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Consideration on the Importance of Scheduling in Semiconductor Manufacturing Lines: Focusing on Existing Major Studies

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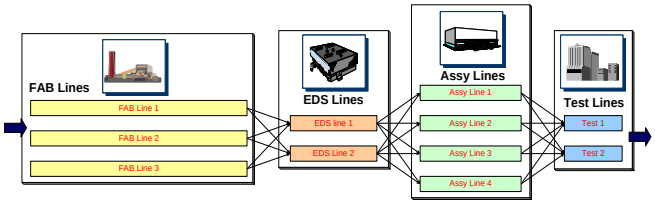
ABSTRACT

In order to secure and maintain a competitive advantage in the semiconductor industry, technological superiority and advanced production operations that support manufacturing technology can be said to be more important than in other industrial fields. In particular, the complexity of scheduling in a semiconductor manufacturing line (FAB) where complex process processes exist is very large, so the development of a scheduling methodology can be considered very difficult. In this study, we introduce the background that emphasizes the importance of schedule planning in semiconductor manufacturing lines and existing studies focused on processes that require schedule planning to be reflected in particular detail. Additionally, the conclusion presents limitations of studies on scheduling of existing semiconductor manufacturing lines and suggests desirable future research directions.

KEYWORDS: Scheduling, Semiconductor, Limitations Of Studies, Future Research Directions

I. INTRODUCTION

In order to secure and maintain a competitive advantage in the semiconductor industry, it can be said that technological superiority and advanced production management supporting manufacturing technology are more important than in other industrial fields. Semiconductor production does not involve all processes being performed on a single manufacturing line as in general manufacturing, but consists of four stages: Fabrication (FAB), Electrical Die Sorting (EDS), Assembly, and Test, as shown in [Figure 1]. . In particular, the FAB stage manufacturing lines are divided into hundreds of processes, take the longest process time out of the four stages, ranging from 60 days to 30 days, and are the core that has the greatest impact on the yield of semiconductor chips. Processes (Photo, Diffusion, Clean, Etch, etc.) and various process constraints and facility characteristics are included. Therefore, in the semiconductor manufacturing industry, efficient production operation for maximizing the productivity of the FAB manufacturing line, improving yield, meeting deadlines and customer satisfaction can be another competitive advantage that competitors cannot easily imitate.



[Figure 1] Semiconductor manufacturing system

Amidst increasing production volume and fierce competition between companies, the top goal of semiconductor production operations is to improve customer satisfaction through improved productivity and satisfactory delivery, and to improve productivity and reduce production costs through improved yield. In particular, recently, customers in the semiconductor industry monitor the yield information of semiconductor companies in real time, and semiconductor chips from companies with low yields are judged to have potential defective elements even if the chips are good products according to the judgment standards of each semiconductor company, so it is necessary to secure yield. is considered an important factor in improving productivity, reducing production costs, and improving customer satisfaction.

The importance of production operation in a semiconductor production line is due to several factors. Semiconductor manufacturing is an industry that requires advanced technology and complex processes, and the efficiency of

production operations directly affects product quality and company competitiveness. The following are key background factors that highlight the importance of production operations.

Advanced technology requirements: Semiconductor manufacturing requires extremely precise technology. In the process of fabricating nanometer-scale fine structures, the precise execution of each step is important. Production operations play a key role in applying and maintaining these advanced technologies.

Complex process steps: Semiconductor manufacturing involves numerous complex process steps, including wafer processing, photolithography, etching, doping, and metallization. Production operations are responsible for coordinating each stage to proceed smoothly and responding quickly when problems arise.

Time and Cost Efficiency: The semiconductor industry is a highly competitive market where time and cost are critical factors. Through production operations, process efficiency can be maximized and production costs can be reduced by reducing unnecessary waste. This is essential to increase competitiveness in the market.

Quality Assurance: The quality of semiconductor products is directly related to the trust of end consumers. Production operations focus on thorough quality control at each process stage and minimizing the occurrence of defective products. This is important to ensure a stable supply of high quality products.

Inventory and Materials Management: Semiconductor manufacturing requires a variety of materials and consumables. Production operations maintain a smooth production flow through proper management of these materials and inventory control. This is important to avoid production disruptions due to overstock or shortages.

Supply Chain Management: Semiconductor manufacturing is closely linked to global supply chains. Production operations maximize supply chain efficiency through stable supply of raw materials, logistics management, and smooth communication with partners.

