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CONTROLLING COMPUTER INTEGRATED MANUFACTURING SYSTEM USING DATA MINING

MANOJ KUMAR*

Declaration

Abstract

Data mining is a powerful technology used in the manufacturing industries to discovery useful information. In these industries, computer integrated manufacturing system was in widespread use. Data mining technology could be integrated with computer integrated manufacturing system in order to analyze the data of the real situation of the manufacturing process. This paper proposed architecture that integrated data mining technology with process control in computer integrated manufacturing system. The result of this paper shows that the process yield rate can be improved, through the use of automatic and optimum parameter manufacturing. The proposed method and system architecture can be also applied in the process analysis in various manufacturing industry.

Keyword : Data Mining, Computer Integrated Manufacturing, Advanced Process control, Manufacturing Industry, Ant Colony Optimization

Introduction

In the digital era, the population that access the digital information has increased dramatically because of the widely accepted environment. The advanced and common information technology has become the necessary tools in the operation of enterprises and our daily life. In additional, the information technology is also applied to lots of domain such as academia and industry. In the academia, it aid students, teachers and researchers to discover knowledge and solve problems in campus. In the industry, computer integrated manufacturing (CIM) system were in widespread use in modern manufacturing

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companies. In order to improve the product quality and yield rate, more and more new technology are used in the manufacturing.

In the knowledge economy era, to discovery the hidden useful information from daily operating and manufacturing data will affect the competition of enterprise. Data mining technology is a powerful tool for enterprises to discovery useful information. In the manufacturing industry, data mining system could be integrated with CIM system in order to analyze the data of the real situation of the manufacturing process. The production yield rate could be improved, process cycle time, manufacturing cost and inventory could be reduced.

Therefore, an effective integration of information technology and algorithm, together with appropriate decision making model, they could help the insufficiency in the analysis and prediction capability of the current management information system. Some researches used information technology to improve the yield rate in semiconductor manufacturing industry. Irani applied machine learning to semiconductor manufacturing. He proposed a Generalized ID3 algorithm, a modified decision tree algorithm, was applied to build systems which used in semiconductor manufacturing process (Irani & Cheng & Fayyad & Qian, 1993).

In order to control the quality of the LCD product, Hideyuki and Yuko used data mining technology to discover factors which would lead to problems in LCD manufacturing (Maki & Teranishi, 2001). These reports had contributed significantly in improving the factory preference (Dabbas & Chen, 2001). Furthermore, manufacturing management is another important issue in semiconductor manufacturing industry. The traditional statistical process control detects process abnormity, but do not automatically take remedies. The feed back control was used to redeem the defect of the SPC. However, feedback control will continuously adjust the input process parameters, the difference between measured value and target value will thus becomes smaller, however, over control could happen which in turn increases the process variance (Baliga, 1999). Professors of MIT proposed related researches on Advanced Process Control (APC), APC combined statistical process control and feedback control, it used past process data to predict the parameter setting of next process lot (Bowing, 1994). This could reduce process variances due to machine aging, consumption of chemicals, change of environmental conditions such as temperature and humidity.

This paper proposed a method which integrated data mining technology and process control with CIM system. This paper took semiconductor foundry as an example, actual production data in semiconductor foundry was collected, data mining method used to extract specific pattern and rule. The results of data mining were used as reference for feedback control in the manufacturing process.

Related Work

A. Semiconductor Manufacture Processes

In the modern semiconductor industry, to provide customers with high efficiency and high quality services became a great challenge to semiconductor manufacturer. For example, the derived product of Integrated Circuit(IC) can meet the current requirements for light weight, thin, short and compact. Along with the improvement in process equipment, most advanced production technology in the industry can perform a half line width of 0.13 micron. Owing to this superiority leads to the continuous increase of unit production capability of integrated circuit, the unit prices get reduced rapidly. Hence, enterprise can reduce its materials and manufacturing cost effectively via new technology and continuous improvement on process capability and yield rate. In addition, the requirement of cost is no longer confined to the cost of equipment.

