Semiconductor Inspection System for Next-generation

Yasutsugu Usami
Seiji Isogai
Isao Kawata

OVERVIEW: The miniaturization of semiconductor devices is accelerating year by year, as represented by the technical roadmap of ITRIS (International Technology Roadmap for Semiconductors). Along with this trend, the increasing cost of inspection tools and systems is becoming an issue. Based on its know-how of how to optimize operations and support applications, Hitachi has developed an integrated inspection and evaluation system with a high return on investment (ROI) as a solution.

INTRODUCTION

THE miniaturization of semiconductor devices has been accelerating and has reached the 130-nm level. Along with this miniaturization, efforts have been made to improve productivity. The construction and operation of productivity-enhanced lines have already come about, mainly for large-diameter, 300-mm wafer fabs. To improve yields steeper ramping up has been required regardless of the miniaturization or complexity of the manufacturing processes. This has led to a demand for a system that integrates and controls high-performance inspection and evaluation tools. Furthermore, to optimize the control, it will become more and more important to provide application support and operational know-how.

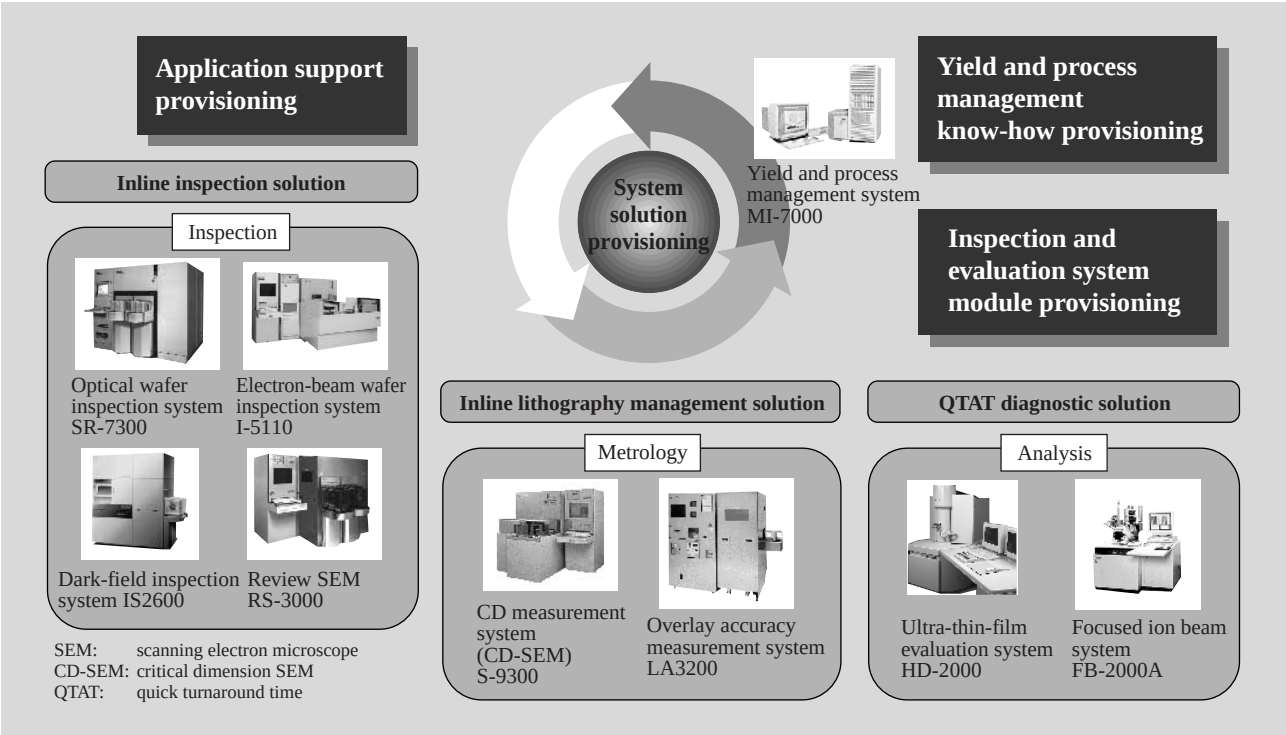

Fig. 1—Hitachi Semiconductor Inspection and Evaluation System.
Total solution for supporting yield and process control of semiconductor manufacturing lines. Hitachi provides system solutions for supporting the yield enhancement of semiconductor production lines. An inline lithography control solution with a CD-SEM at its center is provided in an inspection and evaluation system module. An inline inspection solution that inspects and controls wafer production to classify detected defects is also provided. A QTAT failure solution that analyzes the causes of failures based on inspection and review results is provided. Hitachi also supplies tools linked to form a system and provides customers with support and know-how by totally managing data to enable optimum operation at customer sites.

