IMPROVE – A joint European effort to boost efficiency in semiconductor manufacturing

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Agenda

- Manufacturing Science as “Competitiveness Enabler”
- The IMPROVE Project at a Glance
- The R&D Topics and Support Activities of IMPROVE
- Summary & Outlook
Manufacturing Science as “Competitiveness Enabler”
The „European“ Context

“Semiconductors are critical to European industry and welfare and must be prioritized to keep the European industry competitive.”

Yet…

“In spite of enormous efforts, the European semiconductor base is shrinking and more and more companies are choosing to outsource device manufacturing to other regions, mainly to Asia.”

SEMI white paper, 2008
Manufacturing Science as “Competitiveness Enabler”
The „European” Context

- To maintain and improve its competitiveness the European SC manufacturing must rely on advanced solutions in **Manufacturing Science**
- The development of these solutions
  - can only be done through **cooperation** between industrialists, SMEs, academia and institutes
  - must take advantage of the existing **technology clusters** around the SC manufacturers
  - requires the **support** of Europe and National PA's

**ENIAC first project call, Sub Programme 8**
**Target Activity 1: Advanced Line Operation (Manufacturing Science)**

**Objective:** To allow European device makers to increase the productivity and sustainability of the most advanced CMOS and derivative technologies semiconductor fabs
Manufacturing Science as “Competitiveness Enabler”
… for “More Moore” or “More than Moore”?

Two Technical Challenges for the Future…

Scaling down CMOS (More Moore)
- Down to the 22 nm node and below
- Manufacture devices in high volumes at reduced cost per die

Managing high-mix and heterogeneity (More than Moore)
- Increase of non productive time (gating metrology, recipe qualifications, wait and down time)
- Stagnating equipment reliability, availability and utilization
- Increasing variations by increased number of equipment per process step (and vice-versa)

... one Objective
To enable the production of high-quality nanoscale devices at reasonable cost
Manufacturing Science as “Competitiveness Enabler“
Pave the way from “reactive” to “predictive” manufacturing

- Solutions to **Process Control** issues, e.g.
  - Virtual metrology
  - Dynamic control plan
  - Data mining and data reduction
  - Data / time synchronization

- Improving **Equipment Efficiency**, e.g.
  - Predictive Maintenance
  - Remote diagnostics
  - Lots scheduling
  - Resources planning
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The IMPROVE Project at a Glance (1/3)

Implementing Manufacturing science solutions to increase equipment productivity and fab performance

Main objective: IMPROVE European Fab's Competitiveness, by

- improving processes reproducibility and quality
- improving the effectiveness of production equipment
- shortening cycles time and improve learning curve

Three Manufacturing Science R&D Topics

- Virtual Metrology
- Predictive Maintenance
- Dynamic Control Plan

Two Support Activities

- Survey, Specifications and Architectures
- Equipment Forum
The IMPROVE Project at a Glance (2/3)

Key figures
- 3600 men-months over 3.5 years
- 100 full-time researchers
- January 2009 to June 2012
- 35 partners over 6 countries

Academia/Institutes: 53%
Solution Providers: 26%
IC Manufacturers: 21%
The IMPROVE Project at a Glance (3/3)

The IMPROVE Partners

- 6 major European IC manufacturers
- 2 Institutes
- 12 Academic labs
- 10 Solution providers
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- The IMPROVE Project at a Glance
- The R&D Topics and Support Activities of IMPROVE
  - Fabs’ status & requirements – What are the needs?
  - Architecture & specifications to keep solutions re-usable
  - Virtual Metrology
  - Predictive Maintenance
  - Virtual Equipment
  - RoI Calculator
  - Adaptive Control Plan
  - Guidelines for long-term applicability
  - The Equipment Forum
- Summary & Outlook
R&D Topics and Support Activities of IMPROVE
Fabs’ status & requirements – What are the needs?

Technical 1-2 day workshops at each manufacturing site

- Discussion about more than 60 questions
- Status of…
  - Data Infrastructure, Control Infrastructure
  - Manufacturing and Logistics
- Requirements for…
  - Virtual Metrology, Predictive Maintenance
  - Adaptive Control Planning
  - Sensor Networks
  - Master Framework
  - Return on Investment
R&D Topics and Support Activities of IMPROVE
Architecture & specifications to keep solutions re-usable

Based on the survey results and user requirements, common architectures and specifications were developed and transferred to the technical work packages.

Example: Fab-wide architecture
- Architecture comprises a "top-level" view...
- ...and also a clear specification of functionality and interfaces (UML).
R&D Topics and Support Activities of IMPROVE
Virtual Metrology

Objective

- Development of virtual metrology algorithms to **predict physical and electrical characteristics** of the wafers from the process tools parameters and advanced sensor data

Expected benefits

- Improved process understanding and process control
- Reduction of cycle time by avoidance of measurement steps
- Increased productivity of equipment and people

Place of execution of VM in a process flow
Example: Trench-etch process

- Predict etched-depth in a trench-etch process, two depths
- Variety of statistical modeling techniques assessed
- Data quality monitoring for tracking of process and potential VM adjustments
- Consideration of critical integration aspects (automation, interpretation, speed)

Prediction of etch depth by stepwise linear regression
R&D Topics and Support Activities of IMPROVE
Predictive Maintenance

Objectives
- Development of predictive maintenance techniques to **improve equipment reliability** whilst optimizing the maintenance frequency and increasing uptime.

