AMD

Design for Controllability: Immersion Lithography

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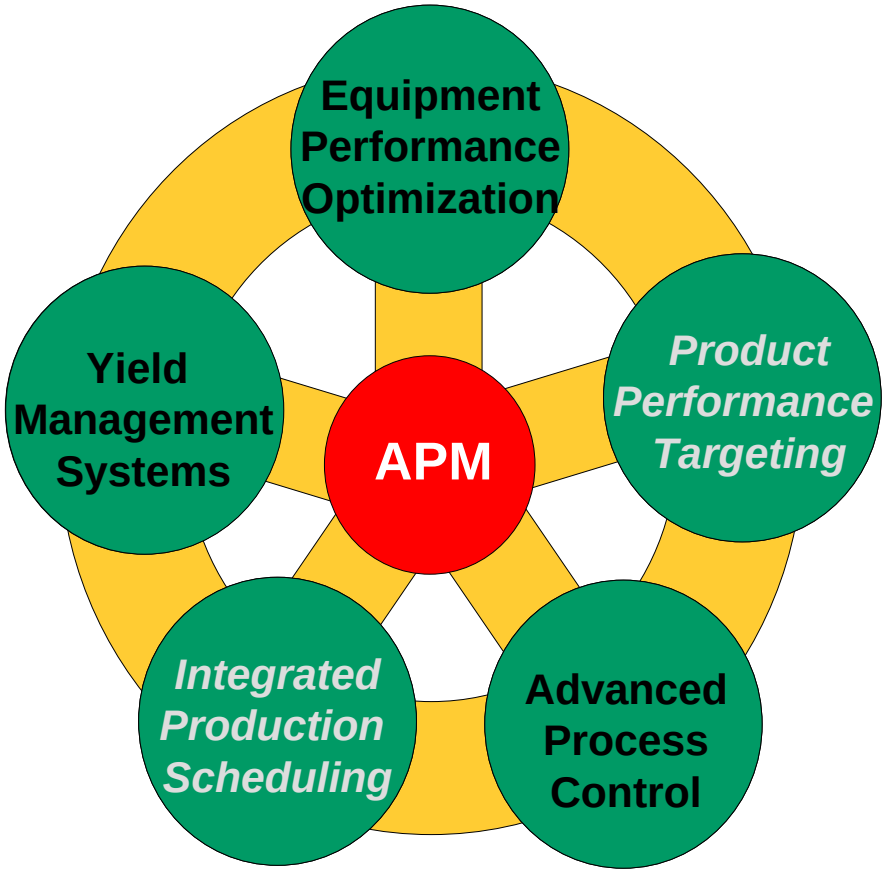
Introduction
Maximizing Manufacturing Efficiency



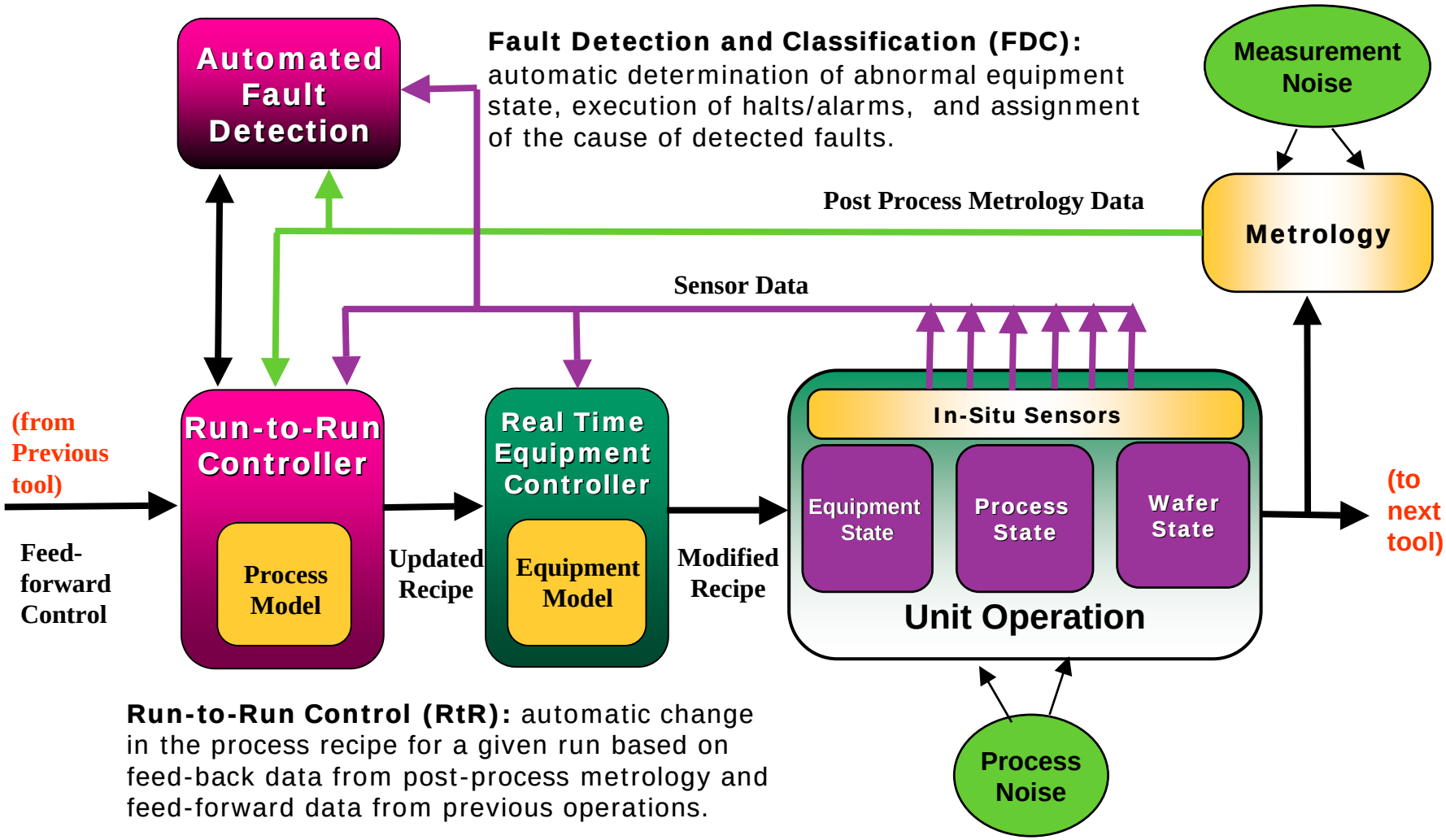
What is Automated Precision Manufacturing (APM)?

