IE Interfaces
Vol. 20, No. 3, pp. 277-287, September 2007.

Advanced Planning and Scheduling (APS) System Implementation for Semiconductor Manufacturing: A Case at Korean Semiconductor Manufacturing Company

Seung-Kil Lim[1] · Yong Ho Shin[2†]

[1]Division of e-business IT, Sungkyul University, KOREA
[2]Northeast Asia Logistics Innovation Cluster, University of Incheon, KOREA

반도체 제조를 위한 고도화 계획 및 일정 관리 시스템 구축 : 국내 반도체 업체 사례

임승길[1] · 신용호[2]

[1]성결대학교 e-비즈니스 IT 학부 / [2]인천대학교 동북아물류혁신 클러스터

Semiconductor manufacturing is one of the most complex and capital-intensive processes composed of several hundreds of operations. In today's competitive business environments, it is more important than ever before to manage manufacturing process effectively to achieve better performances in terms of customer satisfaction and productivity than those of competitors. So, many semiconductor manufacturing companies implement advanced planning and scheduling (APS) system as a management tool for the complex semiconductor manufacturing process. In this study, we explain roles of production planning and scheduling in semiconductor manufacturing and principal factors that make the production planning and scheduling more difficult. We describe the APS system implementation project at Korean semiconductor manufacturing company in terms of key issues with realistic samples.

Keyword: productivity improvement, semiconductor manufacturing, advanced planning and scheduling, system implementation

1. Introduction

Leading-edge technology and high capital investment are the most distinct features of semiconductor business. Recently, effective management of manufacturing process is more important than ever before in this business area. Lower cost and higher customer satisfaction become essential factors for competitive advantage in today's marketplace. Those can be achieved with better management capability, while design and production technologies for high-density integrated circuits (IC) have been main factors for competitiveness in semiconductor industry. Effective management should be made in all areas of semiconductor manufacturing process including design of integrated circuits, production of IC chips and delivery of produced chips to customers. Among these areas, IC chip production process is one of the most challengeable area for reducing cost and improving customer satisfaction since manufacturing cost and customer service quality are significantly influenced

†Corresponding author : Yong Ho Shin Ph.D, Miraequan 308, 7-46 Songdo-Dong, Yeonsu-Gu, Incheon, 406-840, Koera, Fax : 032-858-0964, E-mail : yonghoshin@incheon.ac.kr
Received July 2007, accepted August 2007 after 1 revision

by the chip production process. It requires quite a long production lead-time (at least 30 days and even longer than 90 days for some product types) and very complex operational nature (several hundreds of operations performed by thousands of technology-intensive equipments). Here, production lead-time, called as cycle time, is the duration from the release time at the first production operation to the time it is packed ready for shipment.

Basically, IC chip production process consists of four sequential stages; wafer fabrication, electrical die sorting, assembly and final test. First two production stages are generally referred as front-end stages, while the others are referred as back-end stages. At the wafer fabrication stage, electronic circuits are built up layer by layer on raw wafers, thin discs made of silicon or gallium arsenide, by performing several hundreds of operations. A few hundreds of identical chips (called individual chip on the wafer as *die*) are made on each wafer through the wafer fabrication process. Individual die on wafer is electrically tested at the electrical die sorting stage from which good and bad dies are sorted by marking ink dots on bad dies physically or making electronic map (that contains information about electrical test results for dies) for each wafer using some test equipment. At the back-end stages, wafers are cut into individual dies (that is IC chips) and each chip is placed with lead-frame in plastic or ceramic packages at assembly stage, while burn-in and functional tests for packaged chips are performed at final test stage.

For effective management of IC chip production process, some of planning and scheduling decisions should be made carefully. These decisions include demand planning, capacity planning, production planning and production scheduling decisions. Demand planning is associated with formulating sales plan (based on forecasts and sales targets given by top management) that provides types and quantities of IC chips to be sold monthly, weekly and/or daily for given planning horizon. On the other hand, production planning is associated with determining supply plan (that is production plan to meet sales plan) that provides types and quantities of IC chips to be produced monthly, weekly and/or daily for given planning horizon while capacity planning is associated with deciding how to maintain or acquire production resources such as workers and machine equipment needed to satisfy the production plan. Finally, detail schedules, that are used to determine sequences for jobs and operations at machine equipment in production lines, are generated through production scheduling. In other words, when machine equipment of production lines is available after completing a job assigned to the machine, next job or operation to be performed on the machine is determined by the scheduling decision.

