High-sensitivity, High-speed Dark-field Wafer-defect Inspection System—IS3000

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OVERVIEW: The scaling down of cutting-edge semiconductor devices is just getting faster and faster. As regards the inspection technology accompanying this trend, on the semiconductor development line, all kinds of inspection devices are used, and the DOI causing a fault is detected. Drawing up specific countermeasures to control this DOI thus becomes the main target. At the same time, on the production line, high-speed monitoring—for inspection at high frequency without missing DOIs of production wafers—is becoming mainstream. To meet the above needs as semiconductor processes go beyond the 45-nm node, Hitachi has developed the IS3000 inspection system for patterned-wafers—which can perform such monitoring of defects and foreign bodies at high-speed and high-sensitivity—and implemented this system on the production line. The IS3000 can detect foreign bodies, scratches, pattern shorts, and chipping on patterned wafers at a sensitivity of 50 nm and at high speed, namely, 35-300-mm wafers per hour. In other words, it successfully combines high throughput with high sensitivity. Furthermore, it features user-friendly operability regarding recipe creation, etc., an easy dark-field classification function for automatically classifying the detected defects, an interface with SEM observation, and improved analysis capability.

INTRODUCTION

AS scaling down of the process node towards 45 nm continues, semiconductor devices are going through major transformations regarding introduction of new processes, new materials, and the 300-mm wafer automated production line. During such transformations, whether vertical start-up of a line and stable production can be kept up is becoming

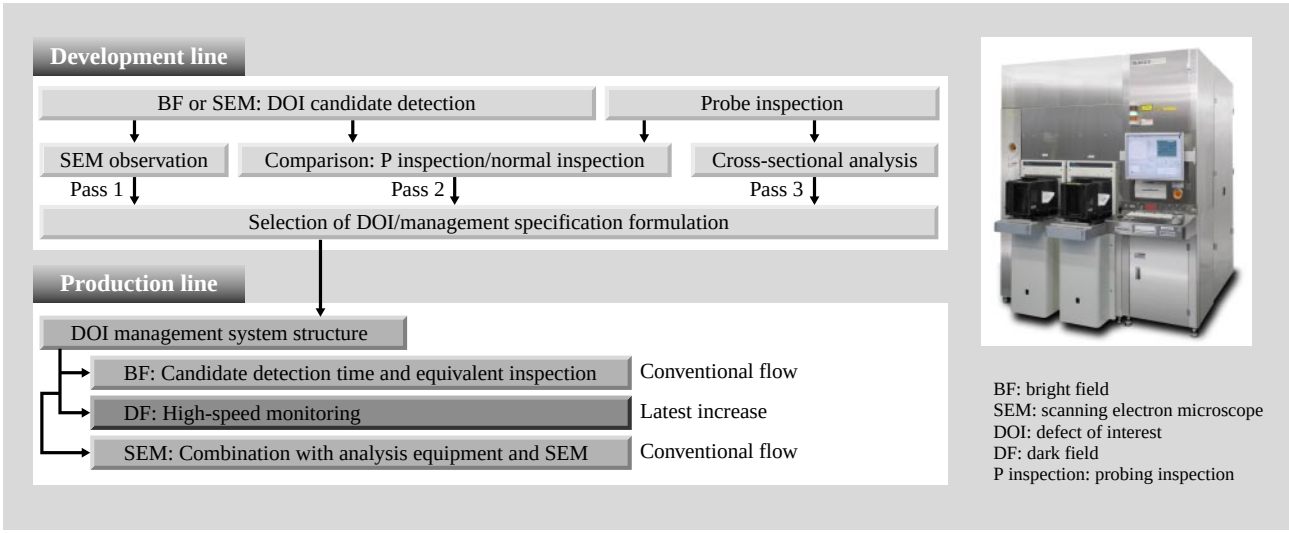


Fig. 1—Features of IS3000: High-sensitivity, High-speed Wafer-defect Inspection Device.
This device incorporates the latest optical system and high-speed stage, as well as a high-speed data processing function, and achieves high detection sensitivity and throughput for enabling 100% in-line inspection of semiconductor fabrication processes beyond the 45-nm node.

