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A MODEL OF A 300MM WAFER FABRICATION LINE

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ABSTRACT

Semiconductor factories are very expensive to build and operate. It is critical to understand how to design and operate them efficiently. We describe a simulation model of a planned 300mm wafer fabrication line that we are using to make strategic decisions related to the factory.

1 INTRODUCTION

A development level model of a 300mm wafer fabrication line was constructed to make design decisions for 75 wafer starts per day (WSD) (Campbell and Laitinen, 1997; Campbell and Norman, 1998; Campbell and Norman, 1999). This model contains approximately 100 tools. This development model was used as the basis for the construction of a model for a 200mm line for Dominion Semiconductor (Norman and Barksdale, 1999). We expanded this model to represent a production environment capable of sustaining 400 and 800 WSD (approximately 300 and 600 tools). We are using the model to make further design decisions for the development line and for the manufacturing line.

300mm wafers (approximately 12 inches in diameter) are going to replace 200mm wafers that are currently in wide use in the semiconductor industry. The larger wafer size requires an entire new tool set and automated material handling systems to deliver the wafers to tools.

The paper includes sections discussing the details of the model, including the tool processing and the automated material handling systems, and the experiments being conducted. We are investigating the level of automation, various layouts, and several operations management policies. Initial model results, which have been obtained recently, are included. We expect to produce significant results and/or counter-intuitive discoveries by the end of the project.

2 MODEL DETAILS

The model was built with simulation tools from AutoSimulations™ Inc. including AutoSched™, AutoSched™ AP, and AutoMod™. The model consists of two distinct parts that communicate with each other: the tool processing and the material handling system that delivers the wafers to the tools for processing.

2.1 Tool Processing

The tool processing part of the model consists mainly of spreadsheets describing the tools and the routing steps the wafers follow through the tools during the wafer fabrication process. Each tool has a tool group name, batching information for batch tools, a scheduling rule, a preferred and alternate stocker, a bay, the number of load ports or microstocker capacity, and preventive maintenance and down time distributions.

Each step in the wafer routing contains the tool group name, the stocker for this step, the stocker for the next step, an alternate stocker, the processing time, setup information, yield probability, and rework information. A routing for a logic product we are studying consists of approximately 500 steps. We are representing three main types of tool processing: wafer-by-wafer, batching, and sampling as used with metrology tools. The wafer-by-wafer processing might be used to represent a photo cell, and the process time per lot is equal to a fixed time plus a variable time times the lot size. Wafer batch processing is used for furnaces and ion implanters. The process time for a lot is the number of batches in a lot times the batch processing time. Metrology tools do sampling, and the processing time for a lot is the sample size times the test time per sample.

2.2 Automated Material Handling Systems (AMHS)

The model has four different versions of material handling systems to move the wafers to the tools. The automated interbay/intrabay AMHS represents vehicles on a centralized monorail for interbay movement and an overhead hoist transporter for intrabay movement. The intrabay and interbay systems interface through stockers at the end of each bay. Each stocker has a lot capacity specified for it.

The second version of the material handling system is called point to point. In this version, vehicles can carry wafers directly from any tool to any other tool. It is not necessary to go through a stocker if the next tool has a load port available.

The third version of the material handling system has an automated interbay monorail system and operators who move the lots within the bays. They interface through stockers the way the fully automated system does. We specify pickup and set down times for the operators and the number of operators in each bay.

The fourth version has operators who move the wafers directly between any two tools without necessarily going through a stocker. There is a pool of operators available for moving the lots between tools.

The material handling systems can be operated in one of two modes: push or no push. In the push mode, lots are pushed to the next tool if there is at least one lot port available. In the no push mode, a lot is pulled to a tool when the tool is ready to process it.

3 EXPERIMENTS

To make the correct strategic decisions for a 300mm wafer fabrication line we must understand the effect of the level of automation, alternative tool layouts, various operations management policies, product and process diversity, demand fluctuations, and factory scale. Simulation experiments are combined with financial analysis to study these effects.

3.1 Level of Automation

We are investigating the difference between the four levels of automation described above in Section 2.2: (1) no automation, (2) semi-automated with operators moving lots in the bays, (3) fully automated using stockers, and (4) point to point.

3.2 Layout

Several different tool layout schemes are being investigated. A serialized functional layout has mostly similar equipment grouped together in one location with some dissimilar equipment that is commonly used before or after the equipment of the key functional group. This allows lots to be processed without having to travel long distances between consecutive steps. Typically, cheaper equipment is distributed to the primary functional group to minimize cycle time and the possibility of starvation of the primary tools. Metrology and clean/wet equipment could be distributed near primary processing groups like photolithography, furnaces, implanters, CVDs, sputterers, etchers, or CMPs.

A stratified functional layout splits the equipment of one or more of the functional groups into two or more subgroups at different locations. One way to split the equipment is based on front end of line and back end of line processing. This layout is meant to limit the number of long travels to a few instances and localize the majority of lot travels to shorter distances between process steps. One way to make this split would be to have a front area with front photolithography, furnaces, and ion implanters, and a back area with back photolithography, furnaces, CVDs, sputterers, and metal etchers. The non-metal etchers could be between these two areas and the CMPs in another area.

3.3 Operations Management

Operations management alternatives include different lot sizes, equipment dedication, and lot scheduling. We are experimenting with fixed lot sizes with one product per lot with 25, 18, and 12 wafers per lot. We are also investigating variable lot sizes.

Equipment dedication can reduce setups and also reduce throughput capability. Similar equipment capable of performing several processes is sometimes divided into two or more tool groups. Each tool group is then qualified to execute a subset of the processes or recipes for which it is capable to perform. Such dedication of tools to recipes is employed partly to reduce or eliminate long setups required when switching recipes.

Several lot scheduling algorithms are being studied. These include first come first served, setup avoidance which selects a lot to process which avoids performing a setup, and coordinated pull which could select a lot before a tool is idle, and the candidate lots include both those in the current and upstream tool groups.

4 INITIAL RESULTS

It has been difficult to obtain all of the data we need to run the model, and to revise the model to include all of the features we want to represent. The model currently includes batching tools with minimum and maximum batch sizes, lots with both 24 and 12 wafers, preventive maintenance and down times, setups, and yield percentages. With no tool running too close to 100% utilization, the version with 12 wafers per lot has a cycle time which is about 16% better than the version with 24 wafers per lot. The model currently does not include the following features: automated material handling system (AMHS), operators, reticle management, more complicated scheduling algorithms, and more product diversity. Smaller lot sizes should have more contention produced by some of these missing features.

5 SUMMARY

The model of the 300mm wafer fabrication line discussed in this paper contains a very realistic representation of a future factory. We are using this model to make strategic decisions related to the design and operation of the semiconductor factory.

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