There are a lot of theoretical studies on production planning and scheduling for semiconductor manufacturing. Especially, production planning and scheduling for wafer fabrication have been main research topic of many researchers since wafer fabrication is the most important and complex process involving hundreds of operations with very long production lead-time. Previous studies on production planning and scheduling for wafer fabrication can be classified into two types according to main objectives of planning and scheduling. The first type focuses on maximizing throughput with minimum cost (Rupp and Ristic, 2000; Vargas-Villami and Rivera, 2000; Elif Akcah and Uzsoy, 2001; Hsieh *et al*., 2001; Lee *et al*., 2002; Lee and Kim, 2002; Kim *et al*., 2002), while the second type has the objective of meeting due-dates of customers' orders or production orders (Dabbas *et al*., 2001; HoriGuchi *et al*., 2001; Kim *et al*., 1998, 2001, 2003; Hwang and Chang, 2003; Vargas-Villamil *et al*., 2003) without sacrificing system utilization. Besides the research results on production planning and scheduling at the wafer fabrication stage, some researchers study production planning and scheduling at other stages of semiconductor production process such as electrical die sorting (Lee *et al*., 2000; Ellis *et al*., 2004), assembly (Potoradi *et al*., 2002) and final test process (Freed and Leachman, 1999; Sivakumar, 1999). Hsieh *et al*. (2001), Hwang and Chang (2003), Ellis et al. (2004), and Kim *et al*. (2003), well summarize previous research results on production planning and scheduling for semiconductor manufacturing.

Despite lots of theoretical studies on production planning and scheduling for semiconductor manufacturing, only a few research results are practically used for effective management of real semiconductor production processes (Murty and Bienvenu, 1995; Malmstrom, 1997; Pickett and Zuniga, 1997). On the other hand, many semiconductor manufacturing companies implement commercial software packages or develop their own (homegrown) planning and scheduling systems for effective management of their production processes. <Table 1> shows survey results conducted by PriceWaterhouseCoopers (currently IBM Business Consulting Services), one of the

Table 1. Planning and scheduling systems used in major semiconductor companies

		Company							
		1	2	3	4	5	6	7	8
	ERP	SAP, 5Years	SAP, 1Year	Oracle, Not implemented	SAP,	SAP, 5Years	Homegrown, 13Years	Baan	SAP, 5Years
SCM Applications used	Demand planning	APO And i2 APO 1Year i2 Not implemented	i2 2Years	i2 1.5Years	i2 Not implemented	i2 0.5Years	Homegrown 2Years	Homegrown	Mimi and Adexz Mimi 4years,
	Supply Chain Planning	APO Pilot	Homegrown 1Years	i2 Not implemented	i2 Not implemented	i2 3Years	Homegrown 10Years	Homegrown	Adexa 1Year
	Factory Planning	i2 Pilot	Homegrown 2Years	i2 2Years	i2 Not implemented	i2 0.2Years	Homegrown 10Years	Adexa Pilot	Adexa 1Year
	Detailed Scheduling	Homegrown 5Years	MES 5Years	MES 3Years		Homegrown 3Years	Homegrown 2Years	Homegrown	Adexa 1Year
	Material Planning	SAP 3Years	Homegrown 5Years	Oracle Not implemented	SAP 3Years	SAP 3Years	Homegrown 1Years	Homegrown	SAP 3Years

Source: Semiconductor Supply Chain Benchmark, 2001, PriceWaterhouseCoopers

largest global business consulting firm, about planning and scheduling systems used in 8 major semiconductor manufacturing companies. Note that major semiconductor manufacturing companies like Intel, Samsung and AMD participated in the survey although real names of the semiconductor companies are not given in <Table 1> due to confidential issues. As shown in <Table 1>, none of the companies has a complete wall to wall SCM applications suite in place; all surveyed have select modules of SCM applications implemented with varying levels of maturity. Also, commercial software packages from professional solution vendors such as i2 Technologies, Adexa and SAP are used for demand planning, supply chain planning, factory planning and detail scheduling. Professional solution vendors mentioned above called their software packages for planning and scheduling as advanced planning and scheduling (APS) suites since optimization techniques and information technologies are applied into their software packages such as mixed integer linear programming, TOC (Theory of Constraints), Web-based multi-tier client-server architecture with large-scale integrated database.

Although there exist a few articles and survey results that introduce industrial cases of production planning and scheduling systems implementation for semiconductor manufacturing, articles are very rare that explicitly reveal key issues to be resolved for successful implementation of production planning and scheduling systems. Sharing industrial experiences in terms of key issues and lessons learned are very important and useful to both academies and practitioners because challengeable research topics and critical factors for successful system implementation can be identified with the experiences. From these reasons, in this paper, we briefly describe several key issues resolved during APS system implementation project at a Korean semiconductor manufacturing company, which may be useful in building similar APS systems at other semiconductor manufacturing companies.

In the following sections, we firstly explain roles of production planning and scheduling in semiconductor manufacturing and principal factors that make the production planning and scheduling more difficult. Then we describe the APS system implementation project at Korean semiconductor manufacturing company in terms of key issues.

2. Production Planning and Scheduling for Semiconductor Manufacturing

As mentioned earlier, IC chip production process consists of four sequential production stages, wafer fabrication, electrical die sorting, assembly and final test. Typically, there exist several production facilities (in other words, production lines) at each production stage, that is, several wafer fabrication lines (called as wafer FAB shortly), electrical die sorting lines, assembly lines and final test lines exist at each production stages. Wafers fabricated at wafer fabrication lines are transferred to electrical die sorting lines, and then sorted wafers are moved to assembly lines. Finally, packaged IC chips at assembly lines are sent to final test lines. Production planning in such production structure is associated with determining (daily/weekly/monthly) production targets at individual production facilities of each production stages to meet sales plan determined by demand planning for given product (that is IC chip) types over planning horizon. Sometimes the production planning for semiconductor manufacturing is called as supply chain planning at the manufacturing-level since production facilities at production stages are connected like typical supply chains.

