New DUV Optical Wafer Inspection System

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OVERVIEW: In the midst of the rapid acceleration in the advancement of technology nodes, there is a demand for improved performance of wafer-inspection systems, namely, greater sensitivity as device size moves toward higher integration and density, newer materials such as ArF resist, Cu wiring and low-k films, and higher throughput with 300-mm-diameter wafers. In response to these demands, Hitachi High-Technologies Corporation, in collaboration with TOKYO SEIMITSU CO., LTD., has developed a new DUV (deep ultraviolet) optical wafer inspection system that can meet the requirements for improved performance. Marketing of the system has begun. This system achieves higher inspection resolution (smaller inspection pixel size) by using a DUV light source, which has a shorter wavelength than conventional white light or UV (ultraviolet) light, thus providing higher sensitivity and higher light intensity. This system also achieves more than twice the throughput of conventional systems through the development of the world's fastest image processing system, which is capable of handling 65-nm nodes or finer, while 90-nm nodes are a matter of course.

INTRODUCTION

SEMICONDUCTOR device technology nodes are advancing rapidly. Some leading-edge manufacturers are transitioning from 90-nm development process nodes to the 65-nm scale, and mass production process nodes are moving from 130 nm to 90 nm. Because of that trend, the use of new fine process technology and new materials is accelerating. As this new technology is being introduced, the detection of minute defects that conventional systems are unable to detect and new modes of defects that are associated with new materials are becoming problems for wafer inspection systems. The market is placing the following demands on optical defect inspection systems:

(1) Highly sensitive detection power capable of detecting microscopic defects

(2) Improved pattern noise reduction and S/N (signal-to-noise) ratio

For next-generation processes	For 90–65-nm node
Inspection mode	Cell-to-cell mode Die-to-die mode Cell-to-die hybrid mode
High-speed inspection	3 wafers per hour (300 ϕ)
Automatic defect classification	RDC as standard equipment
Conformance with safety regulations	For SEMI/S2-0200 and CE-MARK
For FA	For GEM (optional)

RDC: real-time defect classification
SEMI: Semiconductor Equipment and Materials International
FA: factory automation
GEM: generic equipment model

Fig. 1—New DUV Wafer Inspection System.
The latest bright-field optical wafer inspection system that features a DUV optical system which realizes high sensitivity and high throughput for process development and mass production for nodes of 90 nm or finer.

(3) Automatic defect classification function
(4) High detection sensitivity and high throughput

The model DUV (deep ultraviolet) optical wafer inspection system has been developed jointly by Hitachi High-Technologies Corporation and TOKYO SEIMITSU CO., LTD. to meet these market demands (see Fig. 1).

FEATURES OF NEW DUV OPTICAL WAFER INSPECTION SYSTEM

Highly Sensitive Defect Detection

Highly sensitive defect detection is achieved with an optical system that combines a high-intensity, short-wavelength DUV laser light source with super resolution technology instead of the conventional visible light source, and by using a powerful die comparison algorithm.

Reduced Pattern Noise

In patterned wafer defect inspection, the detection of fault defects caused by color variation and grain is a problem. The DUV optical wafer inspection system reduces pattern noise by employing a die comparison algorithm that tolerates differences in brightness.

High Throughput

To cope with the high-volume processing that comes with decreasing inspection pixel size and increasing wafer size, we achieved several times the throughput of conventional systems by developing an image processing system at the world's fastest level.

CONFIGURATION OF NEW DUV OPTICAL WAFER INSPECTION SYSTEM

Optics

The limit of resolution for ordinary optical systems is proportional to the wavelength, λ, and is expressed roughly as $\lambda/2NA$, where NA is the numerical aperture of the lens. Therefore, the resolution increases as the wavelength becomes shorter. A 266-nm DUV laser is used as a stable, continuous oscillation, high output laser. Because the use of a laser eliminates the effect of chromatic aberration, extremely low aberration is achieved and the development of a high performance, wide field of view DUV objective lens is possible. Also, the light source has surplus power, even during high-speed scanning, so various detection conditions such as pixel size and super resolution can be applied, making the system superior in terms of ensuring adaptability to processes. The speckle noise usually associated with laser light sources has been eliminated by developing a low-coherence illuminating optical system (see Figs. 2 and 3).

