A Batch Processing Module

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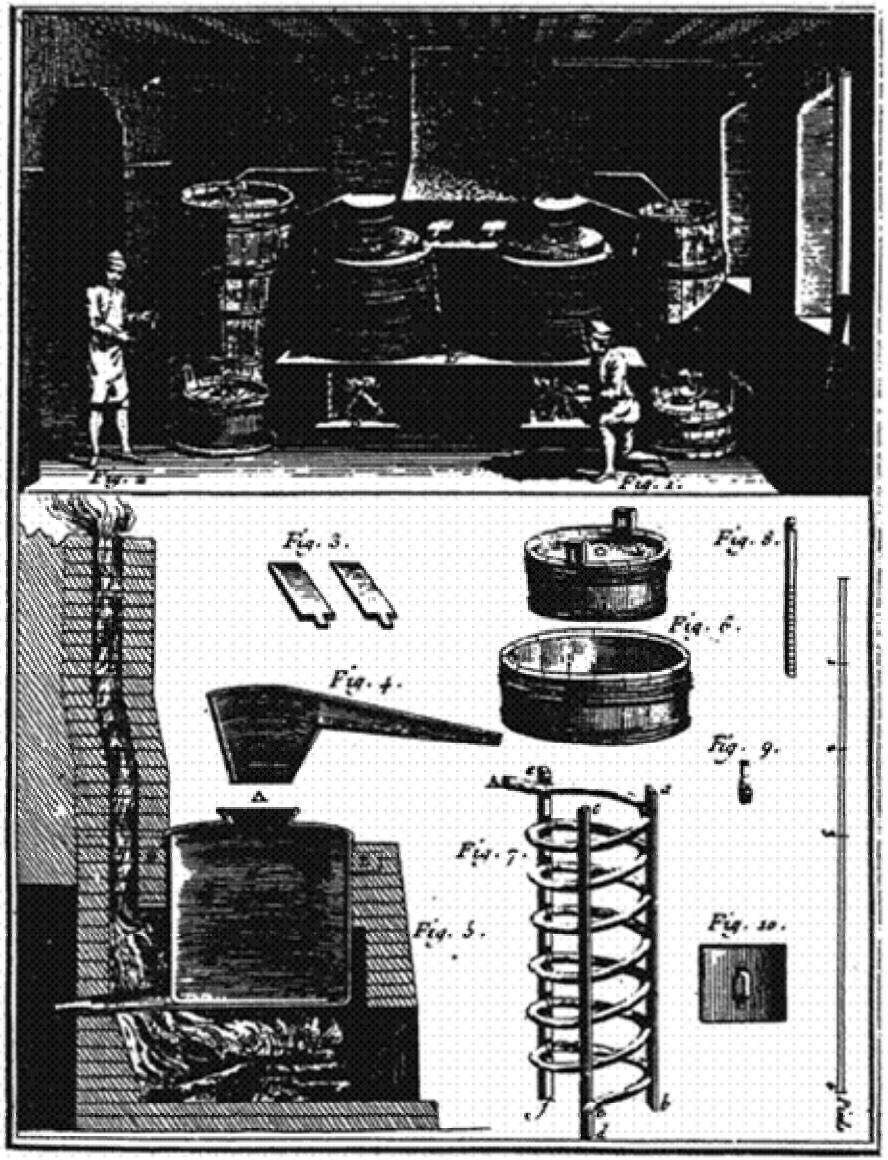
Batch Processing – Definition, Advantages, Disadvantages

- A sequence of one more steps (recipe) usually carried out in more than one vessel and in a defined order, yielding a finished product
- Production amounts are usually smaller than for continuous processing
- Requires reduced inventories and shorter response times
- Final product quality must be satisfied with each batch (no blending)
- More emphasis on production scheduling in batch processing