There exist a large number of machine equipment at each production facilities. For example, a wafer fabrication facility has several thousands of machine equipment that are used to perform operations needed to build integrated circuits on wafers. Similarly, other facilities for electrical die sorting, assembly and final test have large numbers of machine equipment for their operations. Typically, several hundreds of operations are performed on wafers at wafer fabrication facilities and tens of operations are performed on wafers or IC chips at other production facilities for electrical die sorting, assembly and final test. Since wafers and IC chips visit the machine equipment as a form of lot (composed of multiple wafers or several thousands of IC chips), job sequences (that is, which lot should be processed next when machine equipment is available) at machine equipment need to be determined. This is the main role of production scheduling for semiconductor manufacturing. Here, a lot is composed of a number of wafers, typically ranged from 2 to 25 wafers, and the wafers of a lot are cut into individual IC chips at assembly stage. After the wafers are cut into the IC chips, several thousands of IC chips are included into a lot again that visits machine equipment of assembly and final test stages for completing remained operations.

Now, we examine some principal factors that make production planning and scheduling for semiconductor manufacturing more difficult. These factors can be classified into four categories: uncertainty, operational complexity, and multiple objectives and data management.

2.1 Uncertainty

Availability and reliability of machine equipment are well known factors that cause difficulties in effective management of semiconductor production processes. Note that machine availability and reliability are related with machine breakdowns and inconsistent operational performances of machine equipment, respectively. It is said that machine equipment is not available when the machine breaks down or machine is under the preventive maintenance while machine equipment is not reliable when outputs from the machine are not consistent in terms of quantity and/or quality level. Typical results from limited machine availability and unreliable operational performances in semiconductor production are lower utilizations of machine equipment and yield losses of wafers and/or IC chips. Here, yield is usually defined as the ratio of the number of usable items (wafers or IC chips) after the completion of production processes to the number of potentially usable items at the beginning of production (Cunningham *et al.*, 1995). Considering the machine utilization and yield loss in determining optimal production targets at each production facilities and generating detail schedules of lots of wafers or IC chips at machine equipment are not easy since they are significantly influenced by uncertain factors such as machine breakdowns and inconsistent operational performances as mentioned earlier.

2.2 Operational Complexity

Operational complexity is another factor that makes production planning and scheduling for semiconductor manufacturing more difficult. As mentioned in many research papers (Hsieh *et al.*, 2001; Hwang and Chang, 2003; Vargas-Villamil *et al.*, 2003), production processes of semiconductor manufacturing have several distinct features such as reentrant workflows, batching, time-window constraint, sequence-dependent setup time and auxiliary resources. Reentrant workflows, which occur at the wafer fabrication stage, can be explained as multiple visits of lots of wafers to the same machine equipment for several similar operations. Remember that wafers visit machine equipment as a form of lot for their operations as mentioned earlier. Also, note that several layers are built up on wafers layer by layer at wafer fabrication stage and a layer is completed when a series of operations performed by a set of machine equipment are finished. Since the series of operations required for a layer is similar to those for other layers, a lot of wafers can visit the same machine equipment several times for similar operations required by each integrated circuit layer. We call this as reentrant workflow since wafers revisit same machine equipment several times. Batching is another operational characteristic of semiconductor production that can be explained as simultaneous processing of multiple lots of wafers or a large number of IC chips at machine equipment. Batching occurs at some operations of wafer fabrication and final test stages such as diffusion and burn-in test operations. Also, time-window constraints impose additional complexity on production scheduling since those require that an operation be started within specified time-window after previous operation for the operation is finished. Typical example operations that should satisfy the time- window constraints are pre-processing operations performed to prepare main operations such as cleaning operations. On the other hand, sequence-dependent setup times mean that different setup times are needed to perform an operation according to types of operations that were completed before the operation. Sequence-dependent setup time requirements appear in some etching and test operations. Finally, auxiliary resources should be available in order to start some operations for semiconductor production. Typical examples for auxiliary resources are reticles (called as masks) that are used in doing photolithography operations at wafer fabrication stage. Ultraviolet rays are exposed on wafers through the reticles, from which circuits are printed on the wafers since reticles transmits ultraviolet rays according to the circuit image embedded on the reticles. Operational characteristics of semiconductor production mentioned so far make production planning and scheduling more difficult since these characteristics force additional considerations (such as batching, sequence-dependent setup time and auxiliary resources availability) to be included to make production plan and detail schedule.