- Integrated suite of more than 200 AMD patented or patent-pending technologies
- Foundation of AMD's manufacturing strength and competitiveness
- Allows aggressive participation in stringent product performance markets
- Enabler for world-class operational metrics

- ***Provides significant advantages in:***
  - *Manufacturing automation and control*
  - *Minimization of defective die*
  - *Continuous, customer-centric product improvements*

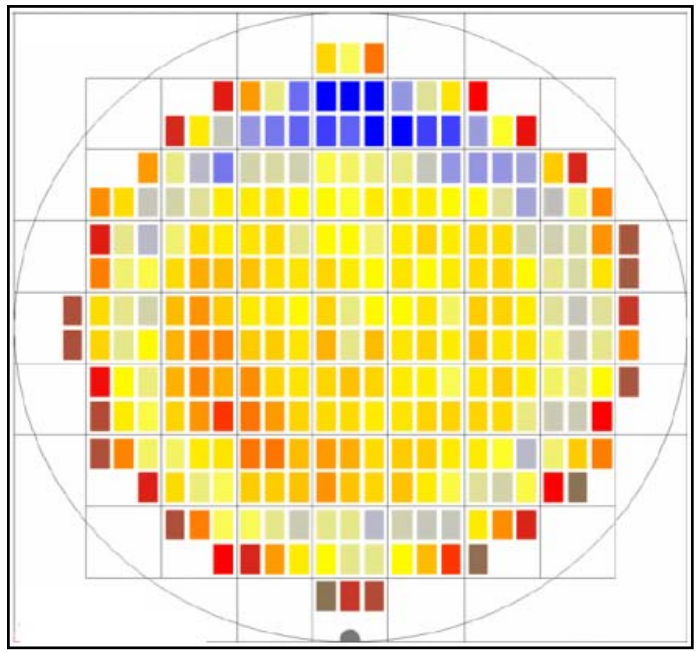
Advanced Process Control

APC incorporates RtRPC and FDC



Wafer Level Control

- Lot–to–Lot variation is generally solved today
- WtW and wafer uniformity issues are becoming dominant
- Example speed map:



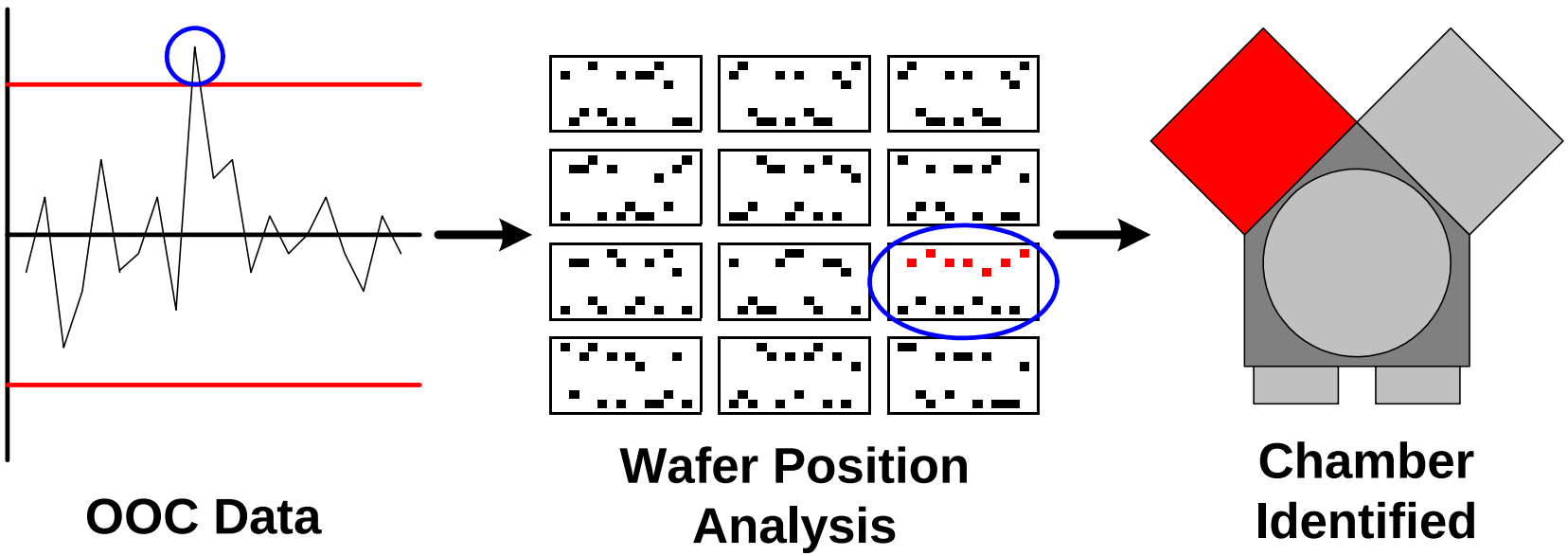
Relationships:

