduce costs, increase net WIP output...
  - PHM can increase consistency in decision-making – data driven
- Reduced *unscheduled repairs* accomplished by the PHM system constantly monitoring and reporting equipment health to the factory.
- *Usage-based or scheduled maintenance* may, with PHM, only be performed only when the equipment condition warrants it – may extend PM cycles.
- The PHM system identifies the root cause of imminent failure.
  - Reduction of diagnosis and repair time, reduces MTTR and labor cost
  - Only the failing parts are replaced, only at the end of their life, reducing parts cost
- The increased availability of equipment also enables higher factory output and/or reduced tool and labor count, reducing the cost per wafer
ISMI PPM Project in NGF Program

- Since 2007 ISMI has had a project called Predictive Preventive Maintenance (PPM).
- The project explores using equipment and factory data to monitor equipment health and predict failures before they occur.
  - In 2009-2010, the project is managing 2 pilots, each executed by a team made up of a key equipment supplier (tool expertise) plus an ISMI member company (factory data access) plus a University Researcher (advanced mathematics). The pilots will conclude in 2010.
- The project also explores integration of factory systems to optimize maintenance scheduling (FDC, Scheduled Maintenance, Condition Based Maintenance (CBM), Predictive Maintenance, WIP and Inventory Scheduling, as proposed for 2011+.
PPM Project Scope

• Through 2009, the PPM project scope was to define the PHM concept for the semiconductor industry via member company and supplier community consensus using:
  – Member company working group
  – Supplier forum
  – Workshops
  – Output was documentation – Vision, Implementation Guideline, White Paper, Data Requirements, Benefits Modeling

• From mid-2009 to end of 2010, the PPM project scope has been focused on performing proof of concept pilots using real data from production tools.
  – Output is pilot reports & benchmarking reports & some software & some IP.
Timeline of project history

- 2007: Vision Document
- 2008: Equipment Implementation Guideline, PPM Research White Paper
- 2009: PPM Implementation Guideline, PPM Data Requirements
- 2010: PPM Cost and Cycle Time, Pilot 1&2 Demo Reports
Pilot 1 Status

• **Data:**
  – 1 PECVD TEOS tool platform
  – 9.5 months of production data from MC fab
  – Maintenance records and metrology data (thickness per wafer, particles, quals (thickness and RI))

• Build model to predict time to failure for chamber performance shifts between observable and non-observable states (Hidden Markov, Markov, Match Matrix models)

• Build hardware hierarchical view of tool health dashboard for process chamber and associated hardware

• Expected completion is late 2010.
Pilot 2 Status

• Data:
  – 4 Plasma Etch tool platforms x 2 chambers = 8 chambers
  – 8 months of production data from fab >3TB
  – Maintenance records and metrology (etch rate, CD, particles) data
• Build model to predict time to failure (RUL=remaining useful life) for 3 costly, low frequency key maintenance events
  1. ESC failure
  2. Vacuum leak {injector seal, window seal, chamber iso valve}
  3. Wet Clean {chamber hardware element wear is root cause}
• Build hardware hierarchical view of tool health dashboard for process chamber and associated hardware
• Using existing tools and knowledge owned by University through ~10 years of consortium. Their tools and our data.
• A large variety of models considered for health and each prediction: PLS, SOM, etc
• Expected completion is late 2010.
PHM Project Look-Ahead - 2011

The PHM 2011 proposal includes:

– performing more pilots at the equipment level (more of same),
– developing and piloting the decision application, and
– developing common component models
PPM Resources from ISMI

• Information to be declassified
  – 4 publications with general guidelines
    • Vision 2007
    • Equipment Implementation 2008
    • Integrated Implementation 2009
    • Data Requirements 2009

• Public Workshops:
  – PPM Public Workshop in San Francisco ~ July 2008
  – PPM Workshop (class type) ISMI Symposium November 2010
Questions and Answers