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EVALUATING THE IMPACT OF PRODUCTION SCHEDULING ON TOOL PERFORMANCE

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Abstract:

Scheduling of a semiconductor manufacturing facility is one of the most complex tasks encountered. Confronted with a high technology product market, semiconductor manufacturing is increasingly more dynamic and competitive in the introduction of new products in shorter time intervals. Simulation provides an effective decision support tool in scheduling of semiconductor manufacturing. Simulation model was developed as a risk assessment tool for one of the implant process area. The model examines the impact of production schedule on tool performance by testing different production scenarios. Production ramping, local buffer capacity, product sequence and product mix seem to be influential factors of the toolset performances.

Keywords:

Semiconductor manufacturing, Scheduling

1. INTRODUCTION

Semiconductor manufacturing is – a multiplex manufacturing system – characterised by; manufacturing technology operating near performance limits – reliability/maintenance, high quality control required for product reliability, re-entrant product flow through processes, huge range of process times and tool capacities. Scheduling of wafer fabrication facilities is among the most challenging planning activities encountered these days due to random yields and rework, complex product flow, time-critical operations, batching, simultaneous resource possession, and rapidly changing products and technologies.

Wafer fabrication is the most technologically complex and capital intensive stage of semiconductor manufacture. It involves the processing of silicon wafers to create the semiconductor devices in the wafer and build up the layers of conductors and dielectric on

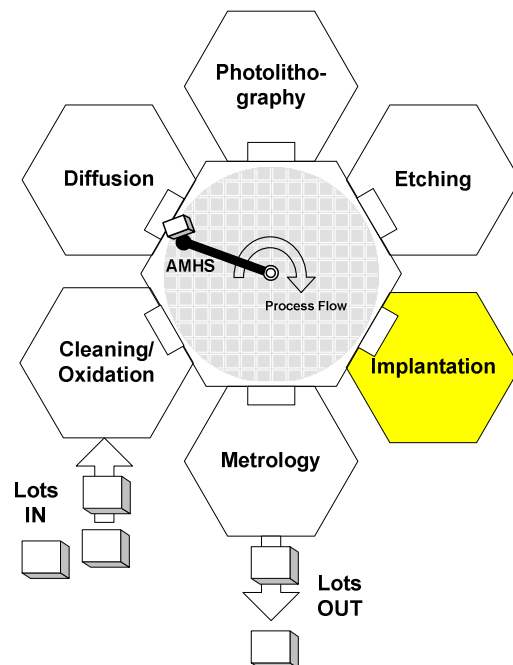


Figure 1: Wafer Fabrication Main Processes

top that provide the complex interconnection between devices. Hundreds of operations are required to build a complex component such as a microprocessor. The main areas in wafer fabrication are shown in Figure 1.

The Dynamic nature of the semiconductor manufacturing means that deterministic models are not capable of handling the variability within the system which arises from:

- Tool dedication to operation/process
- Lot to Lot cascade rules
- Temporary capacity restriction due to maintenance
- Temporary capacity restriction for quality purposes

Manufacturing simulation has become one of the primary application areas of simulation technology. It has been widely used to improve and validate the designs of a broad range of manufacturing systems. Typically, manufacturing simulation models are usually used either to predict system performance or to compare two or more system designs or scenarios [1].

For planning and scheduling of production, manufacturing engineers need to be able to predict the overall factory capability and the best recovery strategy should an unexpected event occur.

2. SCHEDULING PROBLEM

Implant process is one of the critical processes within wafer fabrication. It has a repetitive nature and hence any improvement in the process will consequently improve the overall performance. Lot scheduling is mainly based on the allocation of available tools over time to meet a set of performance criteria. Typically the scheduling problem involves a set of lots (different products/layers) to be processed, where each lot requires a particular set of operations/processes to be completed.

The scheduling of implant tools area is a very difficult activity due to two main issues; complexity and variability. The process builds the required layers using different gases. The sequence of using such gases is essential (i.e., some gases cannot be used after each other and some need longer setup). The process flow is re-entrant and even more dynamic with different gas settings. In addition, the process is sensitive to product/layer changes with associated setup times. There are many sources of variability within the process such as high product-mix, lot priority issues, lack of formal lot scheduling rules within the floor, and gases setups. Maintenance including preventive maintenance, random yields, and labour dedication is also a crucial issue. Moreover, lack of a prior information about future lots for processing mean that scheduling must be real-time, increasing the complexity.

The problems arise as a result to the scheduling problems may vary with;

- low overall performance,
- low tool utilization/ high cost,
- more “Work In Process” inventory build,
- delay in delivery of orders,
- increase in throughput time per lot, and
- increase in tool cycle time.