2.3 Multiple Objectives

Although semiconductor manufacturing companies' objectives for production planning and scheduling may be different among each other according to their market environments and marketing and/or production strategies, there exist common objectives that are considered as more important ones by many semiconductor manufacturing companies. For production planning, maximizing both profit and customer satisfaction are the most important objectives when determining production targets that meet sales plan and/or customer orders. On the other hand, maximizing throughput and utilization, as well as meeting production targets given by production planning are important objectives for production scheduling. Typically, machine equipment in semiconductor production facilities are very expensive. As a result, many semiconductor manufacturing companies want to fully utilize their production resources. On the other hand, they also want to reduce (or optimize) cycle time and its variation in order to improve responsiveness to external and/or internal requirements such as urgent customer orders and order change requests (that is, maximizing customer satisfaction). For cycle time reduction, the level of work- in-process should be reduced since waiting times of wafer lots in semiconductor production facilities can be cut down with lower work-in-process inventory. However, utilization of machine equipment may be harmful as the WIP level decreases for reducing cycle time since the possibility of being machine idle increases due to less work-in-process inventory. Optimizing several conflicting objectives simultaneously, which are required in production planning and scheduling for semiconductor manufacturing, are very difficult tasks.

2.4 Data Management

Data management is another factor that causes high complexity due to huge amounts of raw data. In general, it is necessary to manage data related to demands, products, operations and resources in order to perform production planning and scheduling. Demand-related data includes product type (product code), due-date, production quantity and customer name or code, while product-related data is product code (product number or product name), bill-of-materials and sales price. On the other hand, operation-related data specifies which operations are needed to make a product type and includes operation name and sequence, machine equipment capable of performing the operation and needed time for the operation. Resource-related data includes names and types of machine equipment and auxiliary resources such as reticles, and set up time if required when performing operations at the machine equipment. In addition to data mentioned above, there exist huge amounts of data to be managed. Since several thousands of operations are needed to produce IC chips and tens of thousands machine equipment are utilized for the operations, very large-sized data about operations and resources should be managed. Furthermore, it is difficult and time-consuming tasks to gather these data needed to generate production plan and schedule since many companies often manage these data at different and/or separate information systems.

Factors discussed above are strongly related with key issues to be resolved for successful implementation of production planning and scheduling system for semiconductor manufacturing. In the next section, we will give details for the key issues mainly caused by the factors when implementing advanced planning and scheduling system based on experiences at a Korean semiconductor manufacturing company.

3. APS System Implementation at a Korean Semiconductor Company

At the beginning of 21st century, a global semiconductor manufacturing company in Korea has devoted to the construction of an optimized supply chain to strengthen its competitiveness in marketplace. The company examined all functional areas included in its supply chain from procurement to logistics as well as production in order to identify possible opportunities for improvement or innovation. Several projects were initiated at that time and some continued until early of 2004. The semiconductor company not only produces typical memory chips such as DRAM and SRAM but also some SOCs (system-on-chips) such as ASIC (Application Specific Integrated Circuit) used by most of electronic products like digital camera and cellular phones. The company operates multiple facilities for each production stages of semiconductor production in Korea and some facilities in other countries. For optimizing supply chain, the company focused on the development of APS system since the company thought APS system is very powerful tool in managing their complex semiconductor production process effectively. So, APS system implementation project started at early of 2000 in which most of planning and scheduling activities are included such as demand planning, capacity planning, and production planning and scheduling. Software packages from i2 Technologies were selected and implemented for the core planning and scheduling activities except for production scheduling. The company developed their own production scheduling system after evaluation of several commercial software packages' functionality for semiconductor production scheduling.

In this section, we give brief descriptions of issues occurred during the APS system implementation project but we focus on issues related to production planning and scheduling at wafer fabrication stage, which are the most complex and difficult tasks in the APS system implementation for semiconductor manufacturing. Also, we limit our discussion to production planning and scheduling for SOCs manufacturing since the complexity of the APS system implementation for those products is greater than that for typical memory chips. First, we briefly introduce main tasks conducted during the implementation project and then the issues identified are described. The following are six main tasks performed during the implementation project.

3.1 Process Analysis

Main objectives of this task are to understand current production and business processes, called as AS-IS processes, and to analyze these processes in order to find opportunities for improvement with newly implemented APS system. Large number of interviews and workshops are done for this task. Note that target activities of this analysis are business processes related to production planning and scheduling that are performed by production planners and managers, and operators' works at shop floor for semiconductor production.

3.2 Issues and Requirements Finding

With the results of *Process Analysis* task, issues to be resolved for successful implementation and functionalities requested by users of the APS system are identified. Note that issues and requirements are different in that issues are problems to be solved for successful implementation of the APS system, while requirements are functionalities requested by system users who will use the implemented system for their works. <Figure 1>. depicts an issue rising from setup minimization objectives. The possible modeling

