Production Planning and Control Model of Technology Migration for DRAM Industry

Ying-Mei Tu
Department of Industrial Management, Chung Hua University, Hsin Chu, Taiwan, R.O.C.

Keywords: Technology Migration, DRAM Industry, X-factor, Production Planning and Control.

Abstract: Due to product life cycle has been shortened rapidly, it forces the product generation and technology should be enhanced quickly. When technology generation change occurred, DRAM manufacturers always used the past experiences to handle the change process. However, the issues are totally different and it made the companies suffered many difficulties. In this work, a production planning and control model is developed. The production planning focuses on CCR (Capacity Constraint Resources) to define the complete wafer release schedule and apply X-factor to schedule the production processes during the migration period. Regarding to the shop floor control, there are two control mechanisms to control and monitor the migration process, real time control and predicting control. WIP status is the important factor to decide whether the production planner needs to launch the rescheduling module or not in the real time control portion. Besides, a foresee function is performed by predicting control portion which firing the rescheduling module by the bias between the loading and capacity curves.

1 INTRODUCTION

DRAM industry is a capital intensive, high-tech industry with complex processes. Nevertheless, product generation and technology had been quickly enhanced due to short product life cycle. When new technology emerges, it reveals a lower cost and more effective operation model (Cainarca, 1989). Simultaneously, it also means the current competitive advantages of company will be jeopardized (Hastings, 1994). Under this circumstance, manufactures have to launch new technology and retrofit generation equipment to meet the market demand and reduce manufacturing cost. Chou et al. (2007) pointed out the technology life cycle of semiconductor manufacturing usually won't be over three years. Therefore, the semiconductor manufacturers always face the dilemma of new technology migration. Generally, the major competition factor of DRAM industry is the manufacturing cost. That is why the frequency of technology migration is higher than foundries.

When migration occurred, DRAM manufactures always used the past experiences to handle the migration. However, the issues are totally different that caused the manufactures suffered many unknown difficulties. Generally, the production planning of technology migration should take the planning result of high-level strategy into account, such as the start time of migration, output target of new technology…etc., to set the migration tempo and capacity switching schedule. Nevertheless, the uncertainties and dynamic factors of shop floor (ex: machine breakdown, schedule delay for new generation equipment or equipment retrofit…etc.) can not be taken into consideration in the high-level strategy. Besides, the high-level decision is based on the prediction of technology roadmap, there will be some changes and biases between the setup of high-level strategy and the execution of technology migration process. In order to guarantee a smooth and successful migration process, a robust and effective production planning and control model of shop floor for technology migration is very important.

Many researches have proposed some methods for production planning and shop floor control of semiconductor manufacturing. Regarding to the production planning, queuing theory, linear programming and mean value analysis are usually applied to estimate the capacity requirement of workstations and wafer release quantity (Iwata et al., 2003); (Walid and Gharbi, 2002); (Chou and You, 2001). Nevertheless, the system uncertainty and the

Tu Y..
Production Planning and Control Model of Technology Migration for DRAM Industry.
DOI: 10.5220/0003995005990603
In *Proceedings of the 9th International Conference on Informatics in Control, Automation and Robotics* (OMDM-2012), pages 599-603
ISBN: 978-989-8565-22-8

risk of investment are not taken into account. Besides, many researches focused on release policy (Glassey, and Resende, 1998a, 1998b); (Wein, 1988), (Lou, 1989a, 1989b); (Spearman, 1989, 1992); (Bowman, 2002); (Hung and Leachman, 1996). Either opened-loop or closed loop policy is based on the normal production situation and does not think of the events of products generation changes, equipment retrofit and new equipment move-in. According to the shop floor control, many dispatching rules were developed to fulfil the purpose of higher production performance (Dabbas and Flowler, 2003); (Lee and Kim, 2011); (Louw and Page, 2004); (Hsieh and Hou, 2006); (Hung and Chang, 2002); (Uzsoy et al., 1992). Nevertheless, the issues of process migration were not considered either in the release policy nor shop floor control rule. In general, the production system will be more complicated during the technology migration period, such as the instability of products mix, the changes of capacity. Therefore, the proposed methods won't be satisfied the requirements. Moreover, the experiences of semiconductor management showed that the production management will be extremely complicated when there are over three generation products produced in the same time. System performance will be difficult to keep in such a circumstance. Hence, an efficient and effective planning and shop floor control model for a varied system can not only solve the technology migration issues but also be applied to the foundry with multiple generation products.

