Simulation of Efficient FlowControl for Photolithography Process Manufacturing of Semiconductor

Youngshin Han

School of Electrical and Computer Engineering Sungkyunkwan University
300,Chunchun-dong, jangan-gu, Suwon,
Kyunggi-do 440-746, S. Korea

Chilgee Lee

School of Electrical and Computer Engineering Sungkyunkwan University
300,Chunchun-dong, jangan-gu,
Suwon,Kyunggi-do 440-746, S. Korea

ABSTRACT

Semiconductor wafer fabrication is a business of high capital investment and fast changing nature. To be competitive, the production in a fab needs to be effectively planned and scheduled starting from the ramping up phase, so that the business goals such as on-time delivery, high output volume and effective use of capital intensive equipment can be achieved. In this paper, we propose Stand Alone layout and In-Line layout are analyzed and compared while varying number of device variable changes. The comparison is performed through simulation using ProSys; a window 98 based discrete system simulation software, as a tool for comparing performance of two proposed layouts. The comparison demonstrates that when the number of device variable change is small, In-Line layout is more efficient in terms of production quantity. However, as the number of device variable change is more than 14 times, Stand Alone layout prevails over In-Line layout.

1 INTRODUCTION

Semiconductor manufacturing is traditionally more complicated than any conventional manufacturing area both in terms of technology and manufacturing procedure. Traditional industrial engineering analyses through manufacturing areas are simply not enough to analyze these complex manufacturing areas.

The cost of equipment is, according to the National Technology Roadmap for Semiconductors, approaching 90% of the factory capital costs.

To operate the factory profitably, high machine utilization is a major focus. On the other hand, the factory has to achieve short cycle times to guarantee delivery dates, to prevent high inventories of materials and to keep the production line flexible. Planning capacity in such a environment with constantly changing conditions is complicated.

Photolithography is usually the bottleneck process with the most expensive equipment in a wafer fab. Being one of the processes that is repeated the most during fabrication, any reduction in photolithography cycle-time will reduce overall fab cycle-time. Life cycle of these devices is becoming shorter and shorter as the semiconductor manufacturing technology advances more rapidly. Therefore, the nature of semiconductor manufacturing devices makes preventive maintenance a critical factor for productivity.

Dynamic nature of semiconductor manufacturing process resulting from physical contingency and unplanned breakdown makes simulation a very practical and cost effective approach for analyzing what-if scenarios.

Objective of this study is to compare productivity of two different process layouts, In-Line and Stand-Alone, and set guidelines considering number of lot changes (setup) as the most critical factor.

2 SEMICONDUCTOR MANUFACTURING PROCESS

2.1 Characteristics

It takes 6~8 weeks for making 256DRAM, also the main recipes are over 400 complex processes.

There are multiple semiconductor types and each production line costs move than one billion dollars. Unlike other equipment industries, a semiconductor has some special conditions, the binning and substitution, random yield, complex recipe, rapid change of technologies and products.

2.2 Semiconductor's FAB Processing

The FAB processes are consist of a oxidation recipe which is making oxidation film, a photo recipe which is exposing a special area on wafer, a etching recipe which is cleaning the special area on wafer, a etching recipe which is cleaning the special are by chemical reactor, and a implantation or diffusion recipe that inserting some impurities. Repeating all these processes the FAB recipe is made figure 1.

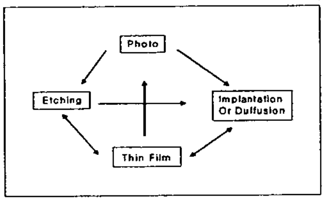

Figure1.Major processes of FAB

2.3 The Photolithography Process

Block diagram of product flow through the lithography area in a fab is shown in figure 2. Typically, the wafer lot to be processed goes through Coat operation, where the wafers are coated with resist. After the wafers are coated, the wafer lot is moved to the Expose operation where the product masks are photographed on the wafers. The lot is then moved over to Develop operation, where the photographed wafers are developed. When once these three steps are done, the lot typically is moved to post photolithography analytical operations. The number of post lithography operations a lot goes through is usually dependent on the product and the mask layer being processed. The rate at which a given equipment can operate is also typically dependent on the product and layer under process. In most of the cases Coat, Expose and Develop equipments can run uninterrupted when once a lot of wafers is loaded on the machine. This study focuses on Photo device consisting of Coater, Stepper, and Developer.