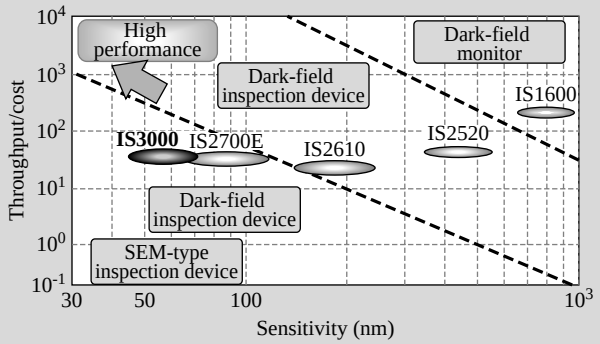
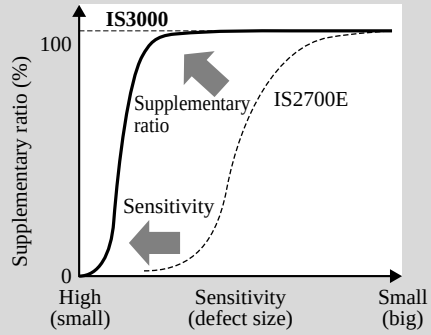


Fig. 2—Position of IS Series.
Combing high sensitivity and high throughput at higher dimensions, IS3000 achieves low cost.



- Combination of high sensitivity and high throughput (In the case of 45-nm-node process, high investment efficiency)
- High sensitivity in new processes
- User-friendly recipe setting

Fig. 3—Development Concept Behind IS3000.
IS3000 is aimed at improving detection supplementary ratio and performance for handling new processes as well as further simplifying recipe setting.

the overriding issue that will determine the fate of semiconductor manufacturers. To improve capacity operating ratio of expensive facilities and equipment, and to detect generation of foreign bodies and defects that occur with increased number of processing operations and improve and maintain detection yields, high-sensitivity and high-speed inspection equipment is being installed on key processes. Moreover, it is becoming a requirement to perform inspection of a large number of wafers. Responding to these cutting-edge process needs, the newly developed "IS3000" is a state-of-the-art dark-field-type inspection system for detecting wafer pattern defects. While maintaining high throughput—the advantage of a dark-field-type defect-detection inspection device—the IS3000 is a ground-breaking detection device that surpasses conventional dark-field types in that it can also detect parts of shape defects and foreign bodies in places other than the top wafer surface (such as between interconnections and in contact holes).

NEEDS REGARDING DEFECT INSPECTION DEVICE FOR PATTERNED WAFERS

In regards to manufactured products like memory systems, whose shrink speed is increasing, for the sake of vertical start-up, the demand for high yield has become much more severe than in the past. At present, however, the introduction of new materials and processes accompanying this shrinking—with new equipment for supporting them—is causing a rapid increase in the causes of yield degradation. As a result, methods dependent on conventional experience and know-how cannot cope with the present situation. Prompt yield improvement depends on measuring many as many in-process wafers under actual processing as possible and gathering data, and how to promptly detect process and fabrication-equipment trouble and give appropriate feedback. Under these circumstances, the following needs must be satisfied:

(1) High detection sensitivity
(2) High throughput
(3) Changeable detection sensitivity targeting scaling up of inspection process
(4) Operability for easy staff handling
(5) Excellent CoO (cost of ownership)

Positioned as an extension to the IS series (see Fig. 2), the IS3000—a dark-field-type defect-detection inspection device for pattered wafers—was developed with the aim of meeting these needs by combining high sensitivity and high throughput while achieving good cost performance.

TECHNICAL CHALLENGES

During device development, in addition to the combination of high sensitivity and high throughput, improvement of the supplementary ratio of foreign bodies and defects, improvement of detection performance for defects generated in new processes, and process scaling up were set as targets (see Fig. 3).

TABLE 1. IS3000 Specification
With the IS3000, inspection at a high throughput of more than 1 lot per hour is possible.

Item	Specification		
Wafer size	300 mm		
Detection sensitivity/ throughput (bare wafer with PSL) (sequential inspection)	0.05 µm/ 5 wafers/h	0.07 µm/ 20 wafers/h	0.10 µm/ 35 wafers/h
Analysis	High-precision defect-coordinates output; defect-size determination, easy dark-field classification function		
External interface	Ethernet* (FTP), SECS, GEM		

FTP: file transfer protocol GEH: generic equipment model
SECS: semiconductor equipment communications standard

* Ethernet is a registered trademark of Xerox Corp.

High-sensitivity Defect-detection Technology

Light scattered from the pattern and light scattered from foreign bodies and defects are differentiated and, to attain high sensitivity, the three technical developments listed below were accomplished.
(1) Miniaturization of inspection pixel size
(2) Shortening wavelength of detection laser
(3) Unique lighting for color defect detection

Consequently, foreign bodies and defects generated in processes beyond the 45-nm node can be detected at high sensitivity, thereby contributing to maintaining and improving yields.

Multimode Inspection Technology

Although sensitivity and throughput conflict, with the current IS series, the two are combined. However, in the case of the latest process that the process node has reached, there have been cases in which higher sensitivity is required for certain key processes. Meeting this required sensitivity, a multimode function that allows detection sensitivity to be switched between three levels is incorporated in the IS3000, making inspection of more processes possible. By meeting these technical challenges, we have combined high sensitivity and high throughput at higher dimensions, and commercialized inspection equipment that incorporates this feature. The main specifications of the IS3000 are listed in Table 1.

