Advanced Automation based on Standards

How other industries can profit from automation concepts in semiconductor manufacturing


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Agenda

- Advanced automation in semiconductor manufacturing – why?
- Standards & automation concept
- Potential for other industries
- The chance of working together
Advanced automation in semiconductor manufacturing

… what comes to mind

Sources: finfacts.ie, computer-oiger.de, xbitiabs.com, de.wikipedia.org, dailytech.com
Advanced automation in semiconductor manufacturing
Economic leverage of semiconductor value chain

- high growth trend (9% over the last 20 years)
- high volatility

Source: DECISION/ESIA/IMF/WSTS, 2011
Advanced automation in semiconductor manufacturing

The productivity gap

25% - 30% / year improvement

Present

Feature size
~12%-14%

Wafer size
~8%

Yield improvement
~5%

Other productivity - Equipment, etc.
~3%

Historical curve
(Moore's law)
<2%

Equipment productivity
~12%-14%

Equipment, etc.
~12%-14%

Ln $ / function

Time

~7%-10%

~4%

<2%

25% - 30% / year improvement

~2%

<1%

~4%

~12%-14%
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Standards

Some history

Most famous standard: "SECS/GEM"

- 1978: Hewlett-Packard proposed that standards be established for communications among semiconductor manufacturing equipment.
- 1980/1982: SEMI published the SECS-1/SECS-II standards
- 1992: GEM standard published
- Continued: HSMS, GEM300, EDA/Interface A, …

“Semiconductor Equipment and Materials International”
- Founded in 1970
- Tradeshows (SEMICON), conferences, networking
- Industry standards (> 800 standards and safety guidelines)
- USA - Japan - Europa - Taiwan - Korea - China
- www.semi.org

GEM
- Defines equipment behavior

SECS II
- Data items, messages

SECS 1
- Electrics/mechanics, transactions
Standards

SEMI E30 (GEM) - Example behavior model

SEMI E72 Equipment Footprint Dimensions:
- Minimum 76 mm (3.0 in.)
- Footprint includes all equipment locations (including the tool)

SEMI S8 - Safety Guidelines for Ergonomics:
- Hand clearance
- Minimum 890 mm (35 in.)

SEMI E95 - Specification for Human Interface:
- Title Panel
- Information Panel
- Navigation Panel
- Command Panel
- Utilities supply
- Access door swing-out
- E15.1-compliant load ports and carrier buffers
- Front user interface
- Possible wall locations, if any (see SEMI 15.1)

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Overview of 300 mm SEMI Standards

Carriers:
- E1.9 (Cassette)
- E23 (Cassette Transfer Parallel I/O)
- E47.1 (FOUP)
- E103 (SWIT) → withdrawn
- E119 (FOBIT)
- M31 (FOSB)

Frames (BEOL):
- G74 (Tape Frame)
- G87 (Plastic Tape Frame)
- G77 (Wafer Frame Cassette)
- G82 (Load Port for Frame Cassette)

E110 (Operator Interface)
E22.1 (Cluster-Tool End Effector)
E21.1 (Cluster-Tool Module Interface)

E70 (Tool Accommodation Process)
E72 (Equipment Footprint, Height, Weight)
E76 (Process Equipment Points of Connection to Facility Services)

E117 (Reticle Load Port)
E152 (EUV Pod)

E127 (Integrated Metrology (IM)):
- E141 (Ellipsometer equipment)

Automated Material Handling System (AMHS):
- E82 (Interbay/Intrabay AMHS SEM (IBSEM))
- E88 (Stocker SEM)
- E153 AMHS SEM Specification

Wafers:
- M1, M57, M62

E144 (RF Air Interface)
E57 (Kinematic Coupling)
E15.1 (Load Port)
S28 (Safety of Robots & Load Ports)

E84 (Carrier Hand off Parallel I/O)
E101 (EFEM)
E62 (FIMS)

E83 (PGV Docking Flange)
E84 (Carrier Hand off Parallel I/O)
E62 (FIMS)

E153 (AMHS SEM Specification)

Interfaces: Equipment – Facilities:
- E97 Facility Package Integration, Monitoring & Control
- F107 Process Equipment Adapter Plates

Equipment-/Process-specific standards:
- E117 (Reticle Load Port)
- E152 (EUV Pod)

Integrated Metrology (IM):
- E127 (Integrated measurement module communication)
- E141 (Ellipsometer equipment)

Equipment-/Process-specific standards:
- E97 Facility Package Integration, Monitoring & Control
- F107 Process Equipment Adapter Plates

Equipment-/Process-specific standards:
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Automation concept

Remote access
- Remote diagnostics
- Remote debugging/fix
- Remote sensing
- Spare parts manag.