- Speed ~ $1/L_{eff}$
- L_{eff} = f(CD,other effects)
- CD $\Rightarrow$ L_{eff} $\Rightarrow$ Speed

Use WtW/FtF (within wafer) control capabilities for next level of product improvement!

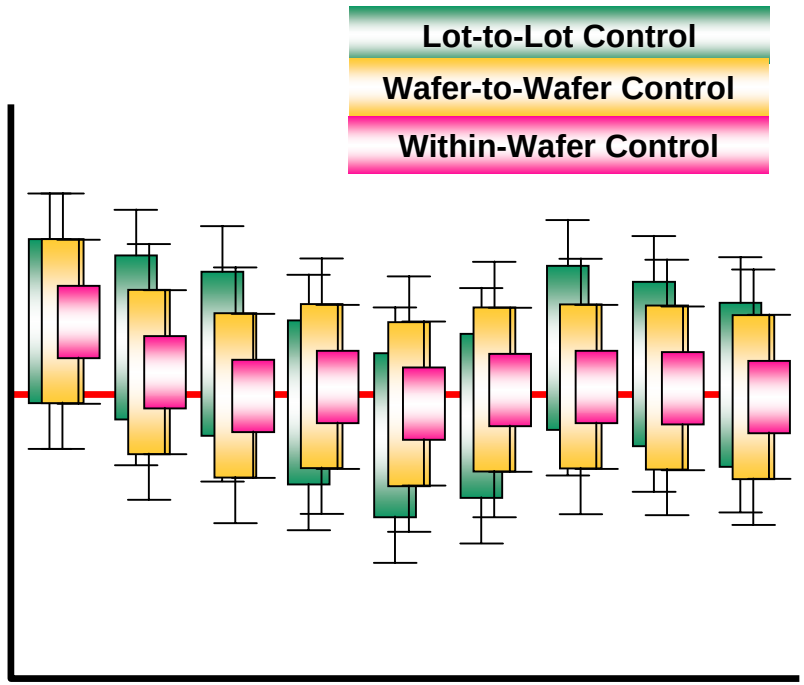
Yield Management at the Wafer Level

- Wafer level tracking allows for faster diagnosis of yield related issues
  - OOC data can be linked to wafer positions
  - Wafer positions can be correlated to processing tools and chambers
  - Chambers with issues can be quickly identified and addressed.