Three more key issues for scheduling had to be established before the problem could be addresses, the qualifying matrix, set up times table, and selection criteria.

2.1 Qualifying Matrix

The manufacturing team uses a qualifying matrix (QM), updated periodically based on manufacturing policies, which defines which tool is capable of processing each layer. For example, the manufacturing team always assigns the hard/complex layers to new tools as the older tools may not be capable of achieving the required quality in a timely manner. Table 1 illustrates a sample of the qualifying matrix showing the tools and the layers on which they are able to perform. A similar table could also be drawn up with regard to product, but in this work it was assumed that all the tools can process a qualified layer on any product. In actual production more than 13 layers and over 9 tools are involved in the toolset represented by the model developed.

Table 1: Sample of Qualifying Matrix

Tool No.	Layer Number				
	1	2	3	4	5
X01	✓	✓			
X02	✓	✓			✓
X03	✓	✓			
X04					✓
X05					✓
X06			✓		✓
X07			✓	✓	
X08		✓			✓
X09			✓	✓	

2.2 Setup times Table

Based on the technological constraints of the process and the technical specification of the devices, the setup times of changing gases to build new layers are different. The variability is very high in this table as the changeover time may vary from 10 minutes to 48 hours. In addition, some of the gases should never be used after some other gases (shown in Table 2 as 'X')

Table 2: Sample of Set up Times

Gas Type	Implant Gases				
	1	2	3	4	5
1	0	10	45	45	X
2	10	0	0	10	45
3	45	0	0	10	10
4	X	45	10	0	0
5	2880	X	X	0	0

2.3 Selection criteria

The schedule generated for a manufacturing run is highly dependent on the particular criteria used in the scheduling process. There are several criteria – most are dynamic – that will affect the selection of a particular tool to process an incoming lot. These criteria can be either process-oriented or wafer-oriented (Figure 2):

- Process oriented criteria relate to the equipment itself such as technology, maintenance,.. etc.
- Wafer oriented criteria relate to the lot information such as product, layer, ..etc.

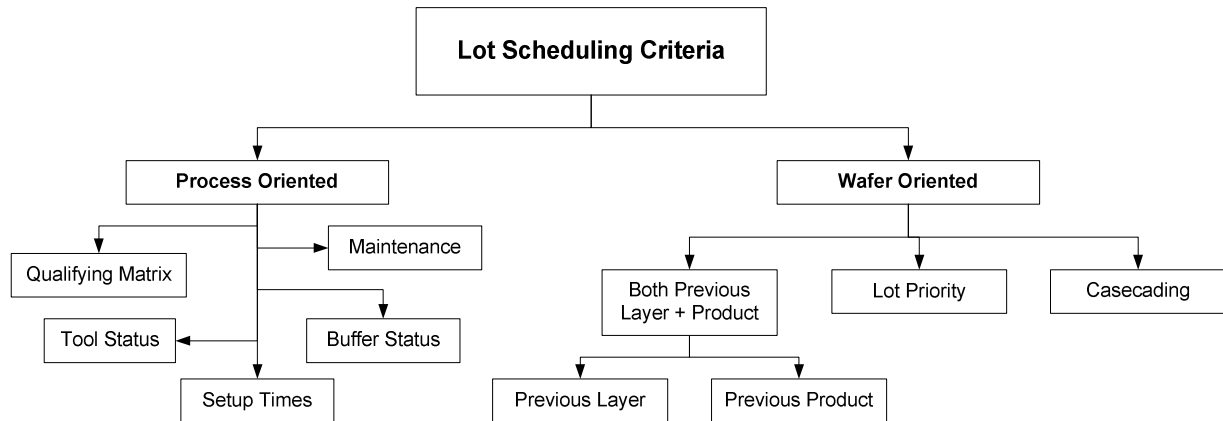


Figure 2: Lot Scheduling Criteria

3. MODEL OBJECTIVE

The goal of the simulation model developed in this project is to provide a risk assessment tool for capacity planning to:

- Study impact of changing selection criteria on performance Enhance overall performance (tool/toolset).
- Study impact of tool qualification on selection.
- Examine the impact of changing ramp profile on WIP inventory in front of the tools.
- Improve tool settings in order to maximize tool/toolset Utilization.

4. IMPLANT SIMULATION MODEL

A detailed simulation model was developed to fulfil the mentioned objectives. The model is limited by certain assumptions which are in line with practical operation of the tools:

- 1) The production ramp is weekly based.
- 2) The maximum number of tools is 12.
- 3) The maximum number of layers to be processed up to 18 layers.
- 4) An operator is always available.
- 5) The qualification matrix is two-dimensional.
- 6) The gases are always available.
- 7) The source life of each gas is determined before the simulation run as well as the maintenance time.