Expected benefits
- Improved equipment control
- Reduction of down time by reduction of unscheduled tool failures
- “Equipment Health Factor” for improved control planning (WP4)

PdM workflow utilizing Bayesian Networks

- Pre-processing: feature extraction, data discretization
- Model creation and parameter learning
- Prediction of faults, component health
R&D Topics and Support Activities of IMPROVE
Predictive Maintenance

Example: Filament breakdown
- Modeling of filament breakdown in an ion implanter source
- Investigation of predicting parameters
- Creation of Bayesian Networks model
- Investigation of soft discretization method for improved model performance
- Comparison of modeling methods in collaboration with partners
- Model still works with noisy data from high mix production environment
Objectives

- Setup of a “virtual equipment” as benchmark tool for virtual metrology and predictive maintenance algorithms
- Utilization of history fab data and simulation of relevant equipment and process behaviour

Expected benefits

- Evaluate selected algorithms using production data sets including the application of typical faults, process drifts, mix and match scenarios, noise effects, etc.
R&D Topics and Support Activities of IMPROVE
Virtual Equipment

Achievements

- Capability to compare multiple VM / PdM models
- Generation of test data sets for common and uncommon situations
- Integration of statistical and physical simulation
- Utilization of “real” fab data sets
- Evaluation of performance and sensitivity of VM / PdM algorithms
- Input data preparation for the VM / PdM algorithms

User interface of the virtual equipment
R&D Topics and Support Activities of IMPROVE
RoI Calculator

Objectives

- Modeling of benefits, costs and damages for calculating investment assessment figures (payback period, RoI, NPV)

Expected benefits

- Economic effects of VM/PdM identified
- Discussion with IMPROVE partners: FMEA and RoI workshops
R&D Topics and Support Activities of IMPROVE

RoI Calculator

Achievements

- RoI Calculator developed, based on:
  - Potential benefits from identified economic effects
  - Potential financial damages from FMEA results
  - Publicly available data from SEMATECH (default values)
  - Identification and estimation of costs with IDM
  - Discussion with IDMs

Economic figures: Payback Period PdM
R&D Topics and Support Activities of IMPROVE
Adaptive Control Plan

Objectives

- Development of a comprehensive approach that reduces process excursions and guarantees an optimal use of various control techniques (metrology, sensors, etc).

Expected benefits

- Yield improvement through incremental set-up of a fab wide comprehensive control plan
- Cycle time and learning cycle improvement through optimal use of various “measurement” resources.
R&D Topics and Support Activities of IMPROVE
Adaptive Control Plan

Example: Predictive sampling strategy for defect inspections

- Implementation of a Wafer@Risk indicator for risk assessment of manufacturing equipment
- Reduction of risk (W@R) by up to 85%
- Reduction of measurement steps by up to 53%
R&D Topics and Support Activities of IMPROVE
Guidelines for long-term applicability

Guidelines cover ...

- Findings from the survey, specification and architecture phase
- Results and lessons learnt from the technical work packages and implementation.

Inputs
- Experiences
- Best practices
- Technical solutions
- Status at partner’s fabs
- State-of-the-art
- Requirements
- Specifications
- Literature
- Other relevant data gathered within IMPROVE

Virtual Metrology
Predictive Maintenance
Adaptive Control Plan
Sensor Networks
Master Framework
R&D Topics and Support Activities of IMPROVE
The Equipment Forum

Objective: **Relay the results and knowledge gained in the IMPROVE project to equipment companies.** As a mid-term effect, it is expected that this will lead to enhanced or novel equipment that better suits the needs and requirements of the IDMs and IC manufacturers gathered in IMPROVE.

- Foster contacts between IC manufacturers and equipment suppliers
- Collection of specifications and requirements for future equipment
- Database for equipment specifications and equipment quality requirements
Discussion

Build a „Who’s Who“ in semiconductors – including SW companies!

Variability of equipment is the first critical point - especially if mix increases and volume increases --> cost increase!

How can we build up a common understanding and "common voice"

Get data back from the fab is important for equipment supplier for further development

Manufacturing science as new science?

Get data out of the tool with context, definition, quality

How can (backend) equipment manufacturers get support from EC

IMPROVE: get data out of the tool with context, definition, quality

Next challenge = Get 3D into manufacturing (convergence with FE)

Role of KET pilot lines? ENI2?

Spill-over from 450 mm equipment to 300/200 mm

Traditional growth of Front-End eq. may end soon (down to 12 nm), then Backend will get the new focus. Equipment landscape will change – IMPROVE will not change much.

Spill-over of manufacturing science solutions to other industries

Roadmapping
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Summary

- Thorough survey, architecture and specification phase inevitable to gain common technical ground
  - Collection of user requirements
  - Transfer of requirements into architectures
  - Avoidance of island-solutions and duplicate efforts
  - Improved communication

- Combination of
  - In-depth R&D (VM, PdM, ACP) and
  - Integration of developed solutions in the manufacturing environment

- Equipment Forum as bridge beyond IMPROVE
Outlook

The IMPROVE project funded by ENIAC to keep manufacturing in Europe – additional activities will follow
- Significant step into R&D of manufacturing science
- Collaboration beyond fab boundaries
- Building block to enhance efficiency in semiconductor manufacturing

Further increase of collaboration and common manufacturing aspects amongst
- Leading edge manufacturers and fast followers
- More-than Moore manufacturing
- Academia & research institutes

Enhance the collaboration in the full supply chain of
- Materials
- Equipment
- Technology
- Device manufacturing

Improve R&D towards “Intelligent Manufacturing” on a global scale for further advances in micro and nano electronics
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More information: www.eniac-improve.eu

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