Other Advantages

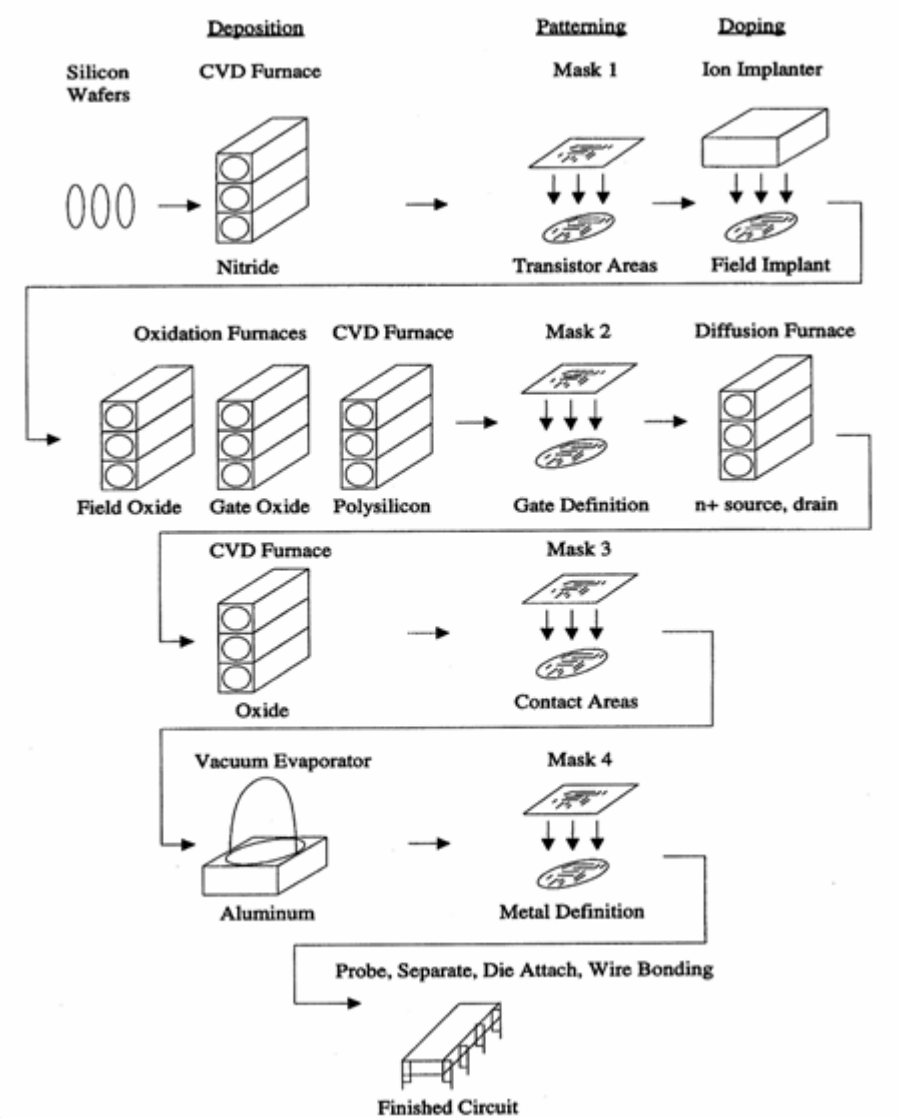
- Batch time can be adjusted to meet quality specs
- Repetition is conducive to continuous improvement in product
- Slow dynamics permit real-time calculations
- Greater agility



Distilateur d'Eau-de-Vie.

Batch Processing Used in Manufacturing

- Electronic materials
- Specialty chemicals
- Metals
- Ceramics
- Polymers
- Food and agricultural materials
- Biochemicals
- Multiphase materials/blends
- Coatings
- Composites