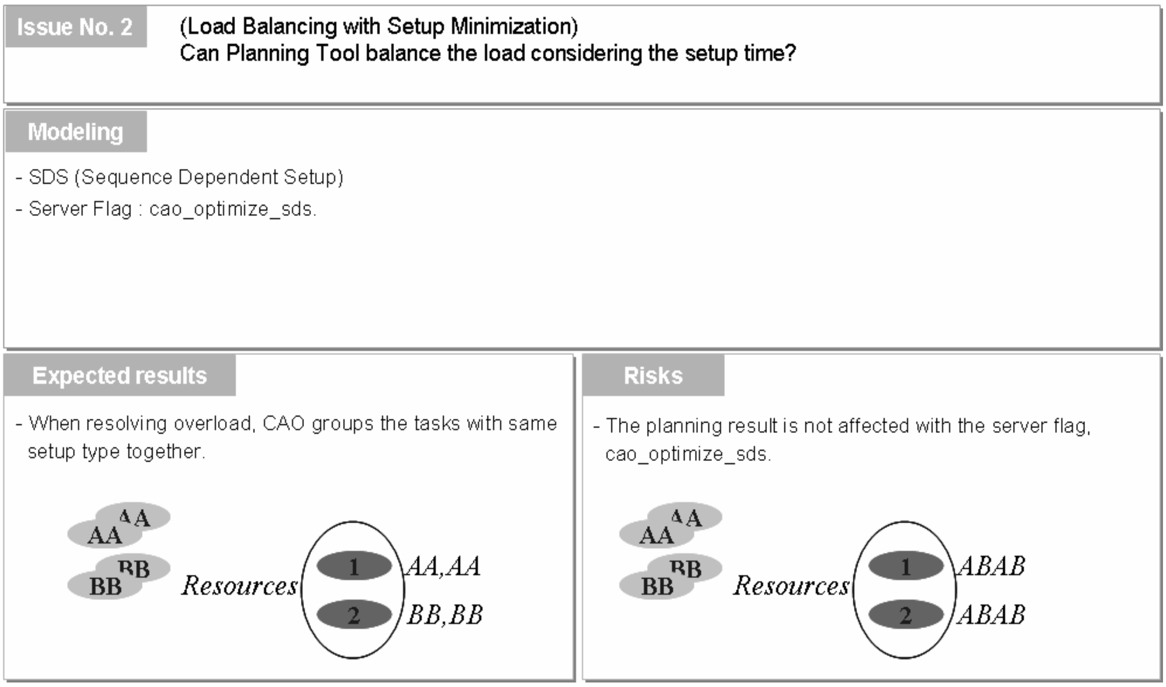

Figure 1. An example of issue and requirement findings

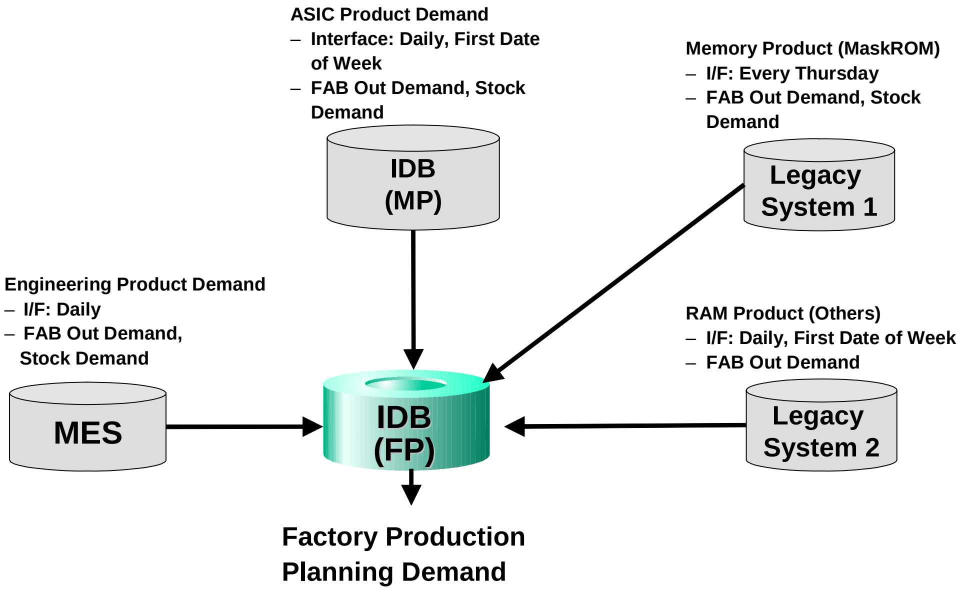

Figure 2. An example for solution mapping (Demand Information for Factory Planner)

methods are supposed and the expected results and risks are explained for the users' validation.

3.3 Solution Mapping

This task is performed to generate solutions for the issues identified by *Issues and Requirements Finding* task. For mapping final solutions to the identified issues, several alternative solutions for each of issues are compared in terms of time and cost needed as well as expected performances on goals of APS system implementation. Also, from this task, we determine which and what functionalities should be provided for users of the APS system. <Figure 2> shows an instance from several solution mapping alternatives. This example describes the solution architecture for inquiring demand order information from legacy and the upper level planning systems.

3.4 Process Design

Based on functionalities of newly implemented APS system, we design improved business and production processes, called as TO-BE processes. Improved processes are devised through several workshops and/or brainstorming of which participants are all of persons related with the APS system such as system users including production managers (of course, top managers of production division) and operators of production lines, and system developers including external consultants and system managers. (Refer to the following figure)

3.5 System Design and Implementation

Included in *System Design* task are modeling database structure and configuring system architecture while *System Implementation* task focuses on installation and customization of selected software packages and developing some computer programs needed for data gathering from several different information systems and providing graphical user interfaces. Here, configuring system architecture is to determine overall system environments such as client-server and/or Web-based three-tier architecture, OS (Operating System) and hardware platforms, and communication structure like intranet and/or extranet.

