

SEMICONDUCTOR CIRCUIT FABRICATION PLANT MANAGEMENT BY DISCRETE SIMULATION

E. PEYROL, L. PIBOULEAU*, J. P. COUDERC, S. DOMENECH

Laboratoire de Génie Chimique URA CNRS 192
Ecole Nationale Supérieure d'Ingénieurs de Génie Chimique
Chemin de la Loge, 31078 Toulouse Cedex FRANCE

Phone : 61 52 92 41

Fax : 61 25 26 90

ABSTRACT

A discrete simulation program for semiconductor circuit fabrication plant management, including the treatment of pieces of equipment and operators has been developed using the FORTRAN language, in order to produce a portable package offering a graphic interface with a standard graphic system (GKS). The program possibilities will be illustrated by presentation of a simplified example, representative of an actual large-scale plant.

**PAPER SUBMITTED AT THE 4TH INTERNATIONAL
CONFERENCE ON SIMULATION OF SEMICONDUCTOR
DEVICES AND PROCESSES
ZURICH, SWITZERLAND, SEPT. 14, 1991**

*Author to whom all correspondence should be addressed.

1- INTRODUCTION

This study has been undertaken to improve the performances of a Semiconductor Circuit Fabrication Plant (SCFP). The need to respond to day-to-day changes in plant status (equipment and/or operators), customer requirements and availability of materials, makes short-term industrial scheduling a complex problem, particularly for microelectronics plants.

Indeed, circuit fabrication on wafers is an extremely difficult procedure that is generally organized as a job-shop operation. Each silicon wafer undergoes several tens of process steps during several weeks. Another confounding factor, from an operation management standpoint, is that the wafer lot flow is not linear through the plant; that is to say, a wafer lot revisits several basic process operations (photolithography, diffusion, ...) many times during its complete fabrication.

Due to the high combinatorial aspect of the scheduling problem, which results from the necessity to take into account a large number of pieces of equipment, operators, and types of circuits to be produced, a rigorous approach based on mathematical programming procedures seems to be cumbersome in terms of computational needs. So, a discrete simulation method has been selected for this work in order to describe a SCFP consisting of time consuming activities which must be performed in a predefined order using a given set of resources.

2- PREVIOUS WORKS

In the framework of multipurpose batch plant management, several approaches have been distinguished in the literature :

- application of minimax algebra (PATSIDOU and KANTOR,1991)
- mixed-integer programming (BIREWAR and GROSSMANN,1990)
- Petri Nets (GOOS and HARTMANIS,1989)
- stochastic models (SLOWINSKI and WEGLARZ,1990)
- discrete simulation (BEL,1983; CUILLE and LUCET,1988).

Our objective has been to develop a simulation program able to determine the whole chronology of discrete events occurring during the operation of a SCFP, starting with a description of the workshop structure, process inventory, operator activities and production requirements. Major tools for simulation of these systems include the set of commercially available discrete-event simulation languages such as GPSS, Simula, SLAM, PROLOG and recently SIMAN (KREUTZER,1986). However in order to produce a portable package, offering a graphic interface using a standard graphic system (Graphic Kernel System, see Ref. GKS), the FORTRAN 77 language has been chosen. Furthermore, a simulation program in FORTRAN being written for a given application, the problem specificities can be taken into account, and so programming can be optimized with regard to CPU time.

3- SIMULATION MODEL

The model must be able to take into account a large-scale, multiproduct batch processing system where more than a hundred product types (regrouped into less numerous classes) are produced in a plant with also, of the order of a hundred significant pieces of equipment.

3-1 Process Description

The main characteristics of the SCFP studied, which have been included in the simulation program are:

- * common resources (pieces of equipment or cells of equipment) can be used at various steps in the fabrication process; for example, a lithography equipment can be used two or three times, at the beginning of the process and in the middle (one week later, for example)
- * the product entrance frequency in some sets of equipment can be different from that corresponding to the total processing time at that step, which gives rise to a product entering before the preceding one has exited
- * several equipments can be used in parallel
- * the capacity of some equipment is not one lot, but of several or of a fraction of lots.