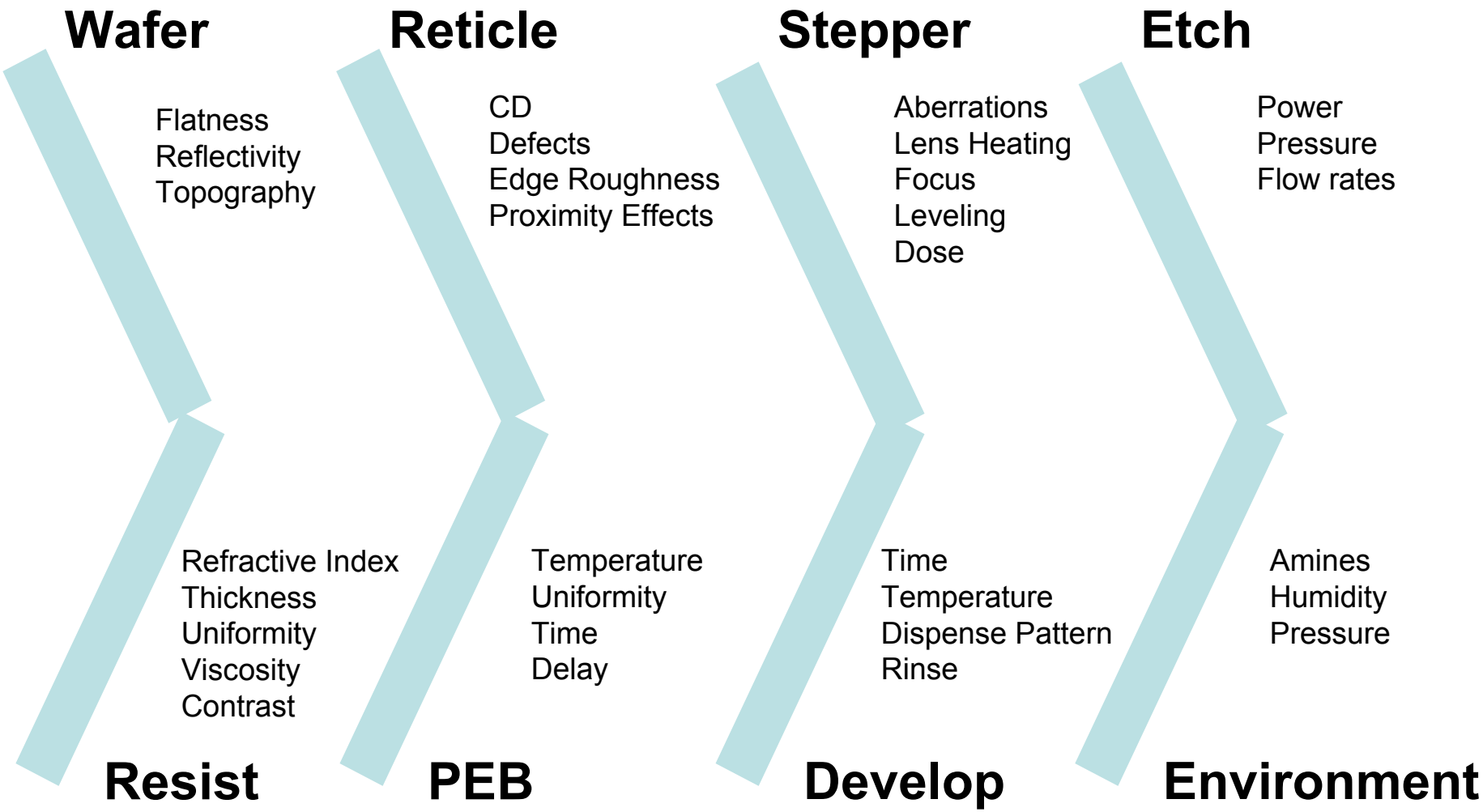
Represe fer fab

(Deposition, Patterning, Etching, Doping, etc)

Unit operations in microelectronics manufacturing are characterized by:

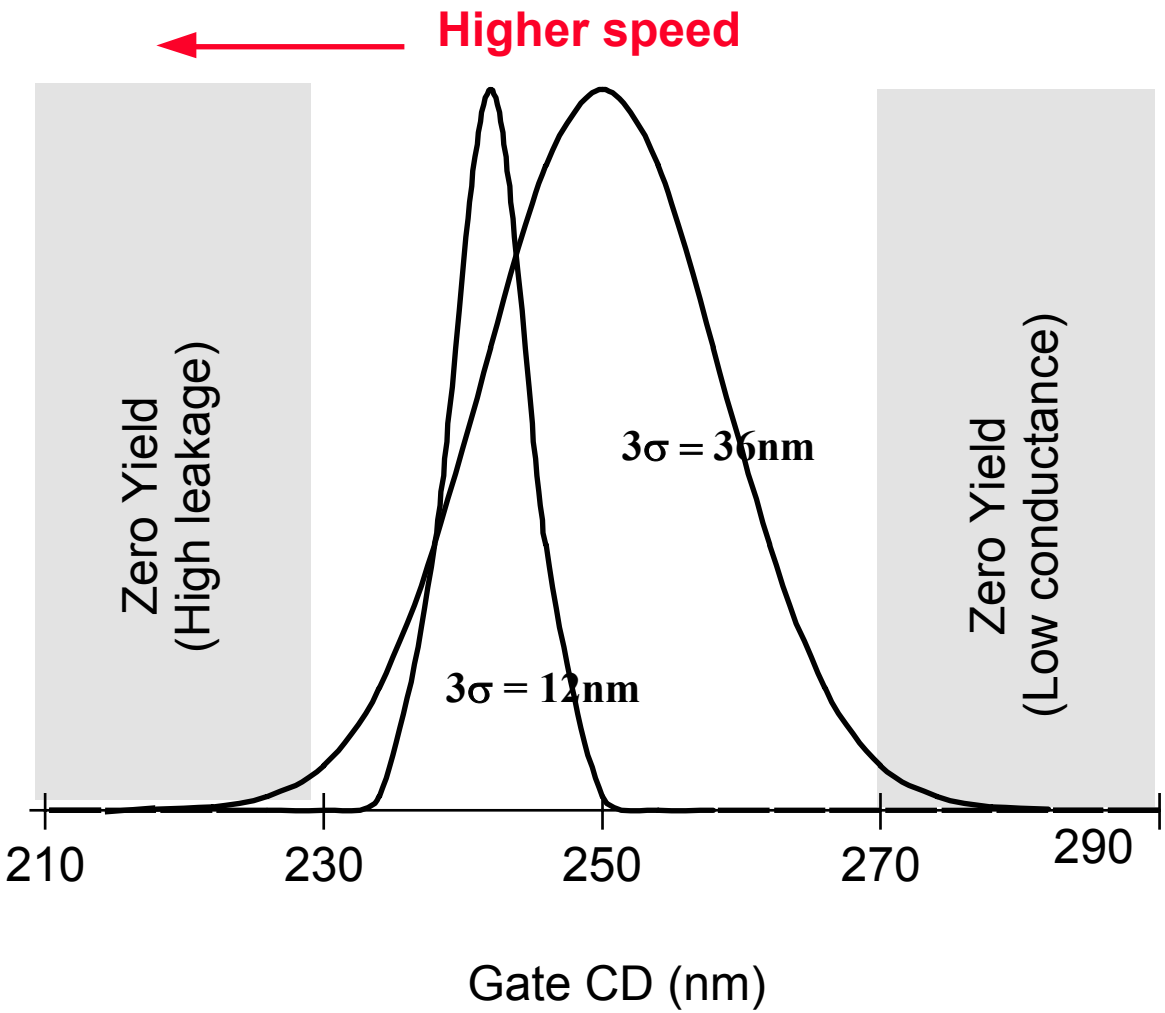
1. Physical/chemical complexity
2. Inability to measure directly many process variables
3. High sensitivity to process changes
4. Multiple inputs/multiple outputs

CD Variation Effects in Pattern Transfer



Why Control Critical Dimension (CD)?

