FEATURE ARTICLE

Full Automatic Spectroscopic Ellipsometer UT-300
Part 1: System Configuration

Yoshinori Nagai, Masaaki Magari

Abstract

The UT-300 Full-automatic Ultra-thin Film Measuring System has been developed to measure the optical properties of thin films in the semiconductor production process. It allows for accurately measuring refractive index and attenuation coefficient as well as thickness of thin films. The UT-300 should meet the needs arising from the sophisticated and diversified semiconductor production lines. We introduce the UT-300 and the related software that enables various features of this system.

1 Introduction

In recent years, the importance of the measurement and control technologies related to thin films has been attracting attention in the semiconductor and FPD production processes. In particular, as thinner gate oxide and low-absorption films have been used in new-generation devices, it has become necessary to evaluate very thin SiO_2 films of 1 to 5nm and other films made of new materials such as high k and low k.

In addition, it has also been required to more accurately evaluate the multilayer film structure (ONO film) used in the flash memory, which has silicone oxide and nitride layered alternately, and the multilayer films on the SOI wafer.

These films require that the optical characteristics such as refractive index and attenuation coefficient, and uniformity of composition be measured as well as their physical thickness. In the past, on the semiconductor production site, film thickness was measured using an interferometer, and optical constants were obtained by measurement of spectral reflectance using a spectrophotometer or by ellipsometry using an ellipsometer with a laser light source. Especially, the spectroscopic ellipsometer, which simultaneously measures multiple wavelengths, has been drawing attention for the analysis and evaluation of very thin films and multilayer films in the semiconductor processes since it allows for high-accurately measuring a broad range of wavelengths ranging from ultraviolet rays to visible and infrared rays. On the other hand, the line width on semiconductor devices has increasingly become thinner to 0.15 to 0.13μm at present and is likely to reach 0.10 to 0.07μm for the next-generation devices.

In order to improve the production efficiency, the diameter of the silicon wafer has been increased to 300mm. For improved productivity of the semiconductor processes, a thin film evaluation system has been strongly desired to comply with more sophisticated and more diversified production lines as described above. Three companies, Horiba, Jobin Yvon, and Horiba Jobin Yvon has developed the UT-300 Full-automatic Ultra-thin Film Measuring System based on a spectroscopic ellipsometer (Fig.1) in response to those circumstances. The principle of this system and the automation system using the latest software are discussed below.

Fig.1 UT-300 Full-automatic Ultra-thin Film Measuring System

2 Measuring Principle and Hardware Configuration

2.1 Measuring Principle

Spectro-ellipsometry is used to observe changes in the polarization (incidence and reflection) that occurs when light has been reflected at the surface of a substance, thereby obtaining information on that substance, such as film thickness and material. The UT-300 uses a spectroscopic ellipsometer that applies a photo-elastic modulator (PEM) for the measuring principle by the phase modulation method. Fig.2 is a photograph of the measuring section of the UT-300 and Fig.3 shows a block diagram of the optical system. As shown in Fig.3, linearly polarized light passes through the PEM in the UT-300 and then becomes elliptically polarized light that has been phase-modulated into a frequency of 50kHz. Therefore, phase contrast Δ and amplitude Ψ can be determined at resolution of only several msec. In addition to cos Δ , sin Δ can be detected, thus resulting in a benefit of improving the measurement accuracy for Δ. Especially, the use of the PEM enables rapid measurement at high accuracy while minimizing the effects of mechanical vibrations.