The decision rule implemented to resolve the product conflicts has been the classical FIFO (First In - First Out) rule. Furthermore several constraints relating to operators (disponibility and number) have been included into the model.

3-2 Program Inputs

The model has been organized to read data sets describing:

- * the products (identification, specifications, class)
- * the equipment (capacity, input frequency)
- * the processing times (by class of products and equipments)
- * the equipment capacity by class of products
- * the equipment interconnections
- * the available operator pools and their specific assignments (with break/lunch periods also)
- * the number of operators by area (the whole plant is divided in working areas)
- * the preventive maintenance tasks
- * the inventory
- * the set of input orders and the date these orders arrive at plant.

3-3 Simulation Program

The description of the processing path for each product in the workshop has been organized as a list of pieces of information concerning the duration of elementary steps and the direct interactions between these steps. The purpose of the simulation program is to generate the

complex interactions between all these steps, associated to a plant having a given topology, and then calculate the date of all events marking the beginning and the end of each step, by using simple Propagation Rules (PR). In the program, unlimited intermediate storages have been assumed to exist for each production step. In order to clearly describe the program, let us define the following concepts.

* **Task**: a task is a major step of operation (a unit operation like photolithography, diffusion, CVD,...) and a subtask is an elementary step within a task (filling or emptying a reactor, dead time,...). The duration of all the subtasks are part of the data required for simulation.

* **Activity**: during the period of time where the state of a product (or a task) does not change, the product (or the task) is said to be engaged in a given activity (which may be waiting).

* **Event**: an event is any change of a product state which starts up a non allocated activity.

In the simulation program, the following events have been considered and managed:

* **Product entry in a step**

- conditions: non allocated step, available product and non active operator(s)
- PR: active product, active step, determination of the new release time for operator(s) and computation of the following intervention date of operator(s) at this step.

* **Operator(s) intervention at a step**

- conditions: non active operator(s)
- PR: i) if the event is the end of a task: available product, available task, determination of the new release time for operator(s)
- ii) if the event is the end of a subtask: determination of the new release time for operator(s) and computation of the following intervention date of operator(s) at this step.

* **Event determined by the set of orders**

- conditions: non active operator(s) (break or lunch period) or non active equipment (maintenance)
- PR: determination of the new release time for this resource.

3-4 Program Outputs

The program outputs provide both statistic reports and the processing path for each product (in a table or graphical format) for a given horizon time. The statistic reports give equipment and operators utilizations (percentage of time the resource spent active), queue statistics (how and where lots are stocked during the horizon time). The horizon time is defined by the user, and so the program execution can offer a global overview of the plant (particularly the process inventory) at any given date. The graphic interface with the package GKS gives the GANTT chart which also provides a very synthetic overview of the processing path for each product.

4- NUMERICAL EXAMPLE

Due to the confidential nature of the industrial SCFP studied in this work, only a didactic example will be presented at the Conference. However, except for the number of products and steps which will be lower than in the actual case, this example has been built up to present nearly the same characteristics as the actual SCFP: resources having product input frequencies less than their own processing times, parallel equipments, common resources, resources processing several lots simultaneously, equipments having a processing capacity less than one lot and two classes of products. In this example, lot and product will represent the same entity and three operators are taken into account, all their interventions are 4 minutes long.