Environmental and safety management: Semiconductor production uses a lot of chemicals and energy, so environmental and safety management is important. Production operations focus on complying with environmental regulations, maintaining a safe working environment, and adopting sustainable production methods.

Technological innovation and upgrade: Semiconductor technology is advancing rapidly. Production Operations is responsible for continuously upgrading manufacturing processes by rapidly introducing the latest technologies and process improvements. This is essential to maintain technological competitiveness and meet market demands.

Market Responsiveness: Semiconductor demand can fluctuate rapidly depending on market conditions. Production operations play an important role in adapting to market changes and satisfying diverse customer needs through flexible production plans and rapid response.

In this way, production operations in the semiconductor production line play a very important role in technical, economic, and environmental aspects, contributing to the overall competitiveness and sustainable growth of the company. In particular, considering the high process complexity of FAB among production operations, the importance of scheduling can be further emphasized in the following aspects.

Managing Complexity: The semiconductor manufacturing process is very complex, requiring numerous process steps and complex technologies. To effectively manage these complex processes, systematic scheduling is essential. This allows you to track the progress of each process step and make adjustments to ensure production is on schedule.

Increase Efficiency: Scheduling plays an important role in maximizing the efficiency of your production line. Through proper scheduling, resource allocation at each process step can be optimized and bottlenecks in the production line can be minimized. This helps shorten production times and reduce costs.

Inventory Management: In semiconductor manufacturing, inventory management of materials and finished products is important. Through scheduling, you can effectively manage the timing of material receipt and product shipment. This prevents increased costs due to overstock or shortage of inventory and ensures smooth operation of the production line.

Quality Control: Scheduling is also closely related to quality control. Through proper scheduling, quality inspections can be efficiently arranged at each process stage, and quality problems can be detected and resolved early. This contributes to improving the quality of the final product and lowering the defect rate.

Risk Management: Various risks exist in the semiconductor production line. Schedule planning helps you recognize these risks in advance and prepare countermeasures. For example, scheduling can be fine-tuned to minimize production disruptions due to equipment failure or supply chain issues.

Strengthening market responsiveness: The semiconductor industry has the characteristic of needing to respond quickly to market changes. Through scheduling, you can secure the flexibility of your production line and quickly respond to changes in market demand. This plays an important role in remaining competitive and meeting customer needs.

Cost savings: Production costs can be managed efficiently through scheduling. By establishing an optimal production schedule, you can reduce unnecessary uptime and energy consumption and optimize the use of people and resources. This leads to overall production cost savings.

Based on this background, the main text introduces major existing studies related to scheduling of semiconductor manufacturing lines, and the conclusion presents limitations of existing studies and desirable future research directions.

II. MAJOR PREVIOUS RESEARCHES

Previous studies conducted on the production operation of semiconductor manufacturing lines were mostly related to general input control techniques and production scheduling, focusing on optimizing production operation at individual lines at each stage. In addition, although Korea is a semiconductor powerhouse, research is mainly conducted overseas rather than domestically. Studies related to input control and production scheduling conducted from the mid-1990s to recent years include Choi et al. [1, 2], Kim et al. [3, 4, 5, 6], Lu [7], Sloan [8], Sung and Kim [9], Hwang et al. Examples include those carried out by [10], etc.

Research results in processes other than the FAB process include Lee et al. [11] and Ellis et al. [12]'s scheduling method in the EDS process, Potoradi et al.'s [13] scheduling method to maximize demand in the assembly process, Freed and Leachman [14], and Sivakumar [15]'s equipment utilization rate in the test process. Research to improve it, etc. Meanwhile, recent major studies by field on semiconductor production line scheduling can be summarized as follows.

Machine scheduling problem: Fang et al. [16] investigated the complex machine scheduling problem in semiconductor manufacturing operations and addressed single machine, parallel machine, flow shop, and job shop scheduling problems under various constraints. The study analyzed various performance metrics related to batch processing, auxiliary resources, incompatible workloads, and reentrant flows.

Self-organization based dynamic dispatching rule: Zhang et al. [17] proposed a self-organization based dynamic dispatching rule to overcome the limitations of traditional scheduling rules. This method is designed to autonomously generate optimal scheduling plans based on real-time conditions.

Multi-objective scheduling approach: Chien et al. [18] addressed the multi-objective scheduling problem of a semiconductor wafer manufacturing system and proposed an efficient approach using artificial neural network techniques. This is a study aimed at simultaneously satisfying the conflicting goals of minimizing average facility utilization and minimizing waiting time and storage time.