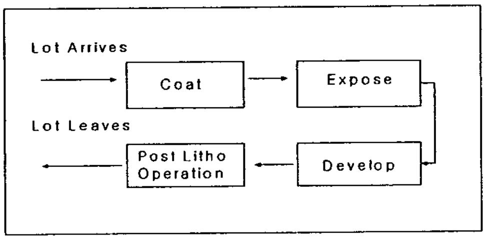

Figure 2. Typical Photo Lithography Process Flow

3 SYSTEM DESCRIPTION

3.1Current Layout using In-Line Process

In-Line process consists of Coater, Developer, Stepper, Wafer, Device Change, Robot, AGV, and Buffer.
Figure 3 shows 12 devices, each of which is a group of equipments for the same process. Assumptions for modeling are as follow; one lot consists of 25 wafers, AGV inside equipment moves on rail to transfer wafers, only one product type and five process steps are considered.

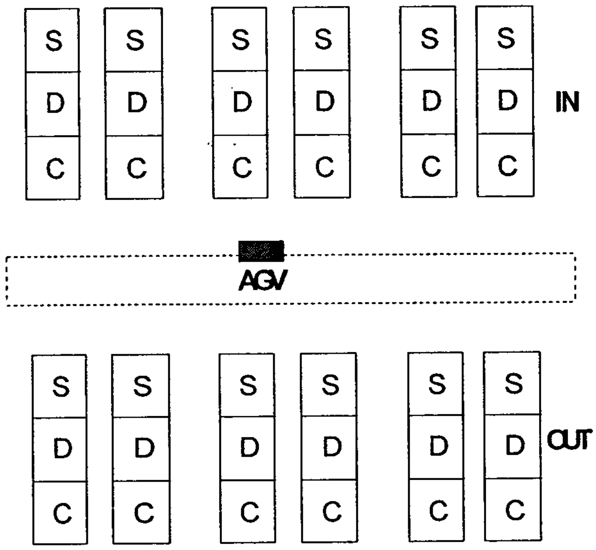

Figure 3. Material Flow in In-Line systems

Each equipment can process up to 4 lots simultaneously. A new lot cannot be loaded to equipment when indexing unit is occupied. Once a new lot is loaded, each wafer is fed into equipment by the indexing unit. When buffer is available, AGV serves nearest equipment. Loading and unloading time is about 25 seconds. Coater, Stepper and Developer time are 4 minutes, one and half minutes, and seven minutes, respectively. Robot 1 and 2 moves wafers first that are heading for Developer. Transfer time of robots are 3 – 5 seconds.
AGV moves on a fixed rail counter clockwise. AGV can hold only one lot at any time.

3.2 New Layout using Stand Alone process

Stand Alone system is different from current layout in that equipments are grouped together based on process.

Groups of equipments are organized and operated separately from other groups with a similar concept of Job Shop. System consists of Coater, Developer, Stepper, Robot, AGV, Tester, and Controller.