Besides, component services, running cost, and leading time are also very important. Therefore, semiconductor manufacturers need a powerful manufacturing system to aid the manufacture.

The CIM system was designed to fit the requirements of manufacture and could tighter production schedule and significantly increase the productivity; and reduce the requirement in manpower, lower expenditure, shorten production time. Production and manufacturing will testing works that all supported by integrated computer system. It is possible to produce high quality products with specs and reliability that meet customer's requirement. Therefore, CIM could improve the product quality. Furthermore, the work in process would be reduced inventory by using CIM system. It is possible to control waiting and setup time effectively and further to reduce the pre-processing time in production and manufacturing.

B. Data Mining

The definition of data mining is "to uncover useful information from a large amount of data." It is an important step in the knowledge discovery in databases process. The purpose of data mining is to extract interesting knowledge from a database, data warehouse, or some other large information storage unit (Cooley & Mobasher & Srivastava, 1999)(Han & Kamber, 2000). From a technical viewpoint, it combines the method of gathering and cataloguing information then proceeds to generate rule-like knowledge from a large amount of data.

Data mining, the extraction of hidden predictive information from large database, is a powerful new technology with great potential to help companies focusing on the most important information in their data warehouse (Westphal & Blaxton, 1998). Data mining scour databases based on hidden patterns, finding predictive information those experts may miss because it lies outside their expectations.

A particular data mining algorithm is usually an instantiation of the model preference search components. The more common model functions in the current data mining process include the following (Michael & Linoff, 1997)(Mitra & Pal & Mitra, 2002).

→ Association rules: describes association relationship among different attributes.
→ Classification: classifies a data item into one of several predefined categories.
→ Clustering: maps a data item into a cluster, where clusters are natural groupings of data items based on similarity metrics or probability density models.
→ Regression: maps a data item to a real-valued prediction variable.
→ Summarization: provides a compact description for a subset of data.
→ Dependency modeling: describes significant dependencies among variables.
→ Sequence analysis: models sequential patterns, like time-series analysis. The goal is to model the states of the process generating the sequence or to extract and report deviations and trends over time.

C. Ant Colony Optimization

The ant colony optimization algorithm (ACO) is one of the data mining methods used in this research. The ACO algorithm simulates the behavior of real ants. As an ant in nature moves, it leaves behind a pheromone trail. The movement of any ants following that first ant depends on the detection of the pheromones on that trail. Not only will the ant detect and follow that trail, it will also seek out newer and better paths based on the amounts of pheromones detected. This pheromone trail can be presented as a numeric value. Therefore, using these numbers, we should be able to calculate and set parameters for pheromone values.

Dorigo proposed the ant colony algorithm, which has been successfully applied to several NP-hard problems. Just as its name implies, the ACO algorithm originates from the study of the behavior of a

natural ant colony. There are three ideas from the natural ant colony that has been transferred to the artificial ant colony: (1) the preference for paths with a high pheromone level; (2) the higher rate of growth in the amount of pheromones on shorter paths; (3) the information exchanged among ants (Dorigo & Gambardella, 1997).

D. Run to Run Control

Semiconductor manufacturing is highly complicated processes and high machine cost. In order to maintain stable product quality, enhance manufacturing efficiency, improve product quality and reliability, the most effective way was to control and monitor the manufacturing process automatically. Therefore, there were some methods of process control applied to manufacturing process. In the manufacturing process, process variances might occur due to some unknown reasons, therefore, the output of the process might become unstable (Kusiak, 2001). In the past, the SPC was the most common method used in the manufacturing process. SPC is a statistical based approach that monitors long-term process performance (Elsayed & Ribeiro & Lee, 1995). Engineers would define the upper/lower spec limit of manufacturing parameters or define the upper/lower control limit of manufacturing parameters. Then, they could trace these parameters to assure the good yield rate. In this research, we used SPC to define the boundary of manufacturing parameters.