Firewall

EE Access Control

Interface C
- Programmatic/remote access to equipment data allowing secure data exchange between support companies and customers

EE Data Collection And Storage

Global EE Data

EE Applications
- APC Application
- OEE Application
- other Application

Interface A
- High-speed port for communication between in-factory data gathering software applications and the factory equipment for purposes of data acquisition

SECS/ GEM Interface
- Controlling/Monitoring of manufacturing equipment by factory software

Factory Network

Integrated Metrology

Control

Data

Interface B
- Data sharing between software applications (e.g. APC applications) and MES

MES
- Equipment Control
- WIP Tracking
- Factory Scheduling

Equipment Engineering Network

EE (Equipment Engineering System)

Equipment Engineering System (EES)

Internet
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Potential for other Industries

Categories of SEMI standards

- 3D-IC (3D)
- Equipment Automation Hardware (E)
- Equipment Automation Software (E)
- Facilities (F)
- Flat Panel Display (D)
- Gases (C)
- HB-LED (HB)
- Materials (M)
- MEMS (MS)
- Microlithography (P)
- Packaging (G)
- Photovoltaic (PV)
- Process Chemicals (C)
- Safety Guidelines (S)
- Silicon Materials & Process Control (MF)
- Traceability (T)

For other industries:
“Put everything to the test. Hold on to what is good.”
(The Bible)
Potential for other Industries
„Big data“ and Advanced Process Control

- Objective: Ensure high quality productivity
- Fundamental goals of APC
  - to obtain measures for process control closer to the process
  - to automate control actions
- Typical APC methods (SEMI E133):
  - SPC, FDC, FP, RtR, VM, PdM
- Basis for APC:
  - Metrology data
  - Data from equipment & processes
  - Logistics data
Potential for other Industries

Interaction of APC elements

- Feed forward
- Process data
- Run-to-run control
- Download of parameters
- Fault detection and classification (FDC)

Process n-1 → Metrology → Sensors → Metrology → Process n+1

Process n

-process data

Download of parameters

Fault detection and classification (FDC)

go / no go
Potential for other Industries
Examples for productivity enhancement by APC

Real-time control of plasma processes by integrated OES
Potential for other Industries
Examples for productivity enhancement by APC

Prediction of maintenance events by PdM

- Ion source
- New
- Used
- Broken
Potential for other Industries
Examples for productivity enhancement by APC

From an ENIAC project on productivity enhancement - IMPROVE

- 9 European Semiconductor manufacturing sites
- Requirement: Integration by utilizing standards!
- Generic framework based on SEMI standards
- Increase of equipment availability in the range of 1%-5%
- Equipment Health Factor (EHF) and the capability to predict equipment failure improve the cycle time by reducing unexpected failure.
- Knowledge of equipment behavior from the modelling work provided a better diagnosis capability and therefore an additional improvement of the equipment availability in the range of 1%.
Potential for other Industries
Lessons learned from APC in semiconductor manufacturing

1. Know your process
2. Make use of standards
3. Use data you already have
4. Take care of data quality
5. Keep things simple and inexpensive
6. Go for low-hanging fruits
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The chance of working together
Results from a study amongst German IC manufacturers

Main challenge:
- How to enhance productivity in a "More than Moore" production environment!
The chance of working together
Results from a study amongst German IC manufacturers
The chance of working together
Starting points towards “Industry 4.0”

First Industrial Revolution
through the introduction of mechanical production facilities with the help of water and steam power

Second Industrial Revolution
through the introduction of a division of labor and mass production with the help of electrical energy

Third Industrial Revolution
through the use of electronic and IT systems that further automate production

Fourth Industrial Revolution
through the use of cyber-physical systems

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Source: DFKI (2011), siemens.com
The chance of working together
Starting points towards “Industry 4.0”

- Semiconductor Industry: APC, logistic simulation
- Semiconductor Industry: APC, manufacturing optimization
- Semiconductor Industry: Logistic optimization
- Semiconductor Industry: Know-how management
- Resilient Fab
- Self-organizing, adaptive Logistics
- Technology data Marketplace
- Sustainability by Up-Cycling
- Intelligent Maintenance
- Smart Factory Architecture
- Networked Production
- Application Scenarios

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The chance of working together
A semiconductor view on “Industry 4.0”

In Semiconductor FrontEnd factories elements of a „Smart Factory“ are already realized.

manufacturing information in real time

paperless manufacturing

products uniquely identified & located

collaborative human-machine interaction

Dr. T. Kaufmann, Infineon
11th Innovationsforum for automation, 2014, Dresden
The chance of working together

Summary

Achievements in semiconductor manufacturing

- Standards and automation concepts evolved over more than 35 years
- Proven as basis for improved productivity

Potential for other industries

- “Hold on to what is good” – knowledge and definitions
- Well experienced R&D and suppliers available

The chance of working together

- From APC-enhanced equipment to cyber-physical systems
- Semiconductor manufacturing: strategic partnerships with other industries, spearheading with products and “manufacturing science”
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Thanks
for your attention!