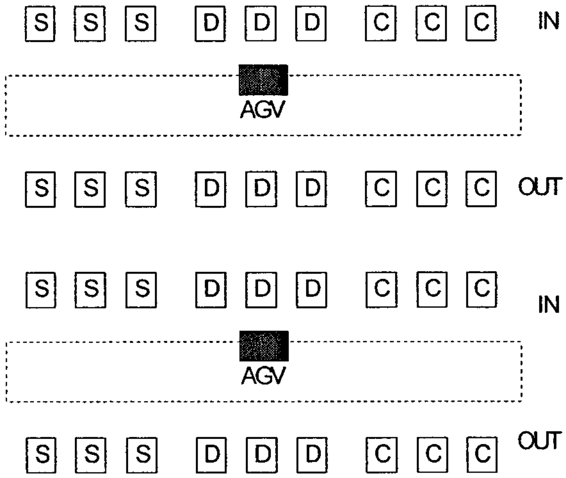

Figure 4 Material Flow in Stand Alone layout

Figure 4 shows AGV carrying four lots at one time. Production conditions are same as In Line layout, however this layout supports that AGV can select alternative equipment within a group if one equipment breakdowns.
In Stand Alone system, there are two 6 sets of Coater, Stepper, and Developer. In this study, simulation model is developed for one 6 sets, and final result of two 6 sets is computed as a double of one set, since two sets are identical layout wise. Then resuls of both stand alone and In-line system are compared.

4. DEVELOPMENT OF SIMULATION MODEL

ProSys which is used as a modeling and simulation tool in this study allows for defining custom algorithms and concurrent animation.

4.1 Current Layout

Figure 5 shows graphic presentation of current layout, where each of 12 processing equipment has Coater, Stepper, and Developer integrated as one unit, and are connected via AGV.

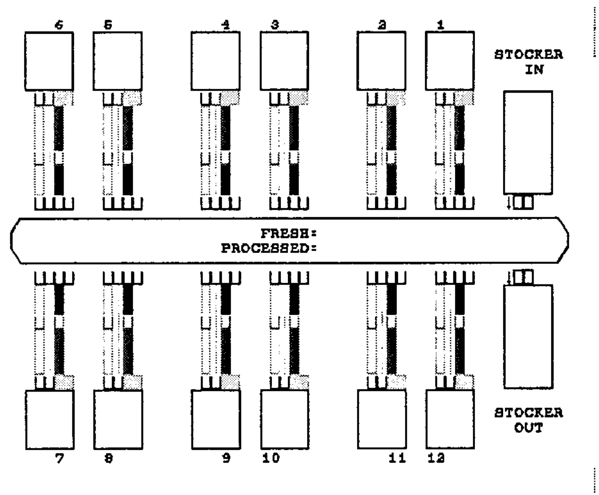

Figure5.Graphic presentation of current In-Line layout

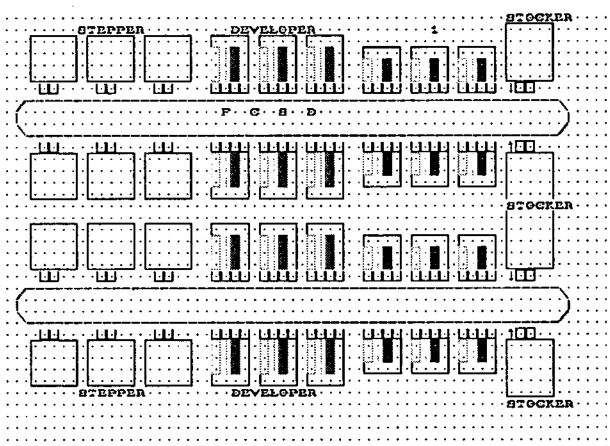

Figure 6.Graphic presentation of proposed Stand Alone Layout

4.2 New Layout using Group Technology

Figure 6 shows new layout using Group Technology, where each equipment is a separate process connected via AGV.

5. EXPERIMENTATION AND ANALYSIS OF RESULT

5.1 Experimental Design

In this study, production quantities of two layouts with number of device change are varied from 6 to 16. Two sets of simulation are performed. First simulation is to compare performance assuming no breakdown and no device change for 24 hours. Second simulation is made for 48 hours, assuming equipment breakdown and device change.