The APC was one of method which could redeem the defects of SPC. The APC would not only detect the abnormal status of the manufacturing process but also adjust the manufacturing parameters. According to the definition of SEMI, the APC including run-to-run (R2R) control, fault detection and classification, overall equipment efficiency (OEE),…,etc (SEMI, 2002). James point out that the R2R control is cutting-edge technology that allows modification of a product recipe between machine "runs," thereby minimizing process drift, shift, and variability-and with them, costs (James & Arnon & Enrique, 2000). Furthermore, the in-depth analyses offered by R2R control overcame barrier in semiconductor manufacturing. There were two types of R2R control including feedback R2R control and feed forward R2R control. The feed forward control could redeem the variability of the material; the feedback control could redeem the variation of the tool. Furthermore, the feedback control could almost used in every equipments and processes.

Sachs pointed out that the APC combines the advantages of both SPC and feedback R2R control to overcome shifts and drifts during process operation (Ingolfsson & Sachs, 1993)(Sachs & Hu & Ingolfsson, 1995). The R2R control process was shown as Fig. 1.

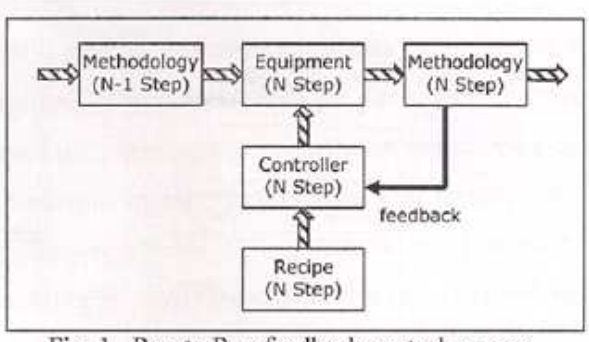

Fig. 1. Run to Run feedback control process

Problems

The semiconductor manufacturing processes will frequently suffer from environmental interference. Under many circumstances, we can find the cause of process interference, but this cause could not be removed or the cost to reduce it is too high. Process yield rate is the key factor of success or failure of a wafer manufacturing company. The affecting problems were summarized as follows:

→ The problem of the complexity in manufacturing process: It usually takes hundreds of steps in the process, some of theses steps are handed by the same machine that is wafer repeatedly goes back to certain machines waiting for process.
→ The problem of the yield rate: Wafer yield will be affected by environment, equipment and materials, especially in the clean room manufacturing environment. The time which wafer exposed in the air is the key factor affecting the yield rate.
→ The problem of data analysis and application: The huge data collected from daily manufacturing process turn into data warehouse and find out the factors affected yield rate and discover optimal manufacturing parameters from historical records.

In the previously research, some researchers had applied the artificial intelligence, neural network, data mining…etc to improve the yield rate. However, this paper proposed a novel method which combined the data mining technology and APC with CIM. It could have better yield rate to meet the requirement of semiconductor manufacturing industry.

System Design

We proposed an information system based on the CIM environment for a real semiconductor manufacturing company which included APC, Manufacturing Execution System (MES), Data Warehouse server, ACO Server, Web Server and Users, as shown in Fig. 2. The system architecture combined the ACO with run to run feedback mechanism in APC to improve manufacturing and production process flow. In this system, at first, we used engineering database to collect data from manufacturing process. Then we pre-processed the data in a structured format and stored in data warehouse as the source data for the ACO server. In the APC mechanism, the feedback control was to predict new observed value based on the past process data and internal measured values, furthermore, the ACO server would also proposed manufacturing parameters in the feedback. In the continuously modified, the update information would improve processes and manufacturing optimization was formed.

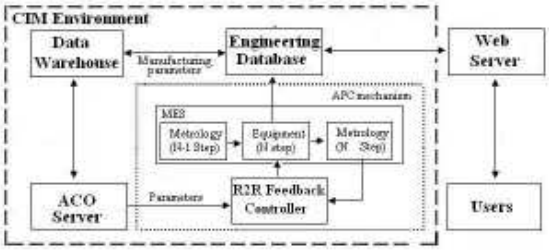

Fig. 2 Architecture of intelligent system based on CIM

In the proposed system, we integrated APC feedback with ACO. The steps of the combined algorithm go as follows:

Step1: Send the manufacturing parameters of the first production wafer shipping box to the data warehouse.
Step2: The wafer shipping box would be tested in to test station.
Step3: Check production, if it meets control parameters, if not, reset it.