- Small changes in CD distribution = Large $ values lost



Control Hierarchy in Batch Processing

1. Sequential control to step the process through a recipe
2. Logic control to deal with device interlocks
3. Within-the-batch control to make set point changes and reject disturbances
4. Run-to-run control to meet final quality constraints
5. Batch production control to maximize utilization of equipment and minimize cycle time

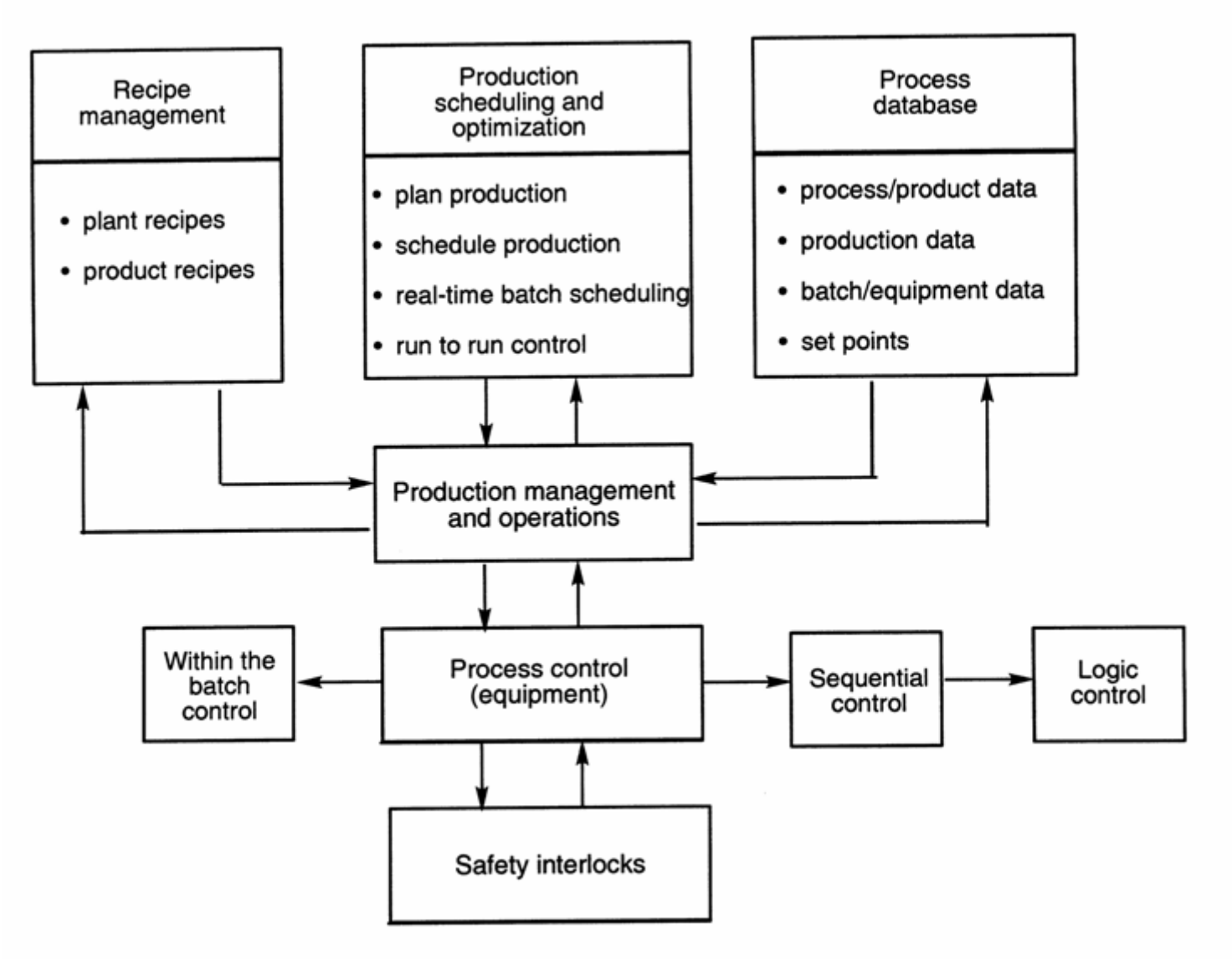
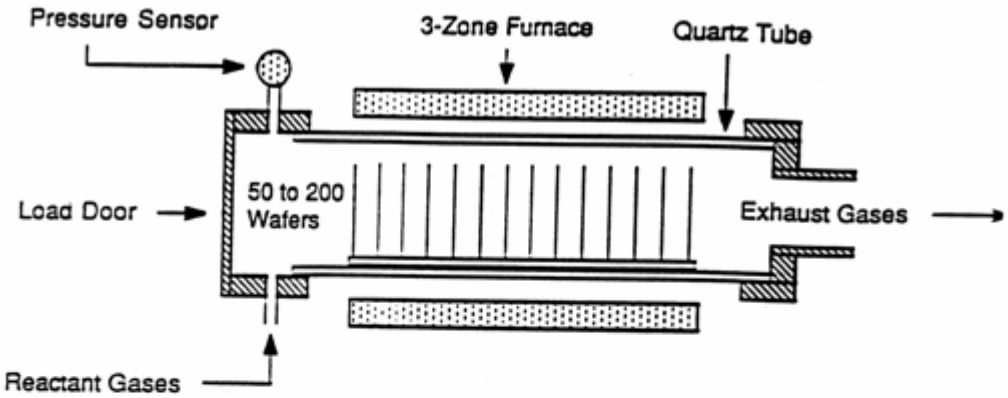