HITACHI'S INSPECTION SYSTEM

Overview

Hitachi provides an inspection and evaluation system that operates in semiconductor production lines. The system and the way it is operated are optimized by integrating data from each tool (Fig. 1). This section describes the system, focusing on the inspection tools.

SR-7300 Optical Wafer-inspection Tool

To cope with the development of advanced semiconductor devices, technically innovative countermeasures are required in optical wafer inspection systems. For one thing, better resolution is needed due to accelerating pattern miniaturization. Resolution and defect detection below the resolution limit that ordinary light can resolve are now required. Also needed is a way to selectively detect defects out of mal-effects such as color variation, which is induced by planarization technologies like chemical-mechanical polishing (CMP). Elimination of nuisance defects is the issue.

Hitachi's approach to improving sensitivity is shown in Fig. 2. It has led to the development of the SR-7300 optical wafer-inspection tool. Super-resolution optics is used for image detection, enabling the tool to resolve miniaturized patterns. When a pattern is miniaturized and made dense, light reflected from the wafer becomes weak, and the captured image becomes dark with low contrast. With super-resolution optics, the diffraction from the pattern is selectively enhanced, then used for capturing the image, enabling the tool to resolve patterns that the conventional method cannot (Fig. 3).

The use of a shorter wavelength and a smaller pixel size has been studied as countermeasures against device miniaturization. However, when using a shorter wavelength, the effect of color variation on the insulation layer needs to be taken into account. Eliminating such mal-effects is a key to achieving higher sensitivity, so a broad-band light source, Hitachi's proprietary technology, is used in the SR-7300.

Miniaturization of the image-detection size, the pixel size, is important, but simply reducing the pixel size does not result in high resolution and high sensitivity. To eliminate the noise factor from captured images, the tool must be equipped with a high-stiffness optic configuration and stage, which must be controlled with high accuracy. The SR-7300 is thus equipped with a high-accuracy high-stiffness stage that can eliminate the noise factor from captured images.

These improvements in the image-detection system increase the resolution of the image drastically. However, that does not improve the defect-detection capability in practical applications. In the wafer-inspection tool, two images are compared, and the differences between them are detected as defects. In cell-to-cell comparison mode, the images of adjacent cells are compared. In die-to-die comparison mode, the images of adjacent dies are compared. If those two images have color variation or a grainy surface, the differences induced by the variation or surface are detected as defects, too. To avoid such nuisance defects, the tool should be operated with reduced sensitivity. A new image-processing technology called "local intensity matching (LIM)," is implemented in the SR-7300 to eliminate the nuisance factors and achieve high-sensitivity inspection. With LIM, data correction is made on a per pixel basis, which zeros out any color-variation-induced differences, resulting in reduced background noise (Fig. 4). LIM enables detection of actual defects with high sensitivity, without detecting nuisance defects.

Furthermore, the sensitivity in die-to-die comparison mode, which used to be about half that in cell-to-cell comparison mode, is improved in the SR-7300 to the level of that in cell-to-cell comparison mode. This will bring innovative changes to the

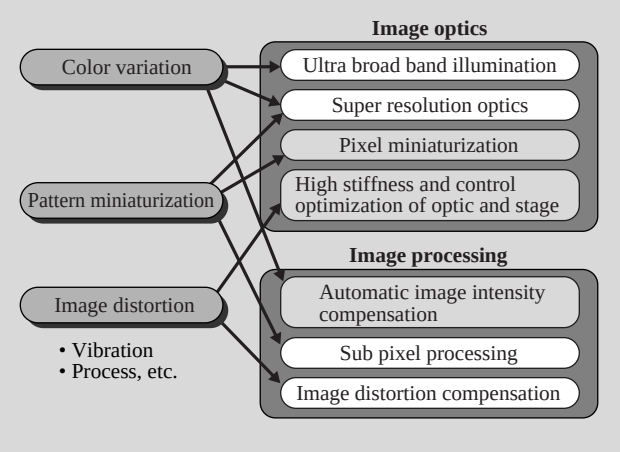

Fig. 2—Hitachi's Approach to Improving Sensitivity.

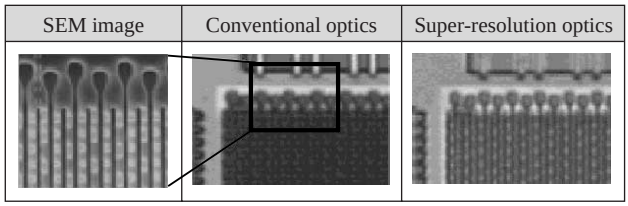

Fig. 3—Image Improvement with Super-resolution Optics.