The performance measure used here, throughput time, is the elapsed time between the lot first entering the toolset and completion of the implant process on the last layer.

The wafer flow in the model is indicated in Figure 3.

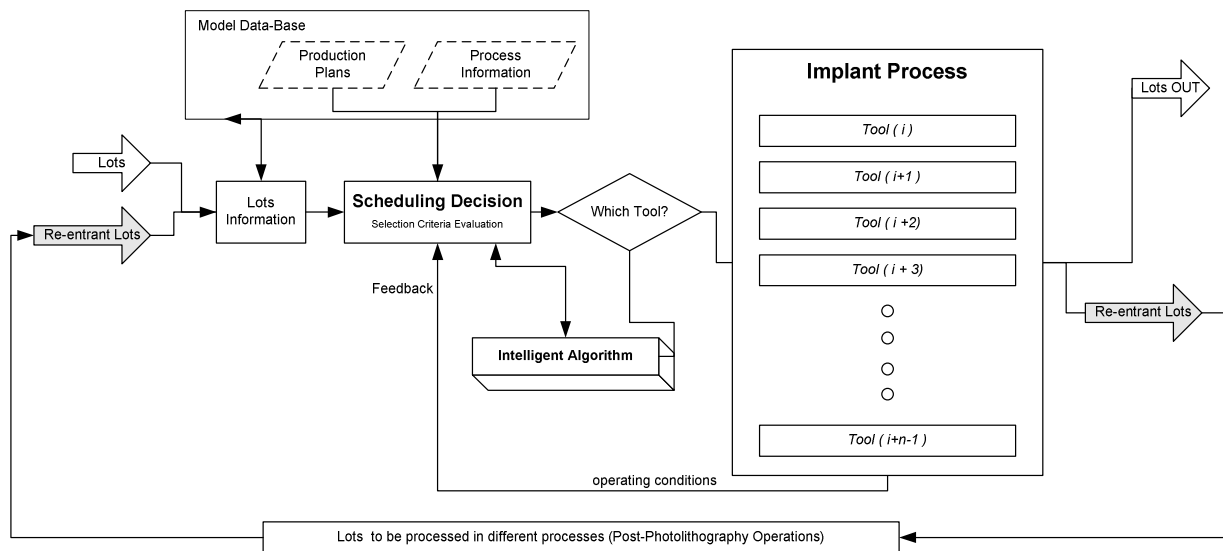


Figure 3: Schematic diagram of lots flow in Implant Simulation Model

The strength of decisions made on the basis of simulation is a direct function of the validity of the output data [2]. It is evident that validation must therefore be an integral part of building any simulation model, right from input data collection through model development to output data analysis. The goal of the approach undertaken for this model was to verify that the outputs from the model were valid and directly useful in the manufacturing site. The overall output from the model was then checked for reasonableness by production staff. The most definitive test established that the simulation output data closely resembled the data from the actual system. A set of different run parameters from the factory floor were provided and simulated to ensure that the throughput time and cycle time levels were close to the actual values. This confirms the belief that the logic and assumptions in the model are correct.

The output format of the model comes in different ways; some is graphical presentations (charts), and the data goes to database file. The output includes:

- Utilisation of each tool per week.
- Cycle time (for each tool, lot, and overall area)
- Throughput Time
- WIP Inventory
- Productivity

5. CONCLUSIONS

Scheduling within the semiconductor industry is a very challenging activity. From manufacturers and researchers' observations, the complexity of this activity will increase in the future with:

- Increased global competition.
- Variations in customer demands.
- Decreasing product life cycle.
- Rapid changes in technologies.

- Constraints (e.g. technological, quality, and production).

The simulation developed here has been effectively used in examining schedules of Implant process. Developing such effective models incorporating all the process details, operating details, and manufacturing procedure details for scheduling is extremely complex. A good simulation model provides not only numerical measures of system performance, but provides insight into system performance [3]. The new model provides a number of interesting insights into the performance benefits from a tacit understanding of system behavior. As one would expect the greatest benefit is obtained from improvements at the lot throughput time and average WIP reduction.

The model takes into considerations the manufacturing constraints that cause high variability in the system (e.g. qualifying matrix, product-mix, and unscheduled maintenance). Since semiconductor manufacturing system with stochastic elements cannot be accurately described by mathematical models that can be evaluated analytically [4]. Thus, simulation is often the only type of investigation possible.

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