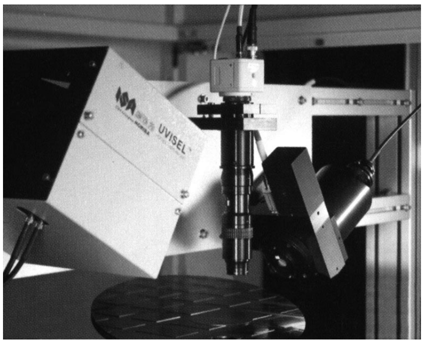

Fig.2 Photograph of Measuring Section of the UT-300

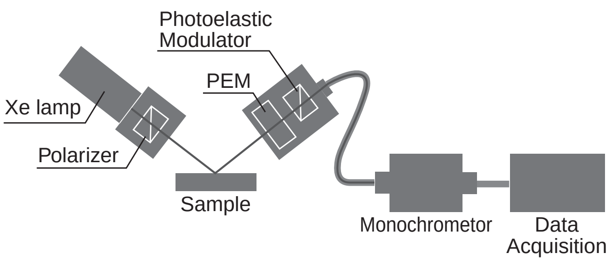

Fig.3 Block Diagram of Optical System

2.2 Hardware Configuration

The UT-300 consists of multiple cassette ports, a wafer handling robot, a wafer alignment unit, an ellipsometer, and a pattern recognition mechanism, and an X-Y-Z three-axial stage on which the wafer to be tested is placed (Fig.4). In order to comply with the latest lines, this system has been designed as being applicable for three types of wafers with the maximum diameter of 300mm and being able to transfer those wafers at a high speed.

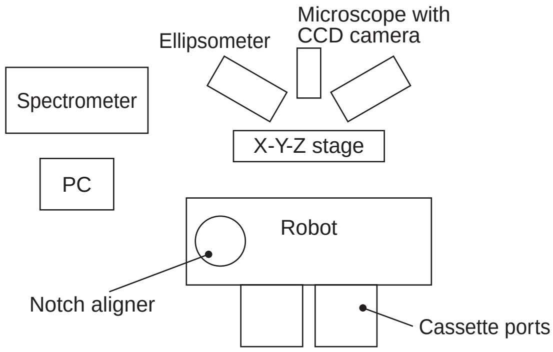

Fig.4 System Configuration of Hardware

3 Software

3.1 System Configuration of Software

Using a personal computer having the dedicated software installed, the UT-300 controls a series of measurement processes including the transfer and control of wafers, pattern recognition, settings of auto-focusing and other measurement parameters; arithmetic processing of film thickness and optical characteristics from the measured spectrum; and display and saving of the measured values. This software system is configured with Robot Manager (RM), Sensor Manager (SM), Ellipsometer Station (ES), CIM Manager, Shell, UT-DMS, and database (Fig.5).

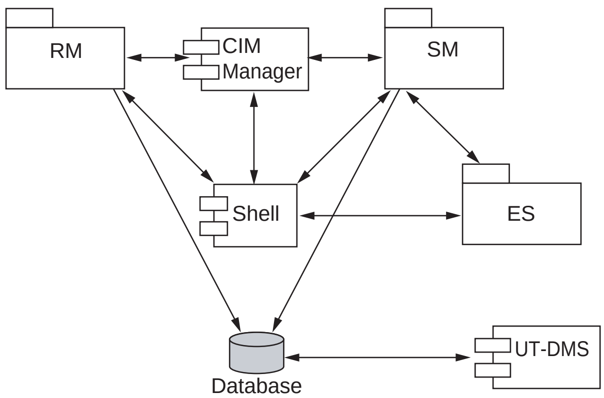

Fig.5 System Configuration of Software

(1) Robot Manager (RM)

RM is responsible for integrating the action recipes of the cassettes and the robot. The robot is always optimally controlled during its operation, so that the throughput of the entire measuring system is maximized.

(2) Sensor Manager (SM)

SM is responsible for the measurement of each wafer, the real-time monitoring of the measurement condition, and the management of measurement history. The measured values are saved in the database.

(3) Ellipsometer Station (ES)

ES consists of two sub-stations, DeltaPsi and Pattern Recognition (PR) Station. DeltaPsi runs measurement with the ellipsometer. PR Station automatically controls the focusing position to maintain constant the pattern recognition and the measurement position in the height direction.