Six products, regrouped in two classes A (products 1,2,5) and B (products 3,4,6), are to be fabricated during production campaign of 200 minutes long, in a workshop involving six processing steps, with two parallel steps (3 and 4), as it is shown in Fig.1 for products of class A and in Fig.3 for products of class B. The elimination of cycles in Fig.1 gives rise to the linear processing path for products of class A shown in Fig.2, where steps are renumbered (the actual numbers of steps are put in brackets); so the step 5 in Fig.3 corresponds to step 2 in the actual plant. In the same way, the elimination of cycles in Fig.3 gives rise to the linear processing path for products of class B shown in Fig.4. In Fig.2 and 4, steps 3 and 7, steps 4 and 8, and steps 2 and 5 are common steps; furthermore steps 3 and 4 (and steps 7 and 8) can process two lots simultaneously, even though capacity of step 6 is one half lot. Finally, steps 2 (and also 5) and 9 have product input frequency of five minutes. The processing times for the two classes of products at each step are given in Table 1 and the input order date of products is reported in Table 2.

Some statistics reports concerning step 4 are presented in Table 3, the processing path of products 1 and 3 of the 7th production campaign are given in Table 4, and queue statistics for step 4 are reported in Table 5. The GANTT chart for the 8th production campaign where the plant is in a steady-state behavior, obtained with the package GKS is shown in Fig.5. Finally, the average time of service for operators is reported in Table 6. In all Tables and Figures, the numbers put in brackets and following the product indexes represent their production campaign.

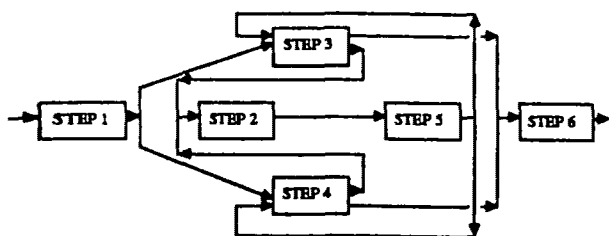


Fig. 1

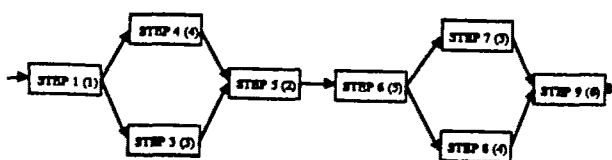


Fig. 2

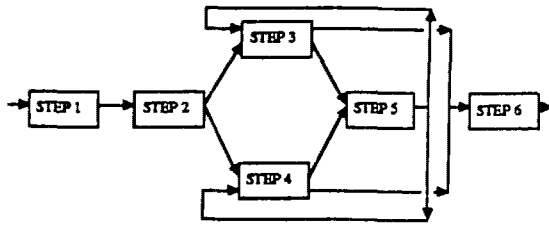


Fig. 3

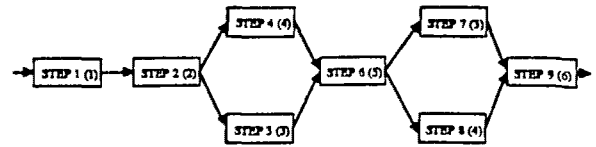


Fig. 4

STEP CLASS	1	2	3	4	5	6	7	8	9
A	10	0	40	40	20	10	40	40	20
B	15	15	50	50	0	10	50	50	20

Table 1

PRODUCT	1	2	3	4	5	6
CLASS	A	A	B	B	A	B
INPUT ORDER DATE	0	0	20	20	50	60

Table 2

Step 4

Number of lots processed : 5 lots
 Flow per hour : 1.5 lots/hr
 Utilization rate : 50 %
 Average time of service : 57.5 %

Table 3

Product 1 (7)

STEP	1	2	3	4	5	6	7	8	9
Input dates	4	-	-	45	88	112	160	-	200
Output dates	14	-	-	86	110	132	200	-	223

Product 3 (7)

STEP	1	2	3	4	5	6	7	8	9
Input dates	34	53	-	92	-	152	-	194	244
Output dates	49	70	-	142	-	174	-	244	269

