Benchmarking Semiconductor Manufacturing and its Applicability to Pharmaceutical Manufacturing

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Presentation Agenda

- Introduction to UC Berkeley CSM Research Program
  - Research program purpose and general approach.
  - Manufacturing metric scores.
  - Summary of best practices.
  - Preliminary conclusions.

- Pharmaceutical Manufacturing Research Project
  - Description and value to industry.
  - Funding and approach.
UC Berkeley CSM Research Program

- Why?
  - Perceived competitiveness gap among producers.

- Charter
  - Measure manufacturing performance.
  - Identify underlying determinants of performance.
  - Benchmark wafer fabrication across industry.
  - Carry out focus studies of important practices.

- Funding
  - Originally by Alfred P. Sloan Foundation; additional funding by Sloan, International SEMATECH, and semiconductor industry.
Value from CSM Research Program

- Developed a **new** industry standard set of benchmarks for measuring manufacturing performance.
- Provided confidential “scorecard” to manufacturing fabs on how they performed against **anonymous** others.
- Identified managerial, organizational, and technical practices underlying good (and poor) performance.
- Identified advances in techniques for defect analysis, scheduling, process development, factory organization, etc..

*Industry view:* Substantial positive financial impact to program participants.
Research Dissemination

- Benchmarking reports (most recent: March 2002).
- Focus study reports (more than 50 reports to date).
- Industry and conference presentations.
- Extension classes for industry managers.
- Academic research papers.
Benchmarking Participants

- 36 semiconductor manufacturing facilities studied:
  - Hyundai and Samsung (2) in Korea.
  - TSMC (2) and UMC (2) in Taiwan.
  - NEC, Oki, LSI Logic, Toshiba, Tohoku and Winbond in Japan.
  - AMD, Cypress (2), DEC, Delco, Harris, IBM, Intel, LSI Logic, Lucent, Micron, Motorola, NSC, Sony, Sony/AMD and TI (2) in USA.
  - DEC, ITT, Lucent, NSC (2) and ST Microelectronics in Europe.
- Over the 1989-2001 period and several technology classes.
Data Collection

- Mail-Out Questionnaire (MOQ).
  - 3-4 years of fab history.

- Data collection:
  - Equipment and facilities.
  - Headcount and human resources.
  - Managerial, organizational and technical practices.
  - Production volumes, yields, cycle times, etc..

- Data entered into relational database.

- Technical metric scores computed.
  - Yield, cycle time, equipment productivity, etc.
Site Visits

- Two–three day visit with a structured inquiry protocol.
  - Team of 6-8 faculty and graduate students (plus interpreter when required).
  - Tour fab for evidence of self-measurement, communication, problem-solving activity.
  - Interview cross-section of organization.
    » Managers, engineers, technicians, operators.
  - Conduct information sessions.
    » On approaches to problem areas (yield, equipment efficiency, cycle time, on-time delivery, new process introductions, etc.).
    » On problem solving resources (information systems, process control, work teams, human resources development, etc.).

- Managerial expectations...
Figure 2.16. CMOS Logic Fab Defect Density
0.7 - 0.9 micron CMOS process flows

Defect density (fatal defects per square cm)

Time

Georgetown University

Washington University in St. Louis
Cycle Time Per Layer

![Graph showing cycle time per layer (CTPL) for different machines (M1 to M7)].

- **M1**: Cycle time decreases steadily over time, reaching a minimum near 98.
- **M2**: Shows a similar trend but starts at a higher cycle time.
- **M3**: Initial cycle time is higher, but it decreases sharply in the first few months, stabilizing around 98.
- **M4**: Begins with a high cycle time and shows a gradual decrease.
- **M5**: Starts with a low cycle time and remains relatively stable throughout.
- **M6**: Displays a sharp initial decrease followed by a slight increase near 98.
- **M7**: Has the longest cycle time and shows a steady decrease.

**Time Range**: From 94 to 99

**Cycle time per layer (CTPL)**: The graph plots the cycle time per layer against time.
I-Line 5X Stepper Productivity

Wafer operations per stepper per day

Time

94 95 96 97 98 99 00 01

Georgetown University

Washington University in St. Louis
Direct Labor Productivity

Mask layers per direct labor per day

fab1015  fab1050  fab159  fab2489  fab254  fab293  fab350  fab408  fab458  fab490  fab510  fab531  fab561  fab580  fab650  fab716  fab768  fab848  fab891
Searched for managerial, organizational or technical practices that were correlated with metric scores.

Typically, a good practice positively influenced several metric scores.

- Firms tend to score well (or score poorly) across several metrics.

Almost every manufacturing fab had at least one practice that the other fabs would benefit by adopting.

No fab was best-in-class in all practices or performance measures.
Key Operational Practices

- Make manufacturing mistake-proof.
- Automate “information” handling.
- Integrate manufacturing data and analyze statistically.
- “Know” your equipment.
- Automate scheduling of manufacturing activity.
Key Organizational Practices

- Develop a problem-solving organization
  - Create member-diverse, problem-focused teams.
  - Provide extensive training and mentoring.

- Manage new process development and transfer
  - Incrementally introduce new process modules
  - “Copy exactly” from pilot plant to production fab.
  - Co-locate process development and manufacturing.

- Reduce the division of labor
  - Allow operators to do some TPM and troubleshooting.
  - Focus engineers on “hardest” problems.
Summary of Major Findings of CSM Study

- Biggest single factor explaining performance is the focus or “religion” of organization:
  - Total Quality Management and process control.
  - Statistical analysis of yield vs. in-line data.
  - Cycle time reduction and on-time delivery.
  - TPM and equipment throughput.
- Weak performers in a given category do not have the relevant focus.
Conclusions from CSM Study

- Independent of technological differences, performance differences among manufacturingfabs studied were substantial.
- Various metrics have different levels of importance in different product segments.
  - Fast ramp of new production processes to high-volume manufacturing is very important.
  - Rates of improvement in yields and throughput are very important.
Conclusions from CSM Study

- Improvement requires rapid problem identification, characterization, and solution by a large, diverse team.

- Common Themes of Successful Approaches:
  - Leadership and development of personnel.
  - Organizational participation, communication, accountability, responsibility for improvement.
  - Information strategy and analytical techniques to support improvement; not blind automation.

- Manufacturers could and did substantially improve performance by adopting CSM research program findings.
Goals

- Benchmark pharmaceutical production across industry.
- Identify managerial, organizational, and technical practices underlying manufacturing and regulatory performance.
- Transfer “learning” to industry.

Value to industry

- Develop standard set of benchmarks for measuring manufacturing performance.
- Identify practices that lead to good (and poor) performance.
- Provide confidential “scorecard” to plants on how they perform against anonymous others.
PMRP – Funding and Approach

Funding
- Seed funding from Georgetown University and Washington University in St. Louis.
- Seeking additional funding from foundations.

Approach
- Currently in pilot phase.
  » Interviews with FDA personnel.
  » Meetings with various manufacturing entities.
  » Developing internet-based survey and plant visit protocol.
- Data collection phase will begin by year-end.
We Want You!

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