3.6 Test and Go-Live

This is the final task from which we test functionalities of the implemented APS system and assess quality of production plans and schedules generated by the system. If the test is passed, users now can use the implemented system (that is, the system is in go-live status), additional works should be done until the test is passed otherwise.

4. Critical Issues in the APS Implementation Project

Now, we describe most critical issues identified in the APS system implementation project.

Issue 1: Hierarchy of Production Planning and Scheduling

First of all, we should determine the best hierarchy of production planning and scheduling since production planning and scheduling for semiconductor manufacturing are very difficult tasks due to several factors as mentioned earlier. Like we often divide a

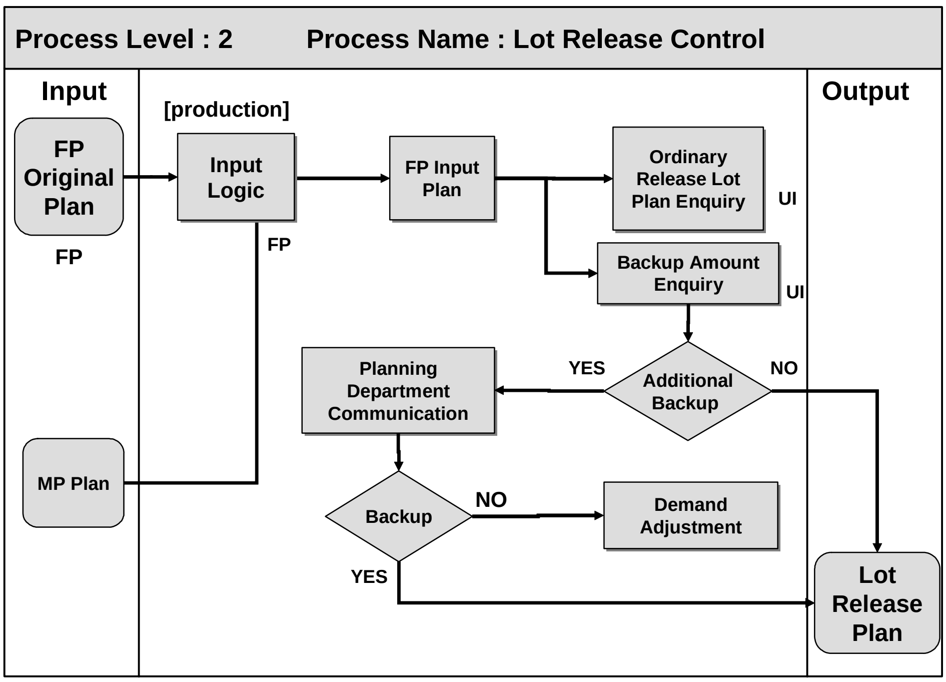

Figure 3. Process Mapping (An example from a realistic implementation case)

very difficult problem into several tractable subproblems in order to obtain feasible solutions in a reasonable amount of time, the hierarchy of production planning and scheduling is needed to divide whole production planning and scheduling decision-making problem into several subproblems and define their relationships. The following figure shows an instance from realistic implementation of planning and scheduling systems at a Korean semiconductor manufacturing company. The objectives, role and running frequency are defined and both the structure and corresponding system can be allocated.

Issue 2: Functionality of Software Package

The second issue is associated with limited functionality of software package. Since most of software packages from professional solution vendors are general-purpose ones, some of functionality needed for semiconductor manufacturing are not supported or do not sufficiently meet requirements of system users. As a result, it is necessary to determine which functionality of software package should be used at what level of satisfaction compared to the requirements of system users.

Issue 3: Data Preparation

Since huge amounts of data is needed for APS system implementation, companies that want to build APS system should prepare the data. However, preparing this data is time-consuming tasks since much of data is dispersed among several information systems and even some are not managed. As a result, it is necessary to make data management plan carefully considering future system developments as well as the APS system implementation.

Issue 4: System Modeling

As mentioned earlier, there exist several factors that make production planning and scheduling for semiconductor manufacturing more difficult. Also, facilities at each production stage have large number of machine equipment and there are large number of product types and operation types. Since most of software packages need a model in order to represent actual system configuration and the performance in terms of quality of plan and schedule, and time required to obtain the plan and schedule is affected by the model, it is necessary to determine how to model the actual system and how to consider the factors such uncertainty and operational characteristics.

Issue 5: Test and Quality Check

One of the most difficult problems in implementing planning and scheduling system is the assessment of quality of plans and schedules that are generated by the implemented system. For the assessment, it is necessary to devise suitable performance measures and systematic test/assessment procedures.