Integration of scheduling and advanced process control: Jin et al. [19] analyzed the impact of integration of scheduling and advanced process control on production performance indicators in semiconductor manufacturing. The study highlighted the important role scheduling plays in equipment utilization, cycle time, and delivery time.

Scheduling challenges and approaches: Leachman and Hodges [20] described various scheduling challenges that arise in semiconductor manufacturing processes and presented various approaches to solve them. This research has contributed to understanding the complexity of semiconductor manufacturing and developing effective scheduling strategies.

III. LIMITATIONS OF EXISTING RESEARCH AND SUGGESTIONS FOR FUTURE RESEARCH DIRECTIONS

We will explain the limitations of existing research on scheduling of semiconductor manufacturing lines and directions for future research. The limitations of existing research are as follows.

Limited response to dynamic environments: Existing scheduling methodologies are designed primarily based on static environments and often cannot respond effectively to real-time changes and uncertainties. This makes it difficult to respond appropriately to equipment failures, process changes, and sudden changes in demand, which frequently occur due to the nature of the semiconductor manufacturing process.

Handling of complex constraints: Semiconductor manufacturing lines have a variety of constraints (e.g. batch processing, reentrant flow, resource conflicts, etc.), and existing research often fails to effectively integrate all of these constraints. This limits its applicability in real manufacturing line.

Lack of data-based approaches: Although recent data analysis and machine learning techniques are increasingly being applied to scheduling, many existing studies still rely on traditional heuristic and metaheuristic methods. These methods do not fully leverage the predictive and optimization capabilities that data-driven approaches provide.

Lack of scalability: Much research focuses on specific problems or small-scale systems, making it often difficult to apply to large-scale semiconductor manufacturing lines or complex global supply chains. This limits the practical industrial applicability of research results.

Lack of an integrated system: Lack of a system that comprehensively handles various elements such as scheduling, resource allocation, and quality management can lead to reduced efficiency. Most existing studies tend to treat these factors separately.

Meanwhile, future research directions can be summarized as follows.

Real-time dynamic scheduling: There is a need to develop dynamic scheduling methodologies that can respond to volatility and uncertainty by leveraging real-time data and machine learning. This allows you to quickly respond to predicted problems and make optimal decisions in real time.

Comprehensive constraint integration: There is a need to develop an integrated scheduling model that can simultaneously consider various constraints. This allows you to more effectively solve complex problems that arise in real production environments.

Data-based optimization: Research on data-based optimization using big data analysis and artificial intelligence must be expanded. This allows accurate forecasting and optimal resource allocation to be realized and production efficiency to be maximized.

Develop scalable solutions: Develop scalable scheduling methodologies that can be applied to large-scale systems or complex global supply chains. This is essential to increase the practical industrial applicability of research results.

Establishment of an integrated management system: There is a need to improve the efficiency of the entire production process by developing a system that can comprehensively manage scheduling, resource distribution, and quality control. This enables integrated optimization of the entire production.

If research proceeds in this direction, it will be possible to more effectively solve the scheduling problem of semiconductor manufacturing lines and increase the possibility of actual industrial application.

IV. CONCULSION

The scheduling algorithm and sensitivity analysis technology reviewed in this study can be supplied in engine form to domestic and foreign production management solution development companies through technology transfer. If we improve the performance of the production management system through future research and develop it into a form that can be applied to LCD or PCB manufacturing lines, which are similar to semiconductor lines, we expect to be able to commercialize the solution and take on the challenge of commercializing it. If successful research is conducted in the research direction suggested in the previous chapter, the following effects can be expected.

From a technical perspective, the first is to secure the best management technology for semiconductor line operation, and the second is to secure semiconductor line operation IT technology through the development of a production management system, which can be applied in practice and secures yield and productivity. It is expected that the development of semiconductor line management technology will be able to advance to the next level. Additionally, by developing a solution for semiconductor line operation, it will be possible to secure operational IT technology that has been dependent on foreign solution companies and consulting companies.

From an economic and industrial perspective, customer satisfaction, yield improvement, and productivity improvement can be expected, and worker costs can also be reduced. This will help further strengthen the competitiveness of the semiconductor industry. In addition, by making it possible to develop solutions to optimize semiconductor line production and operation using original technology, it will be possible to reduce dependence on foreign solutions and contribute to the development of the domestic IT S/W and service industry.

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