Figure 22.19 Batch control system – a more detailed view

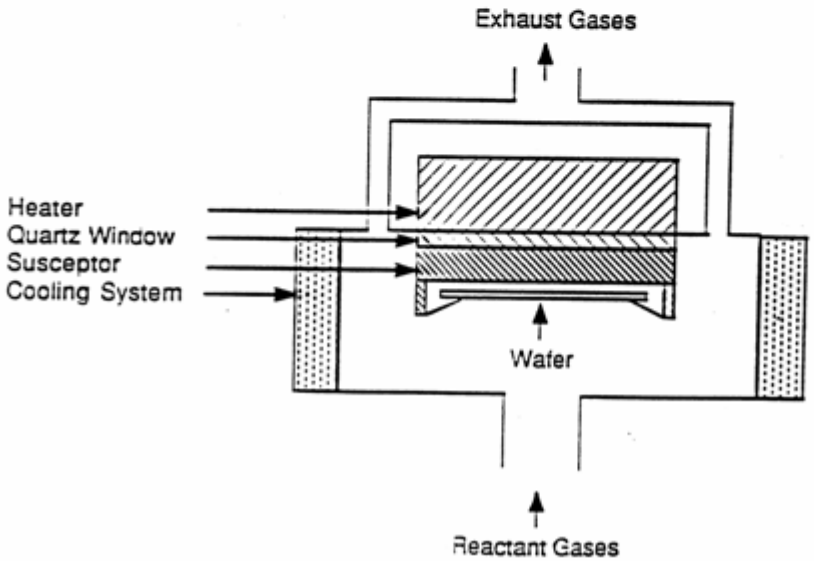
Within-the-Batch Control: Operational Challenges

- Time-varying process characteristics (no steady state)
- Nonlinear behavior
- Model inaccuracies
- On-line sensors often not available
- Constrained operation
- Unmeasured disturbances
- Irreversible behavior

