Improved Simple Simulation Models for Semiconductor Wafer Factories

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Research overview

Complex Production System

High-level Production Control

Measurement & Analysis

Automation of Data Transfer

Dispatching

Simulation

Model

Simulation-based Scheduling

Complex Production System

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Flow of material

Fotos: Fullman-Kinetics, Varian, Sematech International
There are still humans involved!

Foto: Sematech International
How do the tools usually look like?

Fotos: Firma Varian
Characteristics of wafer fabs

- Large number of processing steps, typically several hundreds
- Large number of tools of different types: photo equipment, ovens, etching equipment, ion implanters, ...
- Wafer are built up in layers: reentrant flow of material, jobshop-like way of production
- Frequent machine breakdowns (typical availability: 70-90%)
- Auxiliary resources, e.g., reticles (photo masks)
- Batch tools with complex batching criteria
- Sequence dependent setups
- High level of automation
- Operators with different types of skills
Control factors

- Factory load
- Product mix
- Number of machines and operators
- Preventive maintenance policies
- Production planning & control policies:
  - scheduling vs. dispatching,
  - lot release vs. shop-floor control,
  - ...
Operational modeling

- Model components
  - Tool set: type of tool, setups, breakdowns, ...
  - Secondary resources: worker, photo masks, ...
  - Products: lot sizes, arrival patterns, ...
  - Product recipes: lists of operations
  - Material flow control: lot release rules, dispatching rules
- Most tools seen as blackbox
  - Internal behavior of tool not modeled
  - Exception: cluster tools
Important operational questions

- Most appropriate dispatching rule
- Most appropriate lot release rule
- Output prediction
- Cycle time prediction
- Lateness prediction
- Forecast of short-term material flow problems
- Workarounds after random events (breakdown, operator unavailability, …)
- Effect of product mix changes (surge analysis)
- Practical relevance of schedules (robustness, stability)

No alternative to simulation as a decision support tool!
Motivation for simple models

- Traditionally, only full detail models used for operational planning and control of semiconductor fabs

- Consequences:
  - Long run times of simulation experiments
  - Long run times of scheduling algorithms
  - Too complex to be included in enterprise models for SCM (Supply Chain Management)

- Need for simple fab models
Simple modeling approaches

• Requirements
  – Correct representation of characteristic curve (cycle-time-over-utilization curve), i.e., typically $1/(1\text{-utilization})$ shape
  – Same cycle time distributions as for real fab
  – Mimic typical behavior of fab over time

• Very simple model: cycle time distribution
  – Does not depend on utilization
  – Has infinite capacity
Simple modeling approaches

- **Simple queuing system**
  - Behavior over time not appropriate
  - In general, shape of characteristic curve problematic
Simple modeling approaches

- Simple queuing system with loop (re-entrant flow of material)
Characteristic curve

![Graph showing the relationship between Flow factor and Utilization for Simple and Full detail models. The graph indicates a linear increase in Flow factor with increasing Utilization, with the Simple model showing a slight increase and the Full detail model showing a more pronounced increase, especially at higher Utilization levels.]
Make delays load dependent!
But how to measure load?
Simply count lots in bottleneck loop!
Load-dependent “loop” delays
Improvement of the char. curve

Utilization

Flow factor

Simple
Full detail
Load dependent
Cycle time distributions

- Detailed model
- Simple model
New approach

- Replace delay component by a single server component with load dependant service times
- Consequence: no more lot passing (overtaking)
Cycle time distributions

- Cycle time distributions for Factory X and Simple models.

The graphs show the distribution of cycle times in days, with the y-axis representing the probability density function.
Simple model deviations from full one

deviation [days, days^2]

Expectation    Variance    Expectation    Variance    Expectation    Variance    Expectation    Variance

All Products    Product 1    Product 2    Product 3    Product 4    Product 5    Product 6

70%       90%
Conclusions for simple model study

- Seems possible to have it all: mimic fab behavior + characteristic curve + cycle time distribution
- Simple models useful for analyzing and understanding complex production systems
- Not a tool for beginners
- Not appropriate for all problems
- Pitfall of oversimplification
- Simplification must not be the goal but only the method to reach the goal
- Keep the model as simple as possible but not simpler!
• Models for real fabs too large and too complex: You don’t see the forest for the trees!

• Difficulties to formulate all material flow constraints of real systems, but: Is it really necessary to consider all details?

• Evolution in semiconductor manufacturing towards “lights out” fab
  – no operators but fully automated
  – even more decisions to be made by production control

• Still a lot of work to do to find
  – Better (useful!!!) models
  – Faster planning procedures