Issue 6: System Architecture

It is necessary to determine system architecture that determines the configuration of hardware plat-

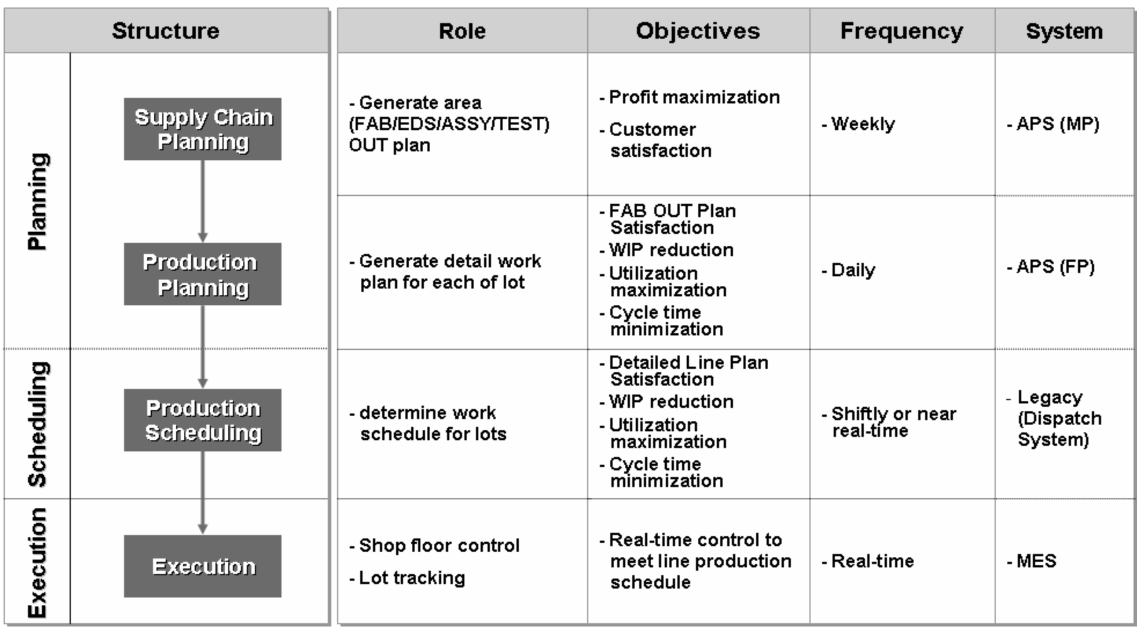

Figure 4. Recommended hierarchy of planning and scheduling for semiconductor manufacturing

forms, O/S platforms and their roles in the entire system configuration. Also, we need to determine appropriate specifications of hardware systems such as memory size, CPU speed and so on.

Issue 7: Training and System Management

When software package from a professional solution vendor is used, it is required that some people should be trained for doing some system management tasks such as modifying and/or upgrading system modeling and system configuration. As a result, it is necessary to determine suitable persons for undertaking the system management tasks and to make a plan for the training.

Additionally, there can be issues for decision making for selecting a commercial ready-made package or legacy system from IT related budget and organizational influences. While a new planning and scheduling system is applied, the project requires the involvement from many organizations like production, planning, marketing and IT departments. Their requirements, conflict resolutions, and organizational reluctance should be considered and an appropriated executive steering committee must play a top-level decision making.

5. Concluding Remarks

In this study, we introduce a real APS system implementation project conducted at one of the largest semiconductor manufacturing company in Korea. Based on actual experiences, we briefly describe several key issues resolved during the APS system implementation project that may be useful in building similar APS systems at other semiconductor manufacturing companies. According to the recent implementation report from the above case, the performance indices show good results. For example, OTD (On time to delivery) increased to 90% from 77% during 4 quarters and the CTPL (Cycle time per layer) was reduced from 1.55 to 1.0 during the same implementation periods. Since articles and research works are very rare that explicitly reveal key issues to be resolved for successful implementation of production planning and scheduling systems, our study that focuses on sharing industrial experiences in terms of key issues are very useful to both academies and practitioners in that both people may find challengeable research topics and critical factors for successful system implementation with the results of this study.

References

Cunningham, S. P., Spanos, C. J., and Voros, K. (1995), Semiconductor yield improvement: Results, and best practices, *IEEE Transactions on Semiconductor Manufacturing*, 8, 103-109.

Dabbas, R. M., Chen, H. N., Fowler, J. W., and Shunk D. (2001), A combined dispatching criteria approach to scheduling semiconductor manufacturing systems. *Computers and Industrial Engineering*, 39, 307-324.

Elif Akcah, K. N. and Uzsoy, R. (2001), Cycle-time improvements for photolithography process in semiconductor manufacturing, *IEEE Transactions on Semiconductor Manufacturing*,14(1), 48-56.

Ellis, K. P., Lu, Y., and Bish, E. K. (2004), Scheduling of wafer test processes in semiconductor manufacturing, *International Journal of Production Research*, 42(2), 215-242.

Freed, T. and Leachman, R. C. (1999), Scheduling semiconductor device test operations on multi head testers. *IEEE Transactions on Semiconductor Manufacturing*, 12(4), 523-530.