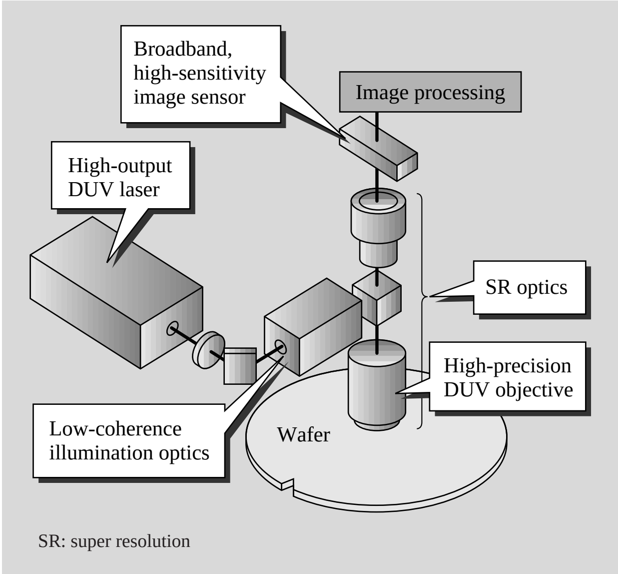


Fig. 2—DUV Optics.
Highly sensitive defect detection is achieved with the field proven SR (super resolution) optical system that employs a 266-nm DUV laser and illuminating optics that remove the speckle noise that is characteristic of lasers.

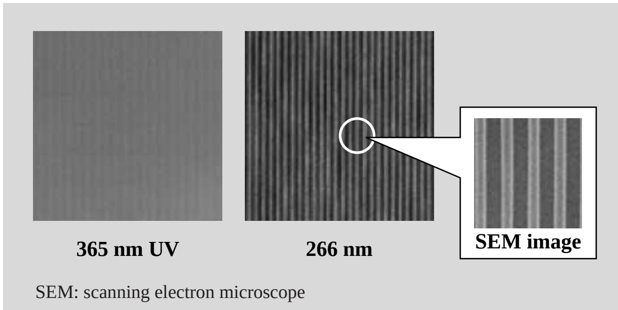


Fig. 3—Effect of Shorter Wavelength.
Microscale sample produced by Hitachi High-Technologies Corporation (0.11 μm line, 0.13 μm space) is clearly imaged.

The demands on inspection systems with respect to inspection of shorts and other defects in copper damascene wiring, which is becoming the mainstream wiring process, are increasing. The reflectivity of copper materials is a minimal at the wavelength of 266 nm, so good image contrast between the wiring and the base material (see Fig. 4) is easily obtained with this optical system.

In addition to the highly sensitive DUV optics described above, a newly developed image sensor and a die comparison algorithm allow the detection of minute differences in images, attaining a detection sensitivity for small defects on the order of a fraction

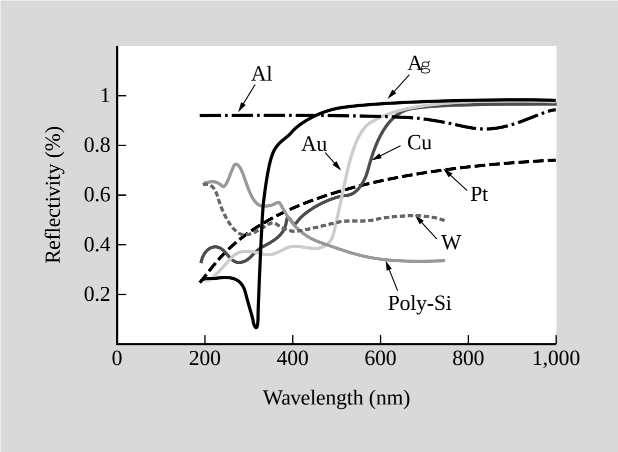
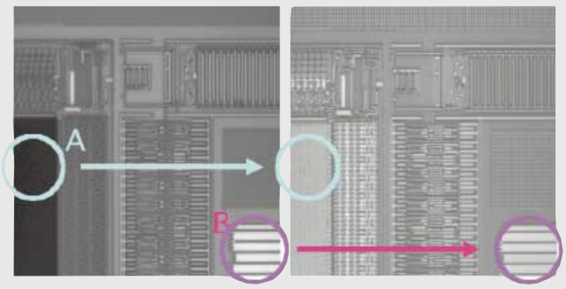