(4) CIM Manager

CIM Manager is responsible for communications with the customer's host computer. It conforms to SECS/GEM, an international communications standard for semiconductor processes or the customer's special specification.

(5) Shell

Shell offers the communications capability between the working area where all the modules are displayed and run, and the modules. The dependency between RM and SM is minimized allowing RM to be easily reused for other sensors.

(6) UT-DMS

UT-DMS allows for accessing the measured values saved on the UT-300 via the network and presenting them in various formats such as two-dimensional display, topographic display, three-dimensional display, and trend graph. Technical employees can access the measured values on the system in a clean room via the intranet from their offices and carry out the checks of the measured values and the preparation of a report.

3.2 Measurement Sequence

The UT-300 performs measurement in the following sequence (Fig.6):

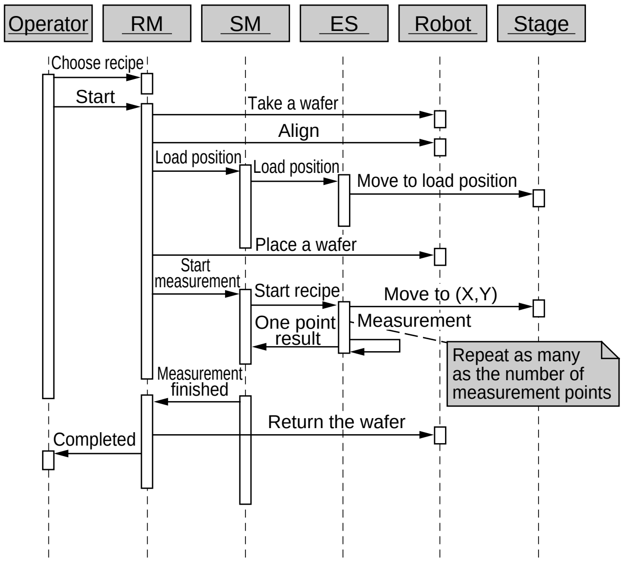

Fig.6 Measurement Sequence

(1) Setting up the Sample (control by RM)

Each wafer is taken out from the carrier at the cassette port, rotated, and then centered. After the wafer has been placed on the measurement stage, the measurement start request is issued to SM.

(2) Displaying Measurement and Its Result (control by SM and ES)

SM instructs ES to start measurement and displays the measured values in real time. When RM is notified of the completion of measurement, it returns the wafer to the cassette.

(3) Saving and Reading out Data

The measured values are saved in the database and each technical employee can freely access the database to read out the measured value.

3.3 Communications System

The communications for the UT-300 conform to Generic Equipment Model (GEM), which is a comprehensive model of communications and control for semiconductor manufacturing systems, and are applicable for all the semiconductor production lines throughout the world. Horiba is now developing a communications module for the host computer in accordance with various new standards (E87, E40, E90, E94, etc.) advocated by Semiconductor Equipment and Materials International (SEMI). This communications module will allow for carrying out the detailed monitoring and control of the system and for networking the system with the customer's production line, host computer, and intranet.

3.4 Advantageous Features

Based on the above software, the UT-300 has met the needs from the device production process site and achieved the following high operability and functionality:

(1) Setting up a Measurement Recipe

Once a cassette containing wafers is loaded to the system, the system automatically determines whether or not a wafer exists at each slot. The operator selects all the wafers at a time or any specific wafer, sets up a recipe, and then instructs starting measurement. The system will sequentially take out each wafer from the cassette, carry out measurement in accordance with the recipe, and then return the wafer to the cassette. Fig.7 shows the setup screen for a measurement recipe.