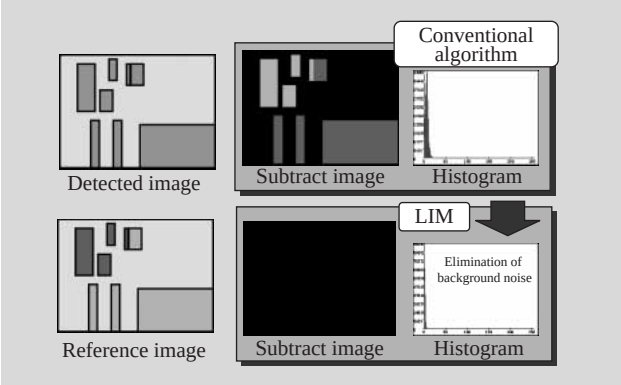

Fig. 4—Elimination of Background Noise by LIM.

inspection of system LSIs and logic LSIs, which need die-to-die comparison as a major part of their inspections.

I-5110 Electron-beam Wafer Inspection Tool

As the miniaturization of semiconductor devices proceeds further, the number of fine fatal defects that cannot be detected even with a high-sensitivity optical inspection system is increasing.

Hitachi's I-3010 electron-beam wafer-inspection system has played an important role in the field of wafer inspection. Hitachi has now released a new model, the I-5110. It is suitable for system LSIs and logic LSIs with its powerful comparison modes, cell to cell, die to die, and hybrid. In hybrid mode, the tool can scan an array area in cell-to-cell mode and a random area in die-to-die mode in one scan.

In addition to such new functions as hybrid comparison, the performances of several components have been improved. One improved component is the defect distribution inspection (DDI) mode (Fig. 5). Due to its intrinsic configuration, an electron-beam wafer-inspection system has a rather small output compared with that of an optical inspection system. An electron-beam system is thus not suitable for inspecting the complete area of a wafer. However, as the miniaturization of semiconductors proceeds, the occurrence of very small but fatal defects at certain locations in a wafer is increasing. It is thus increasingly important for an electron-beam inspection system to inspect the whole wafer. A method is needed for faster inspection with reduced sensitivity for an enlarged inspection pixel size. Unfortunately, the advantage of an electron-beam inspection system does not work in this method. With the I-5110, the sampling rate can be set to skip scan the whole area of a wafer quickly with high sensitivity.

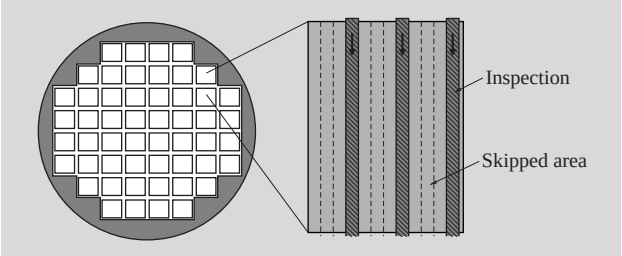

Fig. 5—Illustration of Defect Distribution Inspection (DDI) Mode.

RS-3000 Automatic Defect Review SEM

As the miniaturization of semiconductors proceeds and the number of defects explodes, the need for a high-efficiency SEM review tool has been increasing. Hitachi has provided the S-7840 and S9200 review tools. However, to answer the strong and increasing market needs, Hitachi has developed a fully automatic review SEM, the RS-3000.

The RS-3000 is a strong tool for improving the yield of advanced-semiconductor production lines by categorizing defects as fatal or not fatal. This defect separation is done by automatic defect reviewing (ADR), and then automatic defect classification (ADC).

The RS-3000 is a high-speed review tool at 600 defects per hour (DPH).

It can capture four kinds of SEM images per defect (Fig. 6): a secondary electron image, a left oblique image, a right oblique image, and a voltage-contrast