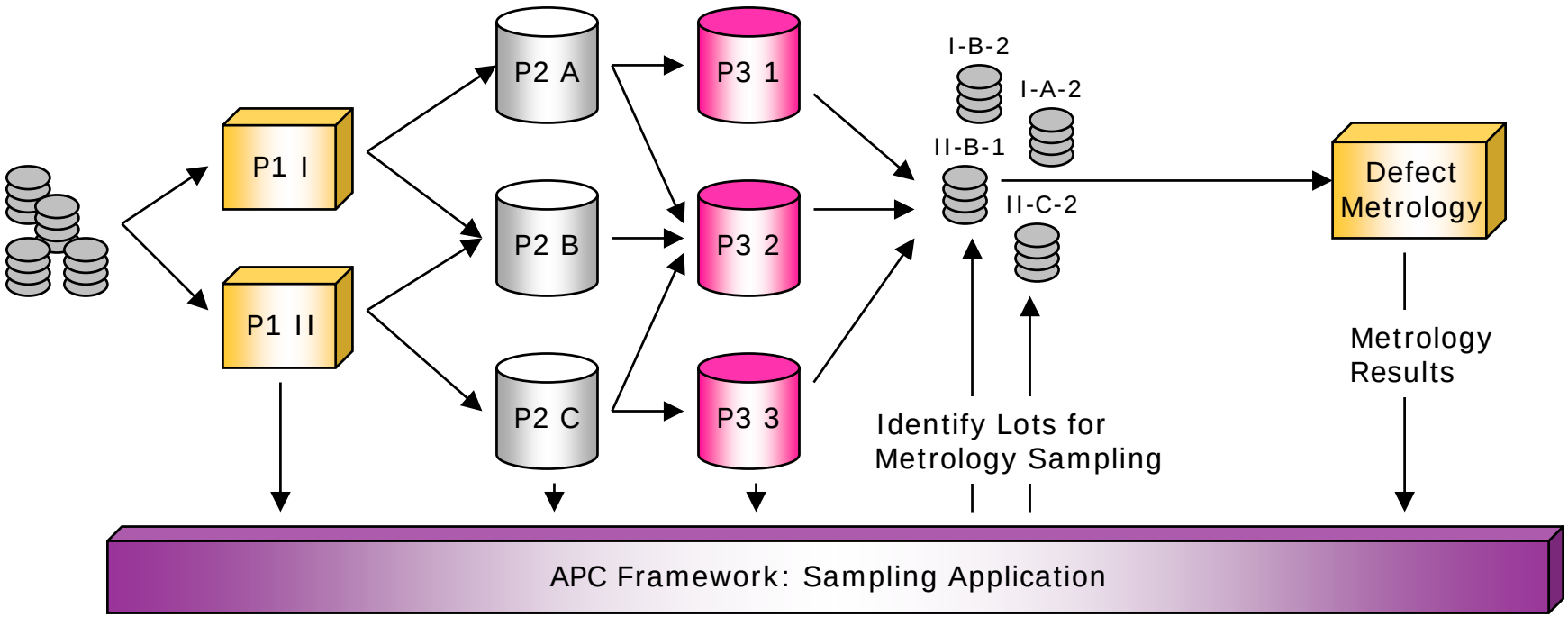


300mm Advanced Process Control
Wafer Level Control and Dynamic Sampling

- With the increased cost and complexity comes the imperative need to ensure each wafer is processed to target
  - Wafer-level becomes critical to eliminating sources of variation.
- Dynamic Sampling enables wafer level control
  - Allows for collection of more information from the same amount of data
  - Reduces the need for metrology capital



Fab-Wide Control Technology
Dynamic Defect Sampling



- The Dynamic Defect Sampling application identifies tools that need increased sampling due to elevated defectivity.
- It will also work with the dispatching system to reduce the uncertainty in which process tool is responsible for the increased defectivity.

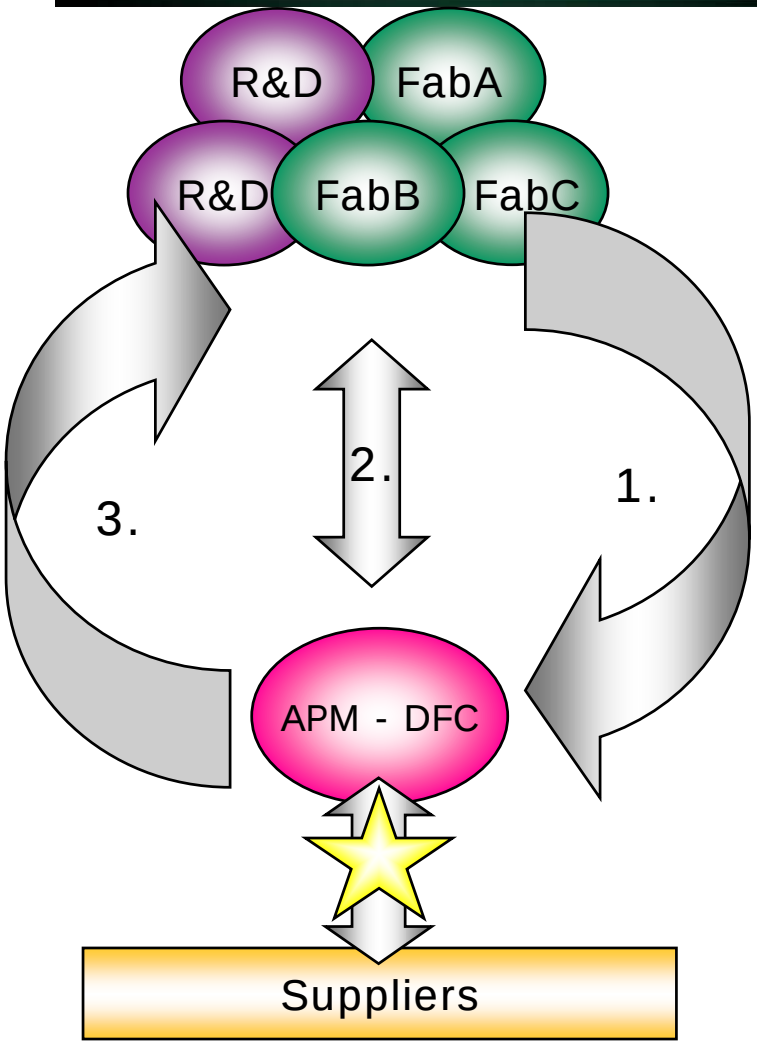
Design for Controllability (DFC)