Multiwafer Hot-Wall Reactor



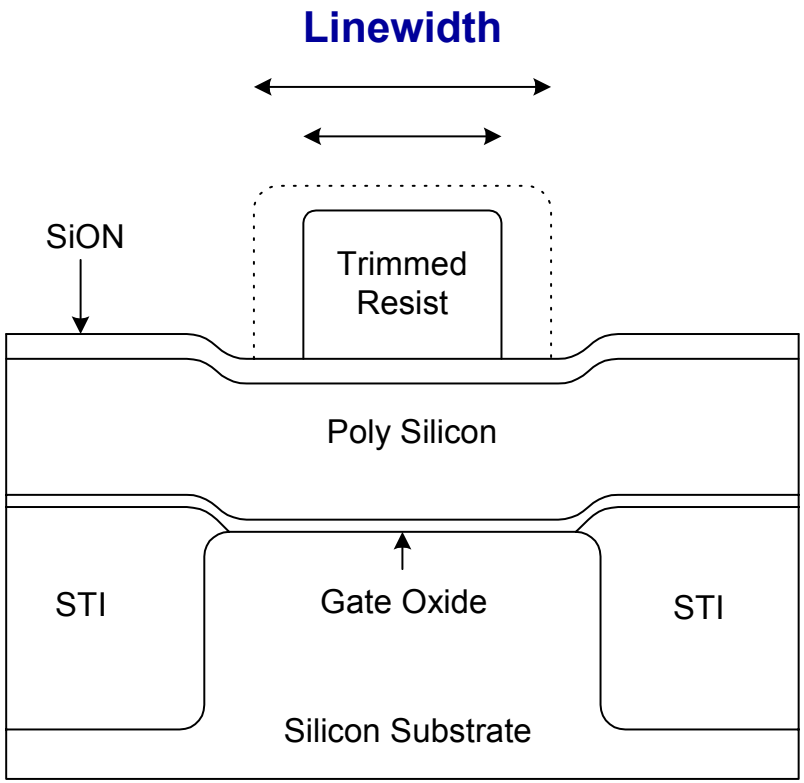
Single Wafer Cold-Wall Reactor



Run-to-Run (RtR) Control

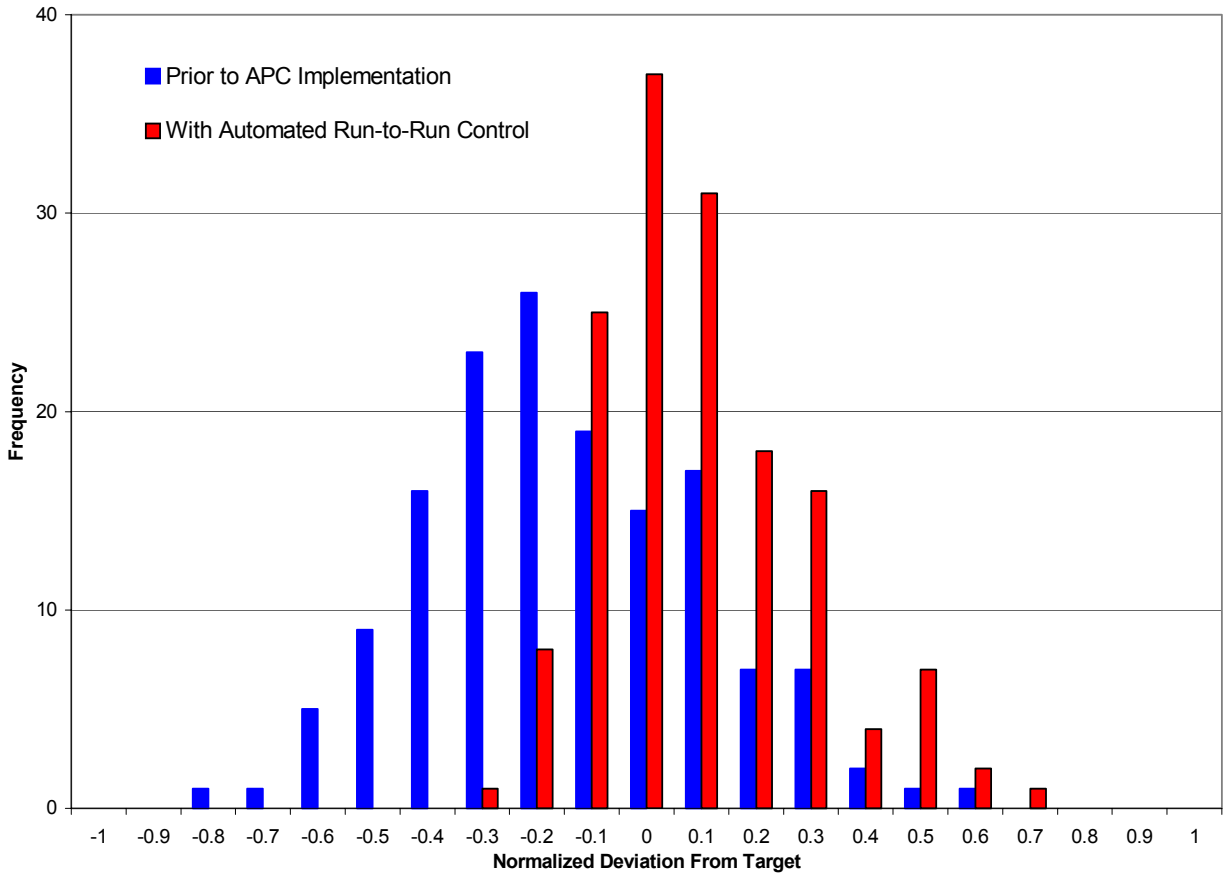
- Keeps batch process product on target by using feedback to manipulate batch recipe for consecutive batches
- Required due to a lack of in situ, real-time measurements of product quality of interest
- Extremely useful where initial conditions or tool states are variable and unmeasurable
- Supervisory controller determines optimal setpoints for real-time control loops (typically PID)

Application: Resist etch process



- The incoming pattern is masked with linewidths greater than required.
- An additional step is added to the etch process which etches the resist pattern.
- The resist etch step trims the lines to the proper resist linewidth.
- The rest of the etch transfers the resulting mask pattern into the polysilicon, creating the poly gate structures.

Results – Increased C_{pk}



Metric	Uncontrolled	Controlled	% Change
Mean Deviation From Target	-0.201	0.045	-77%
Standard Deviation	0.254	0.188	-26%
Cpk	1.05	1.7	+62%