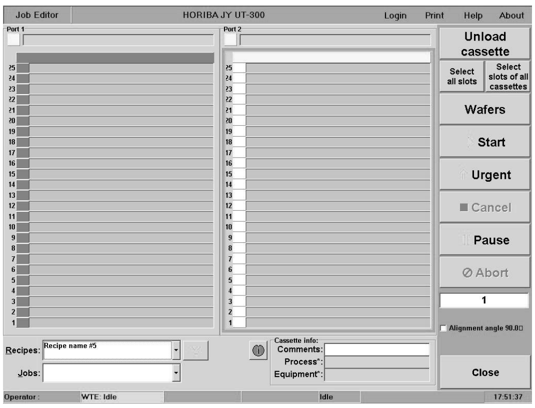

Fig.7 Setup Screen for Measurement Recipe

(2) Monitoring the Operating Situation of the System in Real Time

The current measurement situation is displayed in real time (Fig.8) to allow the operator to check the operating situation of the system at a glance.

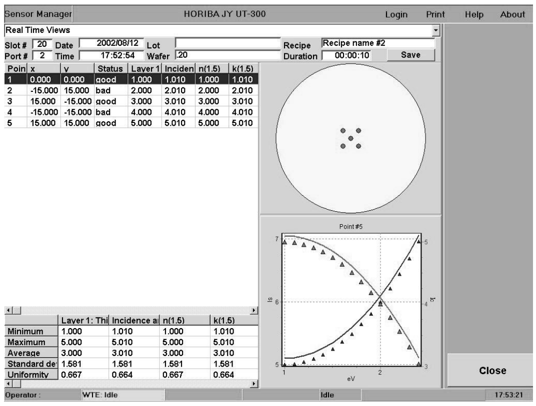

Fig.8 Real Time View

(3) Displaying the Trend of Measured Values

A series of measured values is displayed on the screen to allow the operator to determine whether each wafer is acceptable or not and find any process anomaly in an early stage.

4 Global Development of Software by UML

The software for the UT-300 has pursued for an open, flexible architecture to quickly comply with market needs. For this purpose, it has been jointly developed by three companies, Jobin Yvon (JY), France, Horiba's Moscow Representative Office (HMR), Russia, and Horiba, Ltd., Japan (HOR). JY was responsible for the development of the sensor, and HMR and HOR for the development of the robot, database, and common sections. Since this system is very diverse and complicated, the persons in charge of the software development sometimes visited the customer to verify the customer's requirements. At this time, we used Unified Modeling Language (UML), a universal representation standard, to analyze the customer's needs and propose our ideas. UML was very useful as a common tool for the software development.

Our software development team comprised French, Russian, and Japanese members who had different language and technical backgrounds. This development was a new type of challenge to all the members. UML was also useful for evaluating whether or not the design details of the software module created by the developers in each office were understood by the other developers. The above software module was tested with the dedicated simulation software and finally evaluated by installing it in the actual hardware.

5 Conclusion

Personnel for the semiconductor device production lines expects the UT-300 as an on-site type measuring system that allows for accurately measuring and analyzing film thickness and optical constants in real time. Not a few functions required of measuring systems are common to different fields and different samples under measurement. We applied the architecture for the UT-300, which has been introduced in this document, to the platform for the FF-1000 Inspection & Evaluation System for Large Glass Substrates for Flat Panels and received favorable reputations. In contrast, there are considerable cases in which the flow of information is not appropriate between different fields. For the future, we, as a measuring system manufacturer, hope to help the customers to improve their line productivity through joint efforts with us.

References

[1] Y. Nagai, N. Blayo, S. Hirakawa, N. Garbain et al., UT-300 Full Automatic Spectroscopic Ellipsometer, Readout, No.21, 2000

[2] M. Magari, Software System of UT-300 Full Automatic Spectroscopic Ellipsometer, Readout, No.25, 2002

Yoshinori Nagai

Manager
Product Marketing & Development Dept.
Semiconductor Equipment & Systems Division

Masaaki Magari

Team Leader
Software Development Team R&D Dept.
Semiconductor Equipment & Systems Division