- Concept: Proactively identify control challenges and opportunities in order to engineer control solutions earlier in the development cycle of new tools, processes and product technologies.
- Purpose: Better anticipate manufacturing challenges and develop solutions and methods in collaboration with suppliers early enough to deliver complete control solutions to the manufacturing organizations.
- Control development to date has been after tools are received and installed in the fabs.
  - This type of development is limited in capability and scope by the tool and tool data availability.
  - Tool upgrades and tool software changes are much harder to justify after the initial tool purchase, limiting the ability to augment tool capabilities.
  - Identifying process control solutions and data access needs during the tool development phase is more efficient

DFC Process

1. Define the Challenge
   - Work with suppliers in conjunction with the process/technology development organizations to identify anticipated manufacturing challenges.
   - Identify the most critical APM (control, efficiency, & yield/performance) objectives.
2. Characterization
   - Develop a comprehensive understanding of the challenge through process modeling and measurement technologies.
   - Identify specific tool sensors and tool data requirements including but not limited to data frequency, resolution, data type, etc. to support the best, manufacturable control methods to be transferred to manufacturing.
3. Enhancement
   - Develop the necessary control capabilities to address the manufacturing challenges, in terms of tool, process and control capabilities.
   - Provide improved transfer packages that accelerates time to yield and control improvements during process introduction and ramp.

Organizational Flow



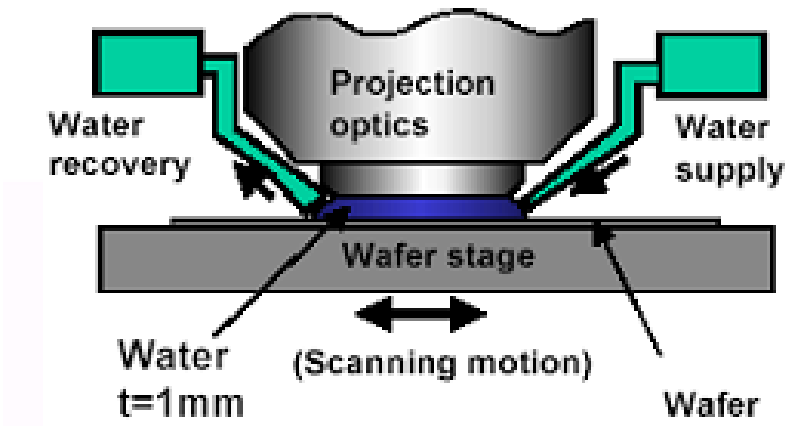
1. Define the Challenge:
   - Identify key objectives, roadmaps
   - Education (needs and opportunities)
   - ID most critical needs, establish program

2. Characterization:
   - Enhance DOE's
   - Gather data
   - Modeling/measurement technology
   - Define solution criteria ★
     - tool data
     - tool sensors
   - Identify most manufacturable options

3. Enhancements:
   - Develop enhancements
   - Implement solutions
   - Augment transfer packages

What is Immersion Lithography?

- Definition: The introduction of a fluid (in this case, H_2O) between the lens and the wafer to reduce or eliminate refraction at the liquid/lens and liquid/wafer interfaces reducing the effective wavelength of the light source.



One way to increase the numerical aperture and refractive index is to employ immersion imaging.

- This technology has subsystems for which factory-integrated, automated control systems have yet to be developed.

Lithography Overview

- Numerical Aperture (NA) is defined as the ability to collect light diffracted from a mask/reticle. The larger the NA the more light is collected. NA is limited by the diameter of the lens.
- Resolution is the smallest feature that can be printed and is a function of NA. As NA increases and wavelengths decrease the resolution improves allowing us to print smaller features.

$$\text{resolution} = k_1 \frac{\lambda}{NA} \qquad \lambda_{eff} = \frac{\lambda}{index}$$

- The index of refraction of H_2O is 1.43 at 193nm
- Using H_2O as the immersion liquid results in an effective wavelength of approximately 135nm
- This is where immersion becomes more attractive than 157nm (dry) lithography

DFC Opportunity: Immersion Lithography

- Immersion Lithography is among the new manufacturing techniques being introduced for the 45nm technology node.
- This new alternative to optical lithography allows suppliers to push the limits of existing optical platforms and track systems without having to make expensive and less proven changes to photoresist systems, mask systems, light sources and optical components.
- Immersion reportedly requires little change to the existing lithography infrastructure, but those that are required will give rise to challenging process/ tool control and fault detection issues in the realm of APM.