Step4: Update the qualified measured result to data warehouse.
Step5: Check the compensation value of control variable in R2R controller; if it is within the upper and lower limit of the control mode.
Step6: If it meets the condition, feedback the compensation value of process parameter to next wafer box.
Step7: Otherwise, send a message to turn off the feedback system of process parameter. Then, pass to APC and used the parameters proposed by ACO server.
Step 8:Update the qualified measured result to data warehouse.

In this paper, the using a recommendation service model which combined The Ant Colony Clustering Algorithm (Chen, 2006) with Association Rules to discover readers with the same interests and the detail description of the data mining methods were as follows.

Generally, manufacturing industries used engineering data base to store the data during manufacturing. The data in engineering database was changing over time, but we needed a huge stable data. We could build a data warehouse to pre-process data. Depending on the sample data of the manufacturing parameters, ACO was obtained that parameters in the same cluster have the similar affect, and then, the APC can recommend recipes that were used in the past process. In practice, it is feasible to cluster all transactions in the databases into several groups. That was, since the transactions in each group were similar with respect to the clustering variables, we could employ the proposed method to find out similar behaviours from the representative records. Furthermore, we combined the ACO and R2R feedback mechanism.

Discussion & Analysis

In the manufacturing industries, automatic controller was used to control machine lot in order to ensure that the process output value for each lot would not gradually deviate from the target value. Therefore, manufacturing of each product lot in the process is involved with controlled actions when APC feedback control was used to control semiconductor processes (Bowing, 1994). This is obviously if you have to pay heavy price for the deviation of the process deviates from the target value (Bowing, 1994). For example, when the system can predict a new observed value depending on the past process data and internal measured values (Diebold, 1995), a continuous information update would improve the process by the feedback control system.

When building the proposed system in the semiconductor manufacturing industry, we should observe the variation of the yield rate. From the statistical data of the equipments, we could get improvement of the yield rate after using the proposed system. Until the system becomes stable and has positive enhancement on the yield rate. The average yield rate after using ACO with feedback control was 90.98%; the improvement was 6.39%.; shown as Fig. 3.

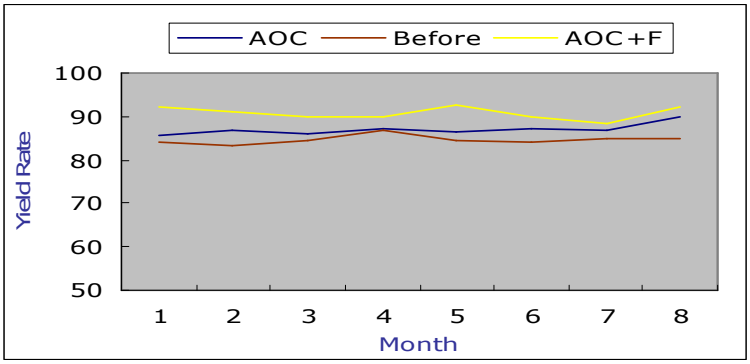

Fig. 3 Yield rate improvement by using combined algorithm

Conclusion

In this paper, we proposed a method which integrated artificial intelligence and process control with CIM system. The proposed system architecture could be applied to the traditional manufacturing industry for the process analysis. In semiconductor manufacturing process, automation and optimum manufacturing parameter could be used to improve the overall process capability and the yield rate. In this paper, we selected clustering data mining technology and the advanced process control to monitor the quality of the manufacturing process. The proposed method and the prototype system architecture could be used to improve the overall process capability and the yield rate in semiconductor manufacturing industry. Moreover, we could broadly apply the proposed method to the traditional manufacturing industry in the future.

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