This paper investigates the technology migration of DRAM industry from manufacturing point of view. In this work, a production planning and control model of technology migration was developed. There are two portions in this model including production planning and shop floor control. The production planning focused on CCR to define the complete wafer release schedule and applying X-factor to schedule the production processes and equipment retrofit during the transition period. Regarding to the shop floor control, there are two control mechanisms to control and monitor the migration process, which are real time control and predicting control module.

2 PRODUCTION PLANNING MODULE

As mentioned above that the migration process has to fulfil the target of high-level strategy. The major decision factors of high-level strategy include the fluctuation of future demand, technology development and company financial situation. The complication and variation of production system are difficult to take into account in the strategy level. Therefore, a robust planning and control model not only can help to a successful migration process but also to find out various migration problems in advance. In production planning module, the major target is to transfer the output targets of new generational products to execution plan. The plan includes the wafer release plan of new/old generational products, the release plan of new generational equipment and equipment retrofit plan. Generally, the placement of new/old generational products will be progressed step by step. Hence, the migration period is divided into several time periods for planning. Furthermore, X-factor is applied to the scheduling process. The following is the procedure of production planning.

Step 1. Set up the time unit
It can be defined as a day, three hours…etc.

Step 2. Plan wafer start schedule
In this step, the wafer start schedule of new/old generational products should be planned by referring the output target of new generational products. Generally, top management will hope to keep the total output of factory as before. However, the manufacturing complexity of new generational products may be higher than old one and it will result to the total output decreasing. Therefore, the total output during migration period should be planned in this step. The sub-steps are as follows.

1) Identify Capacity Constraint Resources (CCR)
Generally, the CCR will be only one of equipment in a factory. However, due to the heavy investment of equipment, several workstations are highly utilized. If we assign the equipment with the highest utilization to be the CCR and based on this CCR to make all plans, the issue of bottleneck shifting will be occurred. Hence, multiple CCRs are suggested and can be the equipment with the utilization rate being higher than the predefined value.

2) Calculate capacity consumption rate of CCRs by new and old generational products
Because the new/old generational products will be processed by the same equipment, the capacity consumption rate should be decided for the calculation of migration plan. The equations are show as follows.

$$CR_M = \frac{C_{O_M}}{C_{N_M}} \qquad (1)$$

$$C_{N_M} = \sum_{q=1}^{x} R_{N_q} \sum_{i=1}^{n} PT_{iN_qM} \qquad (2)$$

$$C_{O_M} = \sum_{k=1}^{y} R_{O_k} \sum_{j=1}^{m} PT_{jO_kM} \qquad (3)$$

$$R_{N_q} = \frac{\lambda_q}{\sum_{k=1}^{x} \lambda_k} \qquad (4)$$

$$R_{O_k} = \frac{\lambda_k}{\sum_{l=1}^{y} \lambda_l} \qquad (5)$$

Where

CR_M :	The capacity consumption rate of new to old generational product in CCR M
C_{N_M} :	The average required capacity for the new generation product in CCR M
C_{O_M} :	The average required capacity for the old generation product in CCR M
R_{N_q} :	The ratio of product q in new generational products
R_{O_k} :	The ratio of product k in old generational products
λ_p :	Arrival rate of product p
PT_{iN_qM} :	The ith processing time of product q in CCR M
PT_{jO_kM} :	The jth processing time of product k in CCR M

3) Compute the reducing quantity of old generational products.

Based on the capacity consumption rate, the reducing quantity of old generational products can be calculated by the following equation.

$$\Delta Q_O = Q_N \times CR_M \qquad (6)$$

Where

ΔQ_O :	The reducing quantity of old generational products
Q_N :	The required quantity of new generational products

4) Release new and old generational products by uniform distribution.

Step 3. Apply X-factor to pre-schedule all production processes.

In this step, the concept of X-factor will be applied to schedule all production process including WIP and new release products, and calculate the loading of CCRs in all time periods. The definition of X-factor is as equation (7) and it has to be defined by new/old generational products and equipment. Regarding to the detailed calculation equations of workstations for the wafer fabrication, please refer to Tu et al. (2009).

$$X - Factor_m = \frac{CT_{pm}}{RPT_{pm}} \qquad (7)$$

Where

CT_{mp} :	The cycle time of product p in equipment m
RPT_{mp} :	The raw processing time of product p in equipment m

Step 4. Plan equipment retrofit schedule.