More About Immersion Lithography

- Benefits
  - Extends current 193nm optical lithography beyond 65nm
  - Increases resolution and depth of focus required to support sub-65nm technology nodes
  - Relies on the same masks, resist and lens concepts of existing dry 193nm systems
- Immersion Sub-systems
  - Liquid Handling Systems
  - Optical Platform
  - Immersion Materials/ Sources
  - Liquid Interfaces

Key to Success

One of the keys to the success of advanced manufacturing for sub 65-nm technology is the delivery of factory-integrated, automated control systems at first-tool install to speed yield and control improvements during process introduction and ramp…

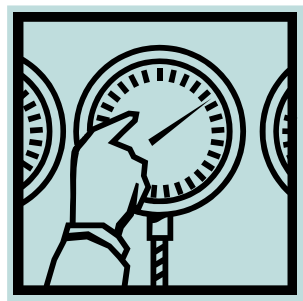
Defining the Challenge

- This initial stage of development seeks to fully identify the scope and nature of a given manufacturing challenge.
  - The highest priority immersion control challenges have been defined by our technology development organizations in conjunction with ISMT immersion lithography programs
- By working closely with our Strategic Lithography Team we are in the process of identifying the following:
  - ★Requirements for tool sensors, data availability, data types, frequency, resolution, etc. necessary for developing control capabilities to address immersion manufacturing challenges.
  - Sources of variability related specifically to the imaging step that influences the ability to meet process window requirements.
  - Potential fault conditions that may affect yield, product and/ or tool performance.
  - Dependencies on incoming substrate properties that can be used for the development of feedforward, closed-loop control.
  - Defects caused by the immersion subsystems that need to be controlled.

