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A Novel Value Innovation for a PE-CVD Fab Equipment by Using Cluster Tool Control Technology

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Abstract: This industrial paper deals with a new value innovation technology for a PE-CVD equipment, which results in productivity, usability, and extensibility enhancement of the system. The cluster tool control technology including control software played a key role in increasing the value of the equipment. Productivity, usability and extensibility enhancement is achieved by equipment remodeling and improvement technique. The technique is applied in a real industrial field of semiconductor mass production line and the verification of productivity and usability enhancement is done by comparing the previous data and the data after improvement. Also the extensibility improvement is proved by the capability of IMS processing of ARCL and AFL with mechanical movement between the processing steps which can not be done in the equipment before.

1. INTRODUCTION

Wafer fabrication processes in semiconductor manufacturing change rapidly according to the change of the device architecture. The CD change of devices has much impact on several wafer fabrication processes than before which means the efforts to adapt the tools to the new desired requirements are harder. How to enhance productivity to gain enhanced price competitiveness in global market and how to adapt the tools to the designed architecture of the new device are key issues in semiconductor manufacturing equipment area.

Cluster tools, each of which consists of several processing chambers, wafer handling robots and cassette operation units as defined in SEMI standards, have been increasingly used for diverse wafer fabrication processes. The ability to quickly convert factories to new process technologies by reusing equipments such as cluster tools is very important in terms of the cost-effective adaptability.

The remodeling and improvement of a cluster tool happens widely in real manufacturing fields because the makers of the cluster tools cannot meet the changing end-user requirements. Furthermore, old cluster tools have many problems: high downtime rate, high cost of software revision, difficulty in supply of hardware parts, and difficulty in extending the functionality to the new factory operational needs.

This industrial paper deals with a new value innovation technology for a PE-CVD equipment which has been used for several years to cover processing steps of old devices. The equipment is remodeled and improved to support a new device processing steps and enhance the productivity of the equipment by using the cluster tool control technology.

This paper is composed as follows. Section 2 gives a general procedure of the works to be done. Section 3 illustrates how to enhance the system productivity, usability and how to apply the remodeled system to a new device process. We show the results of improvements in section 3 and finally a conclusion is derived in section 4.

2. EQUIPMENT VALUE INNOVATION

To apply old equipment control systems to a new equipment remodeling and improvement paradigm, the system is categorized into two parts. One is the remodeling part and the other is the reusable part. The analysis of static and dynamic interfaces between the remodeling part and the reusable part is very important because the functionality of overall system is linked between them. The static analysis for the structure of overall system, lower level structure of hardware modules, upper level structure of the software and system parameters are needed. The scope of dynamic analysis contains the interface protocols, interlock mechanism of hardware and software, processing recipes and sequences, and time control of processing units such as gas box controllers, vacuum controllers, a RF generator, a heater controller, and LFC / MFC controllers etc.

Old system illogicalities are found by inspecting the operations done in the factory and improvements are done for the system usability. System illogicalities are improved by the following subsequent four steps: analysis, a new design for the improvement, implementation and validation / verification.

3. IMPROVEMENT OF THE EQUIPMENT

3.1 Productivity Improvement

Hong, J. et al. shows that the efficiency of the equipment and the productivity of the cluster tool are usually analyzed based on the tables and the graph called machine cycle chart whose input data are the movement history log or the event log of wafers. Critical process time is defined the boundary process time between transfer bottleneck and process bottleneck.

The equipment in this paper has two major process modules, or PE-CVD and cooling process. The time balance between two-type process modules is very important to enhance the productivity of the equipment and the available tuning parameter is the slots of the cooling chamber. Also the operation mechanism can be analyzed to find out which sub operations can be done simultaneously. Furthermore, the scheduler performance of the system is also optimized by finding out the equipment losses.

The productivity enhancements are analyzed by using the experimental data of the most popular recipe based on machine cycle chart analysis. The results are shown in Table 1. The total productivity improvement is 13.3% higher than before equipment remodelling. The changing of cooling slots is most effective than the others because that is the bottle neck of the system.

Table 1. Productivity Improvements

Contents	Improvement (%)
Changing cooling slots	11.70
Vacuum Robot Pre-Rotation	2.39
Skipping double safety checking	0.76
parallel operations	2.55
Total	13.30

3.2 *Usability Improvement*

The usability of the system is improved as in Table 2. Recipe editing operation is easy to understand and modify by supplying it in table type. Track in/out operation is changed to HSMS protocol to support high speed communication with upper level control systems. The data collection of processing can be done in wafer level in addition to in lot level.

Table 2. Usability Improvements

Contents	Before	After
Recipe editing	Macro type	Table type
Track in/out	SECS I	HSMS
Data collection unit	Lot	Lot/Wafer

3.3 *Extensibility Improvement*

How to control the substrate reflectivity and how to prevent resist footing in subsequent photo exposing processes are two major issues in CVD process as CD must be controlled tightly. Linliu, K. et al. show that the use of ARCL(anti-reflective coating layer) and AFL(anti-footing layer) to eliminate reflective notching and footing, tightly control CD and provide etch hard-mask has become very critical for today's device shrink technology.

Equipments can be classified into two groups from the viewpoint of how many wafers are processed simultaneously. One is single wafer processing equipment type and the other is batch processing equipment type. In-situ multi-step(IMS) processing is usually done in single wafer processing equipments. Kiyotoshi, M. et al. introduce IMS CVD process in furnace type equipment where there is no mechanical movement between processing steps.

The equipment in this paper deals with IMS processing of ARCL and AFL with mechanical movement between the processing steps. The mechanical movements are for the uniformity of the thin film. The scheduling logic is quite different from the one of normal processing because the mechanical movements have much influence on each processing step. Therefore the processing recipe steps and the mechanical movement should be considered simultaneously. The equipments use several gas manifolds to support several types of thin films. The normal deposition and the IMS deposition should also be supported to extend the original capability of the equipment.

Thickness of deposition depends on various parameters such as deposition time, over-etch rate, soaking or pre-coating time, and volume of gas flow etc. The thickness of AFL layer is measured and tested according to the experimental values of the parameters mentioned above. Based on this parameter, the processing recipe is optimized. The TOX of AFL is shown in Fig. 1.

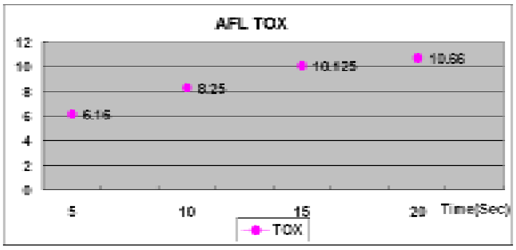

Fig1. Processing TOX change

4. CONCLUSIONS

This paper shows that the cluster tool equipment can be remodelled and improved to enhance the productivity, usability, and extensibility by utilization of the cluster tool control technology. This technology will provide cost-effective factory adaptability to the changing device and processing technology.

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SEMI Standards, SEMI E21-Cluster Tool Module Interface