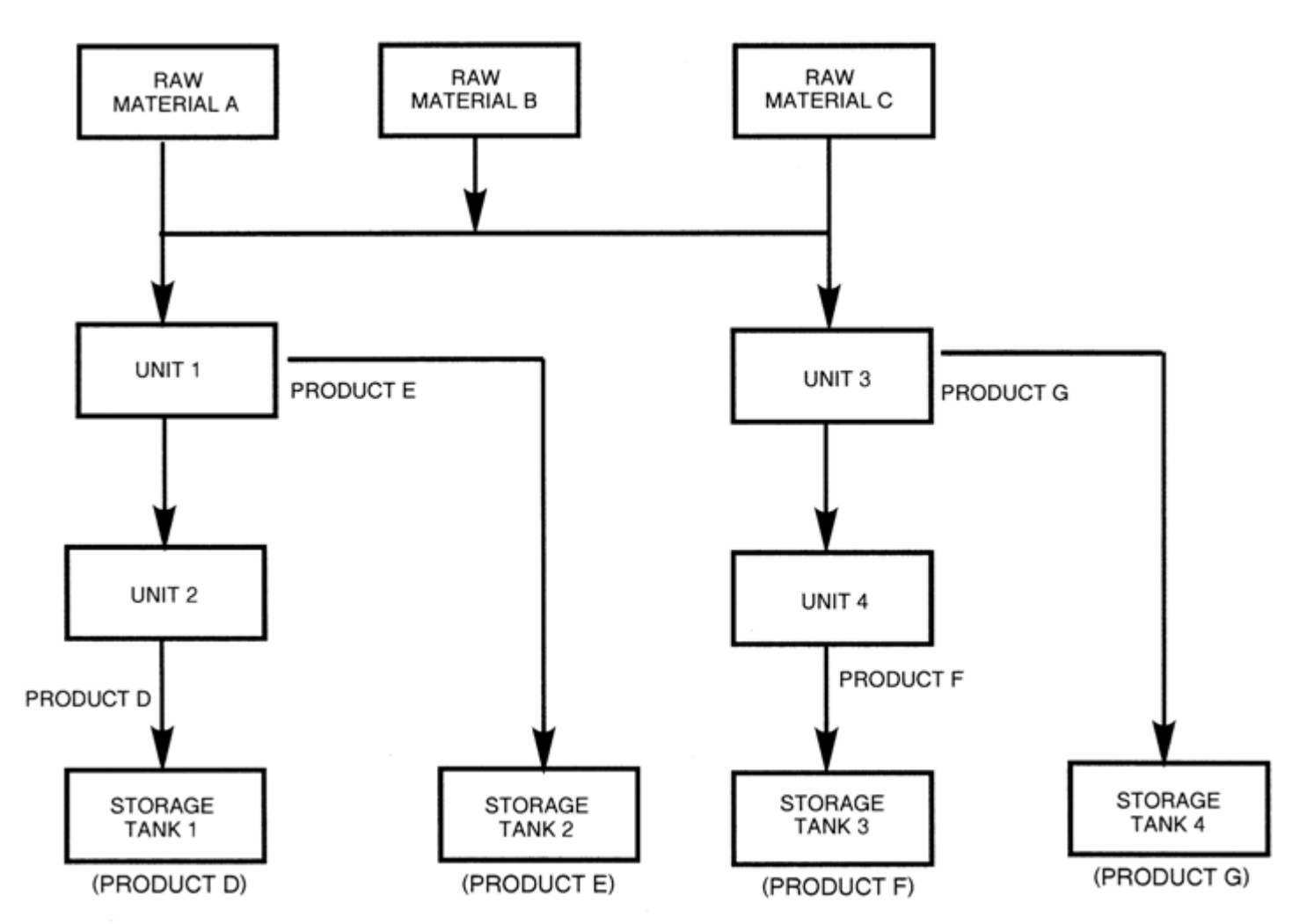
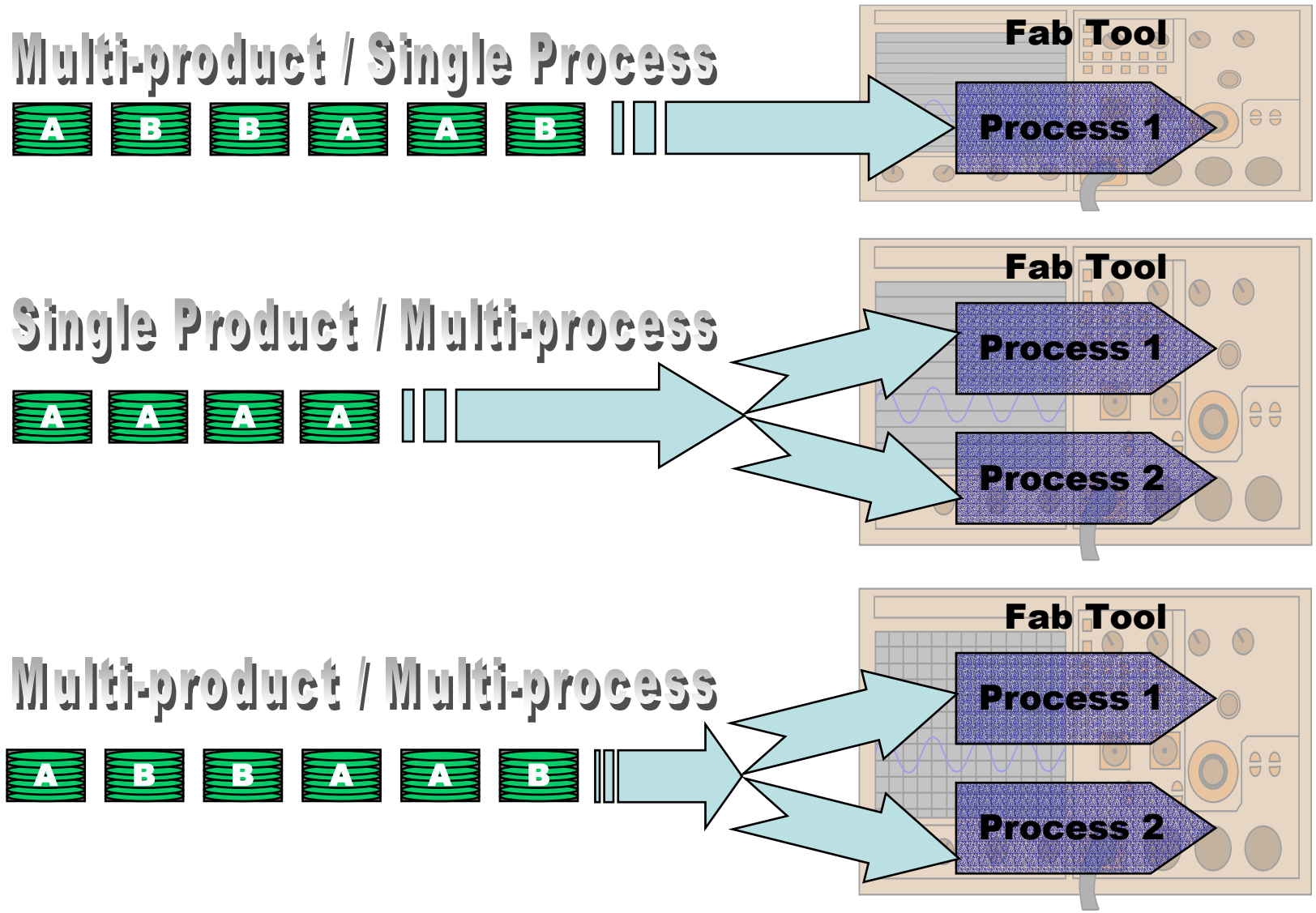