DFC Opportunity #1

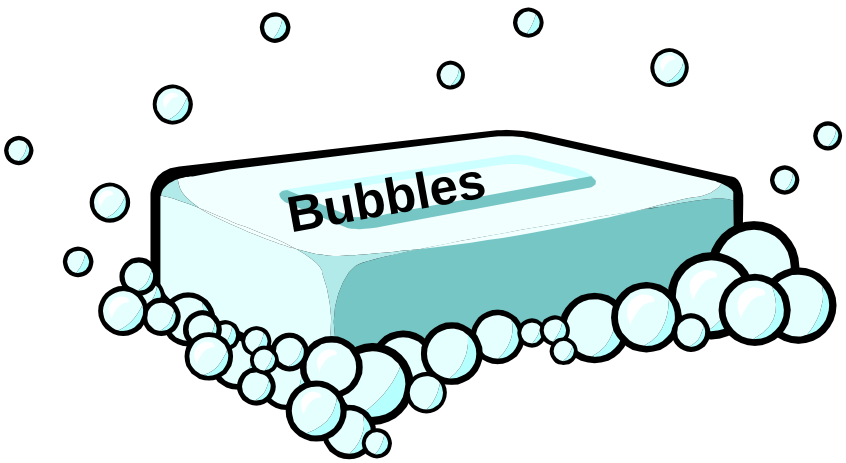
If we know…

water flow conditions



pressure

wafer stage velocity

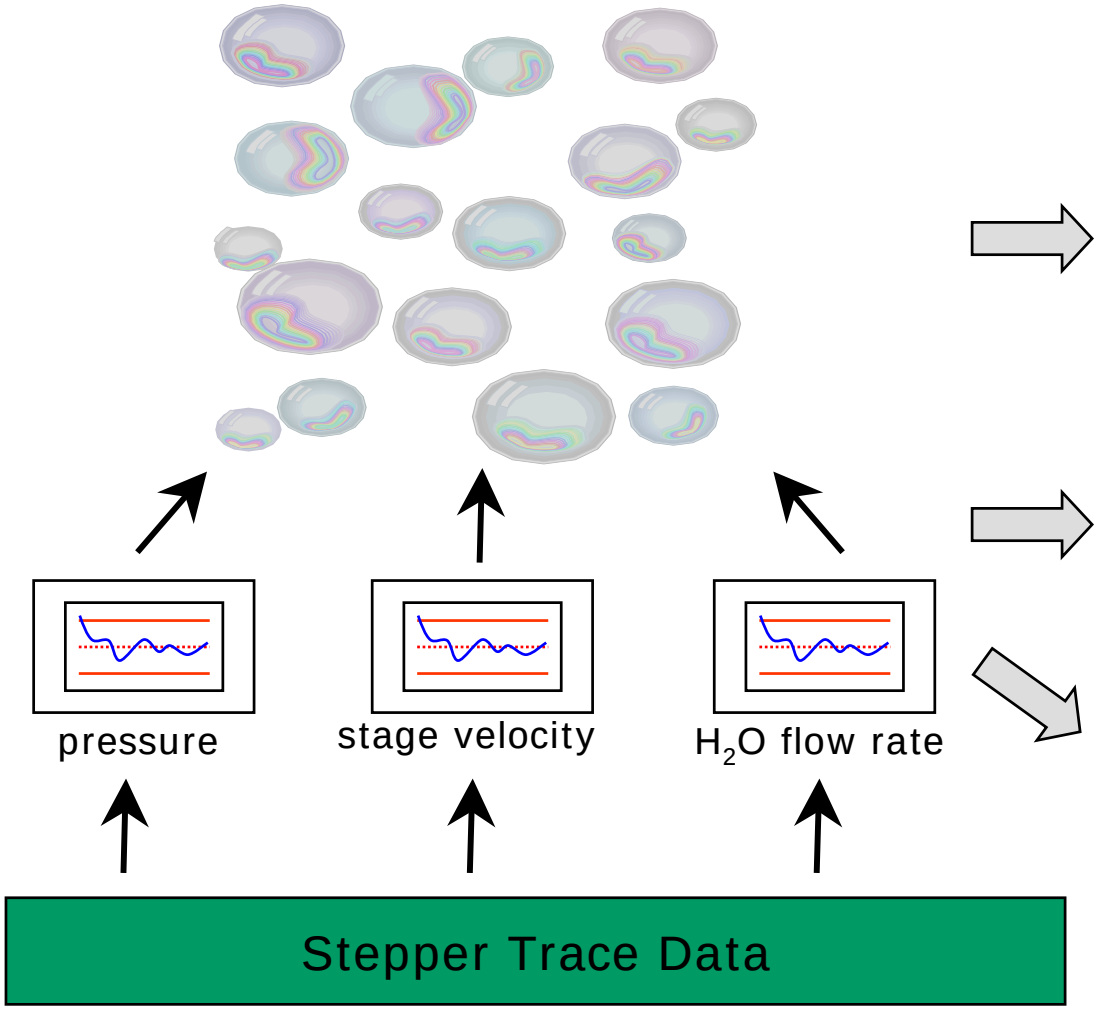


we can predict and prevent…

Immersion Challenge

- Bubble Defects
  - The most potentially serious issue facing immersion lithography
  - Sources of Bubbles[2]
    - Dissolved gases precipitate out of the solution
    - Turbulent flow conditions during the liquid fill
    - Reactions between the immersion liquid and the resist
    - Wafer stage velocity
    - Other process steps related to the coat and develop steps
- Impact of Bubbles on Imaging:
  - Extent of the effect depends on bubble size, location & density
    - Large micron-scale bubbles behave like particles blocking the image[1]
    - Smaller, nanometer-scale bubbles can degrade contrast and blur the edges of features [1]
    - The effects of bubbles on yield still needs to be investigated, however, the ability to detect bubbles and classify them may aid process engineers in proactively resolving issues with the immersion sub-systems, ie. temperature, flow rate, vibrations.

Bubble and Fault Detection System



Yield Management System

- Based on the FDC Charts adjust the dynamic sampling program to allow for the collection of more or less information (ie. more sites/wafer, or /flash)
- Work with process and technology integration to model correlation between critical immersion variables and bubble formation

Prediction

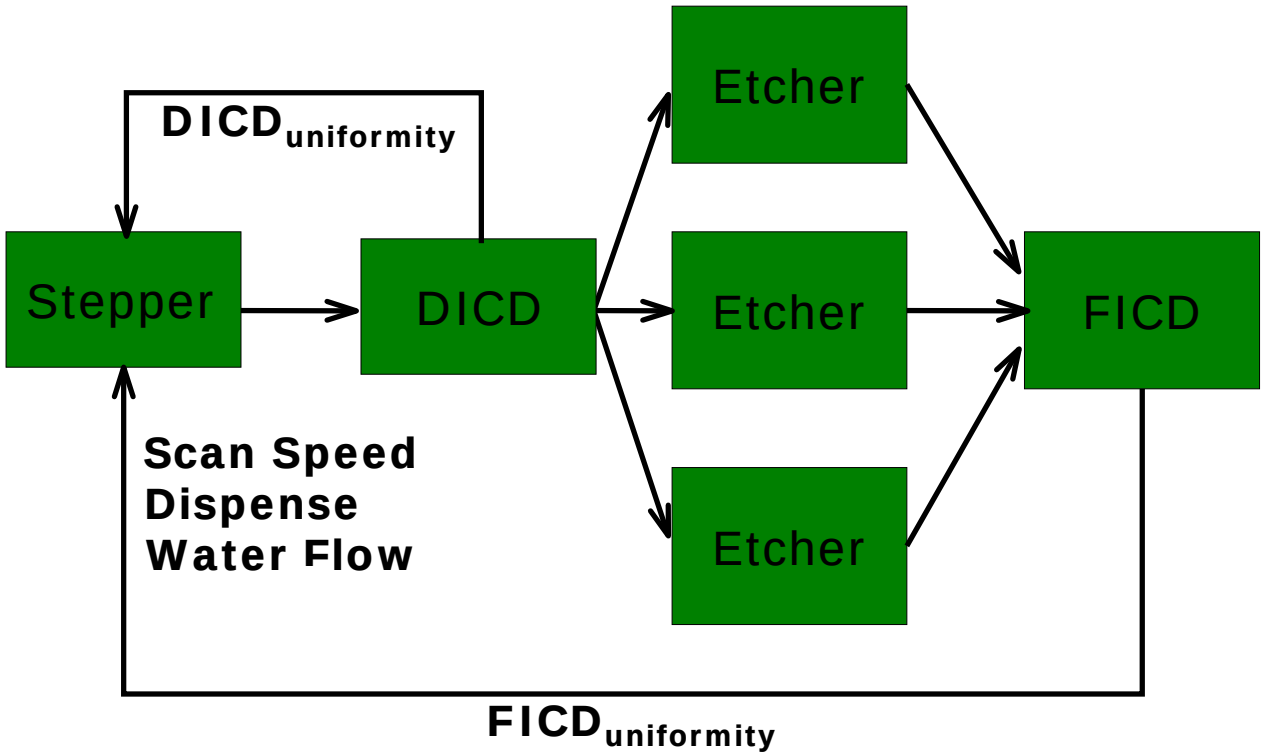
- Calculate probability of bubble defects as a function of critical immersion variables

Fault Detection Charts (FDC)

- detects trends and faults that may indicate the possible formation of bubbles
- Alarm within or after run
- Stop next run if necessary

DFC Opportunity #2

- Scan speed and dispense/water flow thru wafer to control within die uniformity.