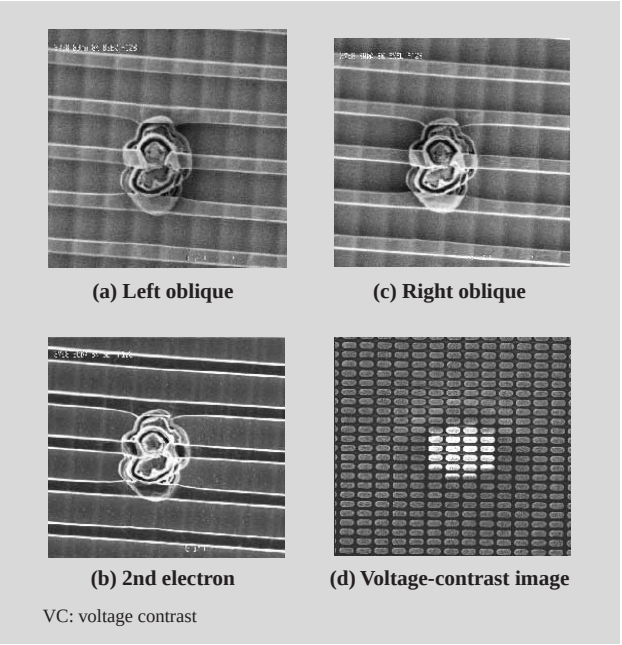

Fig. 6—RS-3000 Review Images.
Voltage-contrast image is of different defect from the others.

image. Those defects whose shapes cannot be judged as either concave or protrusive can be judged using the left and right oblique images. The voltage-contrast image enables the RS-3000 to review the voltage-contrast defects that are detected by electron-beam inspection tools.

The ADC system of the RS-3000 is Hitachi's proprietary technology. It is highly accurate and user friendly. It is an evolutional combined classification method, so it can be configured as a combination of system classification and user classification. User classification classifies defects into categories defined by users, whereas system classification judges the fatality of defects using its own algorithm based on a defect signature, which is extracted from defect images. This feature is suitable for inline use because the system class does not need to be taught.

MI-7000 Yield and Process Management System

The MI-7000 system enables data from various inspection and review tools to be analyzed. Activities for yield improvement and management can thus be done more efficiently. For example, to counter the recent trend of increasing defect counts, defect-filtering functions have been added, which make the MI-7000 more convenient to use. When a filtering function is used, only those defects meeting the designated defect size, category, area, etc. are extracted. The number of defects from inspection tools can then be restricted to match the throughput of the review tools (Fig. 7).

Another function that has been added is one to display the time traces of critical dimensions, of the layer thickness, of the test results, etc. by connecting the MI-7000 with user system. The MI-7000 is thus able to transmit an alarm when a controlled parameter exceeds its limit. A function to support tool-difference analysis and automatic mailing of data has also been implemented. The MI-7000 can now totally support the yield management of advanced LSI fabs. These functions should contribute to the quick start up of 300-mm processes.

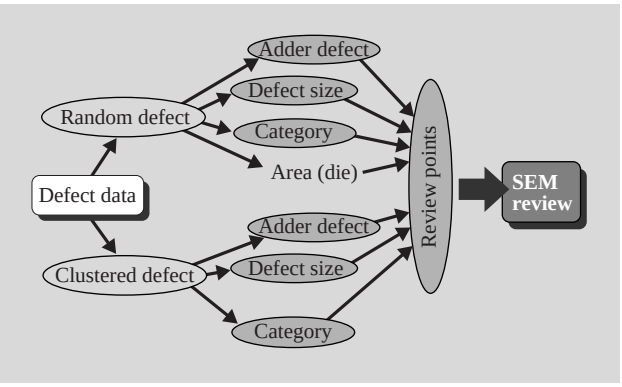

Fig. 7—Filtering Function of MI-7000.

CONCLUSIONS

As described, Hitachi provides various inspection and evaluation tools, and even a total system. Hitachi will continue developing cutting-edge technology and tools for next-generation and providing them to customers. Hitachi will also provide system solutions focusing on providing application support and operation know-how that enables users to optimize the operation of their systems.

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ABOUT THE AUTHORS

Yasutsugu Usami

Joined Hitachi, Ltd. in 1984, and now works at the Electronics System Operations of the Instruments. He is currently engaged in marketing semiconductor inspection systems. Mr. Usami is a member of the Vacuum Association of Japan and the Electronic Microscope Society of Japan, and can be reached by e-mail at yasutsugu-usami@instr.hitachi.co.jp.

Seiji Isogai

Joined Hitachi, Ltd. in 1981, and now works at the Electronics System Operations of the Instruments. He is currently engaged in development of semiconductor-inspection and yield-enhancement support systems. Mr. Isogai is a member of the Institute of Applied Physics of Japan and the Institute of Electronic Information and Communications Engineers of Japan, and can be reached by e-mail at seiji-isogai@instr.hitachi.co.jp.

Isao Kawata

Joined Hitachi Tokyo Electronics Co., Ltd. in 1979. Moved to Hitachi, Ltd. in 2000, and now works at the Electronics System Operations of the Instruments. He is currently engaged in marketing semiconductor inspection systems. Mr. Kawata can be reached by e-mail at isao-kawata@instr.hitachi.co.jp.