In order to fulfill the manufacturing requirements of new generational products, some kinds of equipment should be retrofitted. During the equipment refurbishment period, it cannot work and the capacity will lose. Furthermore, it may hurt the factory throughput if the loss belongs to the bottleneck machine. In this step, the equipment loading from schedule result of step 3 has to apply to compare to the provided capacity. The equipment retrofit can be scheduled when the loading is under capacity.

Step 5. Come back to step 2 and recalculate X-factor when the product mix of new/old generational products changed.

3 SHOP FLOOR CONTROL MODULE

Regarding to the shop floor control, there are two control mechanisms to control and monitor the migration process including real time control and predicting control module.

3.1 Real Time Control Module

Generally, WIP status is an important and sufficient information to reflect the production situation. If WIP level in front of workstation is too high, it reveals the capacity of this workstation is insufficient or there is something wrong in dispatching. Contrarily, low WIP level indicates some problems occurred in upstream workstations or wrong dispatching. Both situations cannot achieve the target of plan. In the real time control module, actual WIP level is taken as an indicator to judge the rescheduling mechanism should be launched or not. The buffer management concept of TOC is applied to control CCRs. Besides, the queuing theory and the capability of factory management are used to define the high and low control limits. When WIP level is over these limits, the response module will be triggered. The control limits are defined as the following equations.

$$HL_j = (\lambda_j \times P(W > 0) \times EW_j) \times (1 + \alpha) \qquad (8)$$

$$LL_j = (\lambda_j \times P(W > 0) \times EW_j) \times (1 - \alpha) \qquad (9)$$

$$P(W > 0) = \eta \times EW_j \qquad (10)$$

$$\eta = 2m_j(1 - \rho_j) / (C_{aj}^2 + C_{sj}^2) \qquad (11)$$

$$EW_j = \frac{C_{aj}^2 + C_{sj}^2}{2} \times \frac{\tau_j(\rho_j^{\sqrt{2m_j+1}-1})}{m_j(1 - \rho_j)} \qquad (12)$$

Where

λ_j: Arrival rate of workstation j

m_j: Parameter of capability of factory management（0~1）

EW_j: Expected waiting time of workstation j

C_{sj}: Number of machines for workstation j

ρ_j: Utilization rate of workstation j

C_{aj}^2: Squared coefficients of variation (SCV) of inter-arrival time of workstation j

C_{sj}^2: SCV of service time of workstation j

3.2 Predicting Control Module

As mentioned above, the real time control module is based on current shop floor information to diagnose the plan can be achieved or not. However, current shop floor status is the execution result. If the result is far away from the plan, the most possible action is to revise the plan. It seems behinds manager's expectation. Therefore, a predicting control function is needed in the shop floor control module. In predicting control module, a foresee function will be performed which will trigger the response module when the bias between loading and capacity curves is over the predefined deviation tolerance (DT). The major task of the foresee function is to predict the production situation in the future. The deterministic simulation is applied to this function. Based on the deterministic simulation, the loading curves of CCRs by time can be defined. As to the capacity curves of CCRs, they can be derived from current capacity, the move-in schedule of new generational equipment and equipment retrofit plan. Fig. 3 is an example of equipment capacity curve and loading curve. Besides, as everyone knows that the accuracy of prediction will decrease as the time increasing. Therefore, the time factor should be considered into the bias tolerance. The equation for defining the deviation tolerance is as follows.

$$DT = \beta \times n \times C_n \qquad (13)$$

Where

β: Parameter of capacity deviation

n: The time period

C_n: The capacity of period n

4 CONCLUSIONS

Technology migration is imperative for semiconductor manufacturing, particularly for DARM industry. The migration of technology will result in dramatic decreases in manufacturing cost and significantly increases competitive advantage. Nonetheless, how to guarantee a smooth and successful migration is very crucial. Therefore, the solution of the production planning and control of technology migration for DRAM industry is proposed in this work. There are two major modules developed in this model, one is production planning and the other is shop floor control. The production planning module is based on the output plan of new generational products to come out the wafer start schedule of new/old generational products, equipment retrofit schedule and move-in schedule of new generational equipment. The shop floor control module includes three sub-modules, real time control, predicting control and response module. Through the shop floor control module, the execution can be monitored and controlled to meet the plan target.

Regarding to the future works, the response module can be enhanced. An ideal response module should provide the detailed action items instead of direction when the abnormal situation occurred. Therefore, an intelligent system should be set up in this module.