To build a control model correlations need to be derived for the following variables:

Output	Process Knob
$DICD_{uniformity}$	scan speed
	dispense velocity
	water flow rate
$FICD_{uniformity}$	$DICD_{uniformity}$

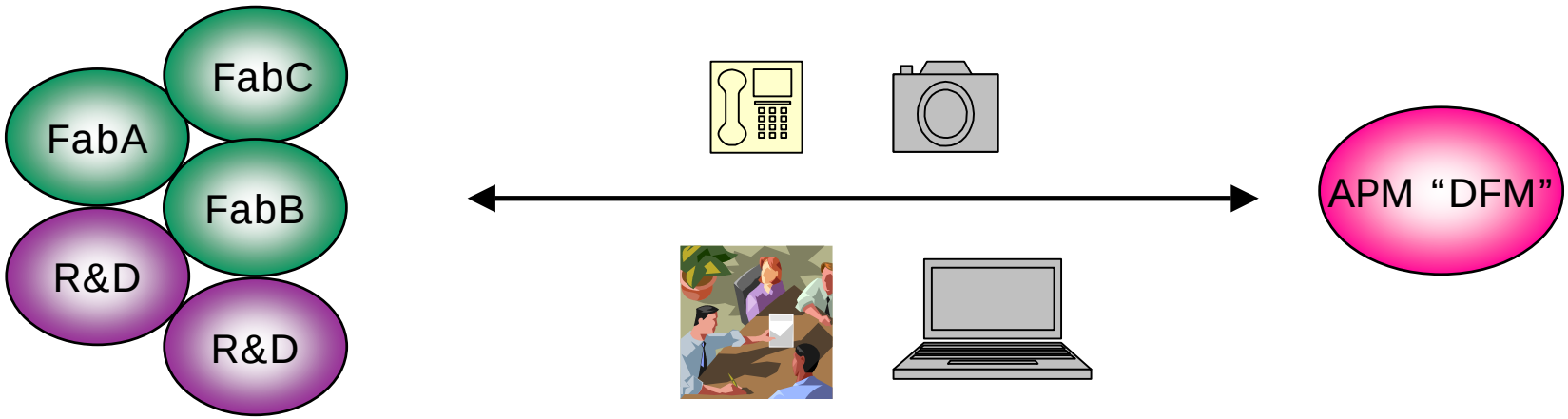
Characterization

- Characterization involves developing a process model, developing the necessary measurement technology and ensuring there is adequate tool visibility and controls to support the derived process model or fault detection program.
- Modeling provides the necessary understanding of how inputs into the process affect the resulting quality metrics or how the trace data correlates to tool performance, defect predictions, and dynamic sampling adjustments.
  - Sensitivities to recipe adjustments and incoming wafer properties are characterized.
  - Sensitivities to specific tool variables that may affect yield, defect formations, reworks, etc. are characterized.
  - Predictive yield and product performance models allow for the identification of process targeting.

Characterization (cont.)

- Measurement technology provides visibility into the process to support ongoing modeling and control objectives.
- ★ Collaboration with suppliers will be essent when the necessary tool controls and trace data are unavailable to support the process model and/or fault detection programs.
- Much of the characterization described above is already performed. This collaboration would seek to leverage that existing information, perhaps augment it with additional information, to facilitate control development.

Effective Collaboration



- Participate in regular face-to-face meetings to ensure clear communication.
- **Define the Challenge** together to meet the needs of all parties.
- Generate standard documentation during **Characterization.**
- Deliver APM **Programs** (RtR and FDC) using currently available and jointly developed utilities.

Final Thoughts

- Defining the challenge and developing control solutions during the design and beta stages of tool development will allow us to deliver factory-integrated, automated control systems at first-tool install to speed yield and control improvements during process introduction and ramp.
- Using Immersion Lithography as an example we have illustrated the DFC concept and its desired outcome.
- DFC encourages supplier collaboration to ensure adequate tool controls and trace data are available to support the process models and fault detection programs
- For 300mm manufacturing DFC enables us to better anticipate manufacturing challenges and develop solutions and methods in collaboration with suppliers early enough to deliver complete control solutions to the manufacturing organizations.

References

[1] Derbyshire, Katherine, Optical Lithography's Liquid Future, Semiconductor Manufacturing, March 2004, Volume 5, Issue 3.

[2] Kandlikar, Staish G., Bubble Entrapement In Liquid Immersion Lithography, SEMATECH Immersion Lithography Workshop, January 27, 2004.

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