Fig. 4—Relationship between Material Reflectivity and Wavelength (spectral reflectivity).
There is a large difference in reflectivity at wavelengths near 266 nm, both between Cu poly-Si and between Al and poly-Si, which is optimum for obtaining high image contrast between wiring patterns and the base material.



(a) Ordinary image **(b) SR image**

Fig. 5—Effect of SR Optics.
SR technology results in higher contrast in part A, a fine pattern at near the limits of resolution. The signal for high-reflectivity part B, where the pattern is sparse, is controlled.

of the wavelength. Furthermore, our aim is to improve sensitivity by means of an original and field proven SR optical system (see Fig. 5), emphasizing pattern contrast close to the limit of resolution. SR conditions that are optimum for the process can be selected, which allows a high degree of adaptability to processes.

Stage

To take advantage of the resolution obtained by the optics, a stage equipped with a laser interferometer and high-speed, high-precision linear motors for the X and Y axes, a high-speed, high-precision real-time focusing function, and a broadband, highly sensitive image sensor were newly developed.

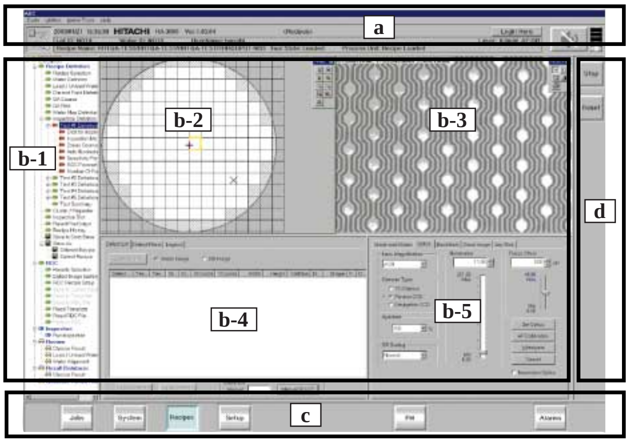


Fig. 6—Screen Layout.
The screen consists of a title panel, information panel, command panel and navigation panel.

Image Processing

To secure the flexibility needed to improve adaptability to various processes, we developed a high-speed programmable image processing system. In addition to the previous die comparison algorithm, it features:

a) Hybrid comparison in which high-sensitivity defect detection can be accomplished by repeated cell-to-cell comparison of the cells at the same time as die comparison, and

b) No decline in defect detection sensitivity, even when the color variation caused by the process is large. Thus, newly developed RDC (real-time defect classification) function has been implemented.

SOFTWARE

User Interface

To implement a unified design and GUI (graphical user interface) environment for the operation and convenient use of semiconductor fabrication systems and inspection systems as Hitachi Group products, the Hitachi Group recommends the application of the Hitachi GUI Design Guide for Semiconductor Manufacturing and Inspection Equipment (referred to as the Hitachi guidelines below), which conform to SEMI specifications. This design is expected to provide an even higher level of customer satisfaction. The Hitachi guidelines are applied in the new DUV optical wafer inspection system's GUI.

Screen layout

The screen comprises a title panel, an information panel, a command panel and a navigation panel.