Figure 22.17 Multiproduct batch plant

Characteristics of batch scheduling and planning problems (Pekny and Reklaitis)

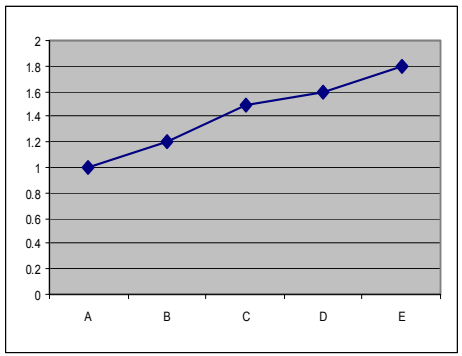
DETERMINE	GIVEN
What Product amounts: lot sizes, batch Sizes	**Product requirements** Horizon, demands, starting and Ending inventories
When Timing of specific operations, run lengths	**Operational steps** Precedence order Resource utilization
Where Sites, units, equipment items	**Production facilities** Types, capacities
How Resource types and amounts	**Resource limitations** Types, amounts, rates

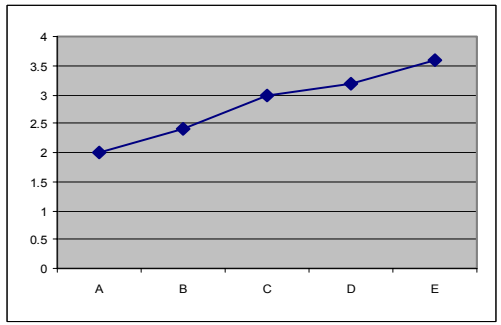
Multi-Product Processing Overview



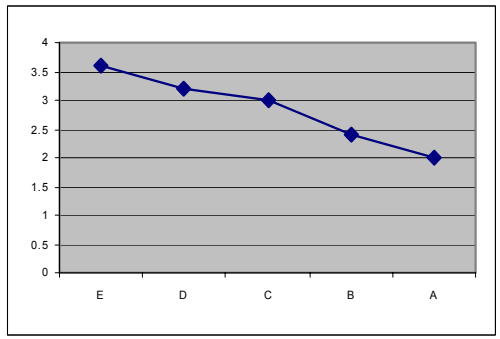
Metrology Variations

Process

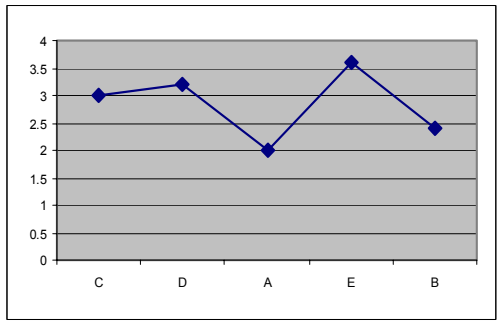




Correct Metrology Ordering



Incorrect Metrology Ordering



Incorrect Metrology Ordering

Integration Across Standard ChE Courses

- discrete logic in process operations
- design for safe operation
- measurement strategies (e.g., end point)
- batch vs. semibatch (bioreactors)
- use of fundamental (nonlinear) models
- numerical methods, statistics
- population balances
- case studies