Horiguchi, K., Raghavan, R., Uzsoy, R., and Venkateswaran, S. (2001), Finite-capacity production planning algorithms for a semiconductor wafer fabrication facility, *International Journal of Production Research*, 39(5), 825-842.

Hsieh, B. W., Chen, C. H., and Chang, S. C. (2001), Scheduling semiconductor wafer fabrication by using ordinal optimization-based simulation, *IEEE Transactions on Robotics and Automation*, 17(5), 599-608.

Hwang, T. K. and Chang S. H. (2003), Design of a Lagrangian relaxation-based hierarchical production scheduling environment for semiconductor wafer fabrication, *IEEE Transactions on Robotics and Automation*, 19(4), 566-578.

Kim, S., Yea, S. H., and Kim, B. K. (2002), Shift scheduling for steppers in the semiconductor wafer fabrication process, *IIE Transactions*, 34, 167-177.

Kim, Y. D., Kim, J. U., Lim, S. K., and Jun, H. B. (1998), Due-date based scheduling and control policies in a multi product semiconductor wafer fabrication facility, *IEEE Transactions on Semiconductor Manufacturing*, 11(1), 155-164.

Kim, Y. D., Kim, J. G., Choi, B., and Kim, H. U. (2001), Production scheduling in a semiconductor wafer fabrication facility producing multiple product types with distinct due dates, *IEEE Transactions on Robotics and Automation*, 17(5), 589-598.

Kim, Y. D., Shim, S. O., Choi, B., and Hwang, H. (2003), Simplification methods for accelerating simulation-based real-time scheduling in a semiconductor wafer fabrication facility, *IEEE Transactions on Semiconductor Manufacturing*, 16(2), 290-298.

Lee, Y. H. and Lee, B. K., and Jeong, B. (2000), Multi-objective production scheduling of probe process in semiconductor manufacturing, *Production Planning and Control*, 11(7), 660-669.

Lee, Y. H. and Kim, T. (2002), Manufacturing cycle time reduction using balance control in the semiconductor fabrication line, *Production Planning and Control*, 13(6), 529-540.

Lee, Y. H., Park, J., and Kim, S. (2002), Experimental study on input and bottleneck scheduling for a semiconductor fabrication line, *IIE Transactions*, 34, 179-190.

Malmstrom, C. (1997), An integrated approach to planning and scheduling at Phillips Semiconductors, *Proceedings of IEEE/SEMI Advanced Semiconductor Manufacturing Conference* D27-D29.

Murty, S. and Bienvenu, J. W. (1995), Global Planning at Harris Semiconductor, *Proceedings of International Symposium on Semiconductor Manufacturing* 18-23.

Pickett, B. and Zuniga, M. (1997), Modeling, scheduling, and dispatching in the dynamic environment of semiconductor manufacturing at FASL, Japan, *Proceedings of IEEE/SEMI Advanced Semiconductor Manufacturing Conference*, 448-450.

Potoradi, J., Boon, O. S., and Mason S. J. (2002), Using simulation-based scheduling to maximize demand fulfillment in a semiconductor assembly facility, *Proceedings of the 2002 Winter Simulation Conference*, 1857-1861.

Rupp, T. M. and Ristic, M. (2000), Fine planning for supply chains in semiconductor manufacture, *Journal of Material Processing Technology*, 107, 390-397

Sivakuma, A. I. (1999), Optimization of cycle time and utilization in semiconductor test manufacturing using simulation based, on-line, near-real-time scheduling system, *Proceedings of the 1999 Winter Simulation Conference*, 727-735.

Vargas-Villamil, F. D. and Rivera D. E. (2000), Multilayer optimization and scheduling using model predictive control: application to reentrant semiconductor manufacturing lines, *Computers and Chemical Engineering*, 24, 2009-2021.

Vargas-Villamil, F. D., Rivera D. E., and Kempf, K. G. (2003), A hierarchical approach to production control of reentrant semiconductor manufacturing lines, *IEEE Transactions on Control systems Technology*, 11(4), 578-587.

Seung-Kil Lim

B.S. Industrial Engineering, Pusan National University

M.S. Industrial Engineering, Korea Advanced Institute of Science and Technology

Ph.D. Industrial Engineering, Korea Advanced Institute of Science and Technology

Principal Consultant, IBM BCS

Senior Researcher, ETRI

Senior Researcher, Samaung Ecconomic Research Institute

Assistant Professor, Division of e-business IT, Sungkyul University

Interests: Supply Chain Design and Operation Optimization, BPR, Enterprise Information System Applications

Yong Ho Shin

B.S. Industrial Engineering, Seoul National University

M.S. Industrial Engineering, Korea Advanced Institute of Science and Technology

Ph.D. Industrial Engineering, Korea Advanced Institute of Science and Technology

Post-Doctor, Le Havre Univeristy, France

Business Consultant, IBM BCS

Manager, Samsung Electro-Mechanics

Senior Researcher, Jungseok Reserach Institute of International Logistics and Trade

Senior Researcher, Northeast Asia Logistics Innovation Cluster

Interests: Supply Chain and Logisitcs Management, Production and Inventory Management, System Integraion