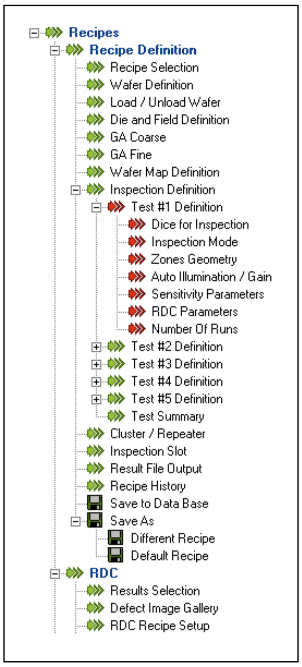


Fig. 7—Menu Tree.
The operation is the same as in Windows Explorer.

The title panel consists of an icon that indicates the host communication status, the system name, a login/logout button, an alarm turn-off button and a light tower display icon [Fig. 6 (a)].

The information panel consists of a menu tree [Fig. 6 (b-1)], wafer map [Fig. 6 (b-2)], video image [Fig. 6 (b-3)], review and classification tool [Fig. 6 (b-4)] and image display control [Fig. 6 (b-5)]. The new DUV optical wafer inspection system employs a menu tree that has a hierarchical structure that reflects the flow of work from top to bottom. The menu tree is organized by operation items and can be used in the same way as the Windows* Explorer menu system that is familiar to many personal computer users (see Fig. 7).

The navigation panel [Fig. 6 (c)] has buttons for “Jobs,” “System,” “Recipes,” “Setup” and “Alarm,” in conformance with the Hitachi guidelines. In addition, there is a button for “PM (preventive maintenance).” When the replacement time for the maintenance parts managed here approaches, a bright yellow highlight is displayed around the “PM” button (see Fig. 8).

The command panel has only “Stop” and “Reset” buttons [Fig. 6 (d)].

Real-time Defect Classification

Features that are judged to be defects by the inspection system but which do not directly affect the device yield are unimportant from the viewpoint of the user. Such defects are called nuisance defects, and

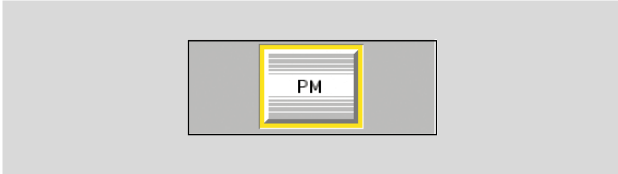


Fig. 8—PM Button Highlight Display.
The periphery of the button is highlighted in bright yellow to attract attention.

include microscopic particles in places where there is no pattern and depressions or protrusions of the wiring surface at the pattern edge. An examination of the attributes of such nuisance defects and true defects reveals that the two types of defects usually have opposite attributes. RDC is a function for the real-time reporting of the final results of classifying what are believed to be nuisance defects into a separate group from true defects on the basis of the difference in attributes so as to exclude the nuisance defects. The new DUV optical wafer inspection system is equipped with RDC as a standard function. The automatic classification of defects (e.g., fault defects) will lighten the burden on operators and review equipment as the number of defects becomes large.

Real-time defect classification operation sequence

The operation sequence for the new DUV optical wafer inspection system is outlined below:

(1) Defect classification

From 10 to 20 typical sample defects are collected for each classification class and classification rules are created for them.

(2) Selection of the inspection results for making the classification rules

Inspection results with multiple attribute information items appended are selected.

(3) Classification with the defect image gallery

Classification is performed again, using defect images displayed in the defect image gallery for each defect class.

(4) Automatic generation of RDC recipe

Classification rules that classify the classes of the defect image gallery with statistically good accuracy are automatically generated.

(5) RDC recipe tuning

The automatically generated classification rules are tuned.

(6) Reclassification of defects

All of the defects in the defect image gallery are

* Windows is a registered trademark of Microsoft Corp. in the U.S. and other countries.

re-classified with the classification rules to confirm the appropriateness of the rules.

CONCLUSIONS

We have described the new DUV optical wafer inspection system.

Inspection technology is playing an increasingly important role in expediting the development of advanced devices and the establishment of mass production factories as we enter the era of 90-nm nodes, and even 65-nm nodes. We will continuously strive to improve system performance to meet the demands of even finer patterns, new materials, and higher speed.

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