Table 4

PRODUCT	INPUT	OUTPUT	WAITING
1 (7)	15	44	29
2 (7)	33	44	11
3 (7)	65	93	28
4 (7)	88	93	5
6 (7)	125	143	18

Table 3

	Average time of service
Operator 1	52 %
Operator 2	68 %
Operator 3	84 %

Table 6

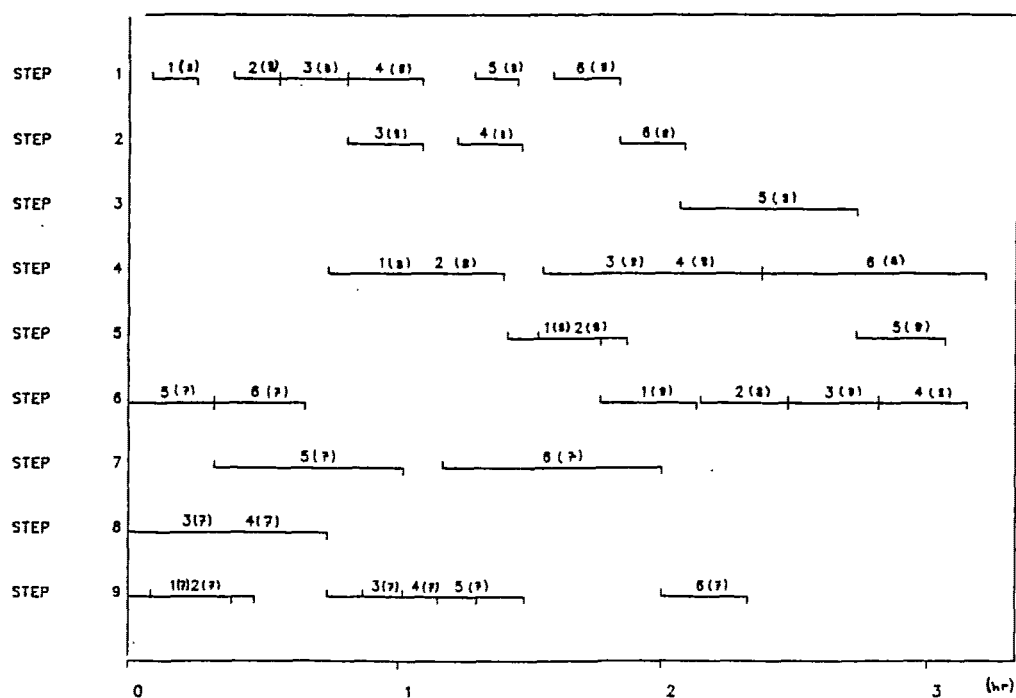


Fig. 3

Acknowledgements - The authors gratefully acknowledge financial and technical support from Motorola Inc. (Toulouse).

REFERENCES

G. BEL, " Méthodes et Langages de Simulation pour la Production Automatisée : Principes, Choix, Utilisation ", Proceedings of AFCET Automatique, Besançon, pp. 41-52 (1983).

D.B. BIREWAR and I.E. GROSSMAN, " Simultaneous Synthesis, Sizing, and Scheduling of Multiproduct Batch Plants ", Ind. Eng. Chem. Res. , Vol 29, pp. 2242-2251 (1990).

P.E. CUILLE and M.C. LUCET, " Discrete Simulation of Batch Chemical Plants Using Prolog ", Proceedings of CHEMDATA 88, Gothenburg, pp. 316-321 (1988).

GKS Norm / ISO / DIS 7942 / revised by ISO / TC 97 / SC 21 / WG 5-2 / 7.4

G. GOOSS and J. HARTMANIS, "Advances in Petri Nets 1989", Springer Verlag (1989).

W. KREUTZER, " System Simulation Programming Styles and Languages ", Addison-Wesley, Reading, Mass. (1986).

E.P. PATSIDOU and J.C. KANTOR, " Application of Minimax Algebra to the study of Multipurpose Batch Plants ", Computers Chem. Engng . ,Vol. 15, pp. 35-46 (1991).

R. SLOWINSKI and J. WEGLARZ, "Advances in Project Scheduling", Elsevier (1989).