For each combination of factors, multiple runs must be made using different random numbers. For this study, n=1 is assumed since all system components are highly automated and randomness is not a critical aspect.

5.2 Summary of Result

In-Line system (283 in and 235 out) outperforms Stand Alone (276 in and 178 out) when no breakdown and no device change is assumed.

Below are simulation results when equipment breakdowns once and device changes for 48 hours. Table 1 shows number of Lot entered in systems with device change. Table 2 shows number of Lot produced in systems with device change.

Device Change	In-Line(Lot)	Stand Alone(Lot)
6	490	420
8	484	412
10	471	416
12	465	408
14	417	430
16	402	436

Table 1.Number of Lot entered in In-Line vs. Stand Alone of Device Change

Device Change	In-Line(Lot)	Stand Alone(Lot)
6	442	344
8	436	350
10	424	344
12	417	350
14	406	352
16	398	355

Table 2.Number of Lot produced in In-Line vs. Stand Alone of Device Change

Figure 7 shows when the number of device change is small, In-Line Layout is more efficient in terms of production quantity. However, as the number of device change is more than 14 times, Stand Alone Layout prevails over In-Line Layout.

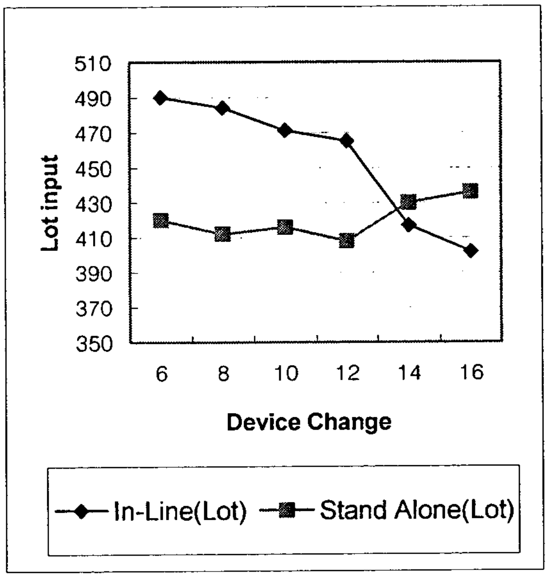

Figure 7. Lot input vs. Device Change

6. CONCLUSION

The result of experiment came out as follows. When we experimented the 24 hours simulation, there was more production amount in In-Line system, and there was little difference in AGV idle time between two systems.

As the equipment breakdown occurs once a day and daily planned lot change increase, the In-Line system is mostly

superior in production amount compared to Stand Alone system in the range that we adopted in the this study. However, as the planned daily production number increases, expected reduction in effectiveness of Stand Alone system is far less than In-Line system. Therefore, if frequency of maintenance and lot change is high or passes certain level, Stand Alone system is found to be more productive.
Presently, both systems are used without particular standard in semiconductor production line, we believe that there will be many advantages not only in the efficiency of equipment but also the production amount.

7. ACKNOWLEDGEMENTS

The authors would like to acknowledge the financial and other support for this project provided by the Korea Science and Engineering Foundation(KOSEF). Project Number:2000-2-30200-003-3

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YOUNGSHIN HAN received the B.S. degree in Economics and the M.S. degree in Computer Science from the Ewha Women's University and she is pursuing the Ph. D. degree in Electrical and Computer Engineering Sungkyunkwan university. Her research interests include manufacturing automation and semiconductor process modeling

CHILGEE Lee the BSEE degree from Sungkyunkwan University, MS degree in Electrical and Computer Engineering from the Arizona State University, and Ph.D degree in Electrical and Computer Engineering from the University of Arizona.
He worked at the Samsung Electronics Co. As a senior research engineer. Currently he is an associate professor of electrical and computer engineering at the Sungkyunkwan University. His research interests are in production optimization, planning and scheduling, and has been supported by the Samsung Electronics Co., the Department of Education and the Department of Industry of Korean Government.