ACKNOWLEDGEMENTS

The author would like to thank the National Science Council of the Republic of China for financially supporting this research under Contract No.NSC 100−2628−E−216−002−MY2.

REFERENCES

Bowman, R. A., (2002). Job Release Control Using a Cyclic Schedule, *Production and Operations management*, 11(2), 274-286.

Cainarca C., (1989). Dynamic Game Results of the Acquisition of New Technology, *Operations Research*, 37(3), 410-425.

Chou, Y. C., Cheng, C. T., Yang F. C. and Liang, Y. Y., 2007. Evaluating alternative capacity strategies in semiconductor manufacturing under uncertain demand and price scenarios, *International Journal of Production Economics*, 105(2), 591-606.

Chou Y. C. and You, R. C., (2001). A Resource Portfolio Planning Methodology for Semiconductor Wafer Manufacturing, *International Journal of Advanced Manufacturing Technology*, 18(1), 12-19.

Dabbas, R. M., & Fowler, J. W., (2003). A new scheduling approach using combined dispatching criteria in wafer fabs. *IEEE Transactions on Semiconductor Manufacturing,* 16(3), 501–510.

Glassey, C. R. and Resende, M. G. C. (1988a), 'Closed-loop job release control for VLSI circuit manufacturing', *IEEE Transactions on Semiconductor Manufacturing* 1/1, 36-46.

Glassey, C. R. and Resende, M. G. C., (1988b). 'A scheduling rule for job shop release in semiconductor fabrication', *Operations Research Letters* 7/5, 213-217.

Hastings, J., (1994). AmCoEx Five Year Comparsion of Used Computer Prices, *Computer Currents*, 9, 20-24.

Hsieh, S. and Hou, K. C., (2006). 'Production-flow-value-based job dispatching method for semiconductor manufacturing ', *International Journal of Advanced Manufacturing Technology*, 30, 727–737.

Hung, Y. F. and Chang, C. B. (2002). Dispatching Rules Using Flow Time Predictions For Semiconductor Wafer Fabrications, *Journal of the Chinese Institute of Industrial Engineers*, 19(1), 61-74.

Hung, Y. F. and Leachman, R. C., (1996). A production planning methodology for semiconductor manufacturing based on iterative simulation and linear programming calculations, *IEEE Transactions on Semiconductor Manufacturing*, 9(2), 257-269.

Iwata, Y., Taji, K. and Tamura, H., (2003). Multi-objective capacity planning for agile semiconductor manufacturing, *Production Planning & Control*, 14(3), 244-254.

Lee, Young Hoon and Kim, Jeong Woo (2011), Daily stepper scheduling rule in the semiconductor manufacturing for MTO products, *International Journal of Advanced Manufacturing Technology* (54):323–336

Lou, S. X. C., (1989a), 'Optimal control rules for scheduling job shops', *Annals of Operations Research* 17, 233-248.

Lou, S. X. C., and Kager, P. W., (1989b), 'A robust production control policy for VLSI wafer fabrication', *IEEE Transactions on Semiconductor Manufacturing* 2/4, 159-164.

Louw, L. and Page, D. C., (2004). Queuing network analysis approach for estimating the size of the time buffers in Theory of Constraints-controlled production systems, *International Journal of Production Research*, 42(6), 1207-1226.

Spearman, M. L., Woodruff, D. L., and Hopp, W. J., (1989), 'CONWIP: a pull alternative to kanban', *International Journal of Production Research* 28/5, 879-894.

Spearman, M. L., and Zazanis, M. A., (1992), 'Push and pull production systems: issues and comparisons', *Operational Research* 40/3, 521-532.

Tu, Ying-Mei, Lu, Chun-Wei and Chang, Sheng-Hung, (2009). "Model To Determine A General X-Factor Contribution And Apply To Cycle Time Improvement For Wafer Fabrication", *Int. J. Services Operations and Informatics*, Vol 4., No. 3, p.272-291

Uzsoy, R., Lee, C. Y. and Martin-Vega, L. A., (1992). A Review of Production Planning and Scheduling Models in Semiconductor Industry Part I: System Characteristics, Performance Evaluation and Production Planning, *IIE Transactions*, 24(4), 47-60.

Wein, L. M., (1988). 'Scheduling semiconductor wafer fabrication', *IEEE Transactions on Semiconductor Manufacturing* 1/3, 115-130.