Simple Operability

As regards production of various products in small volumes, creation of inspection conditions is a huge burden. While inheriting the simplicity of the IS2700, the IS3000 has an enlarged monitor, and by reducing the number of times the screen is changed during operation and constantly displaying the same place on a wafer, the handleability is improved (see Fig. 4). Furthermore, the number of critical parameters to set while creating a recipe is four, so parameter setting can be done in about 10 minutes.

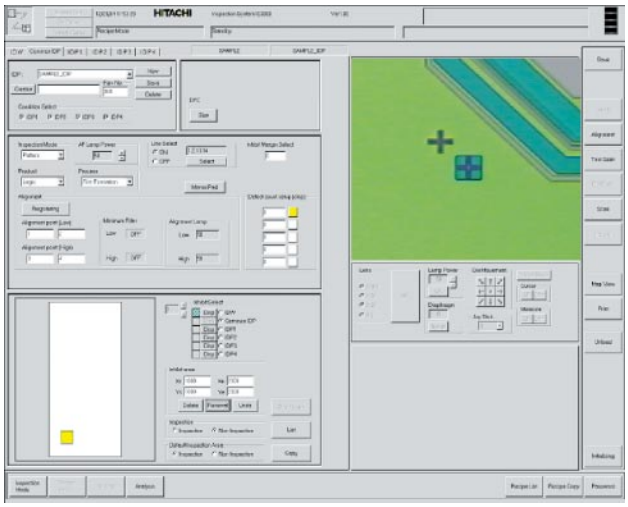


Fig. 4—Example Screen for Recipe Set-up with IS3000.
By enlarging the screen size, necessary information can be displayed at all times. Moreover, the screen is set out in such a way that dialogs do not overlap.

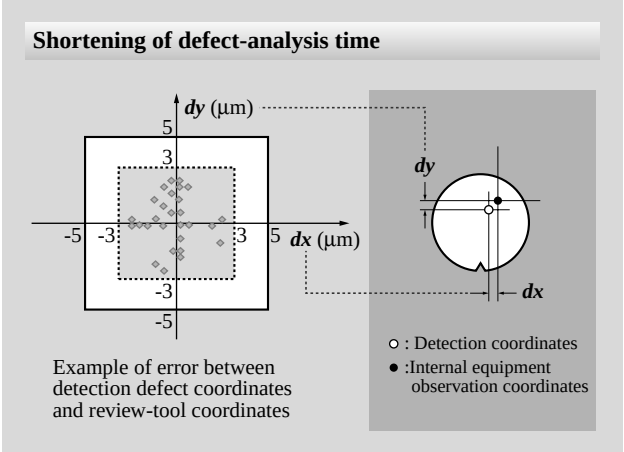
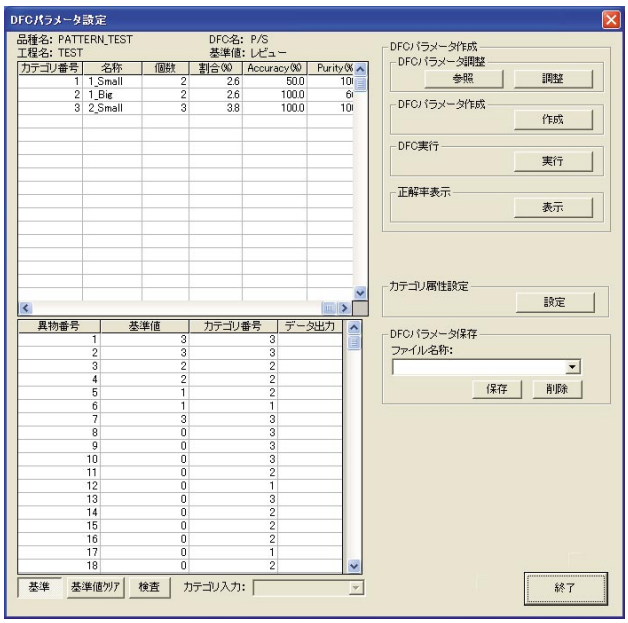


Fig. 5—Coordinate Precision for Foreign-body Detection and Other Analysis Devices.
Coordinate precision is distributed in the ±3-µm range, and by high-precision linking with other review and analysis devices, defect-analysis time can be shortened.

Linked Functions with Other Observation and Analysis Equipment

Based on information regarding the defect and foreign bodies detected by the IS3000, observation and analysis are performed by review devices such as



DFC: dark-field classification

Fig. 6—Screen Shot of Classification Set-up. Classification setting is made easy by linking IS3000 inspection results with review results.

Hitachi's review SEM, the RS-4000. Owing to its high coordinate precision, the RS-4000 enables efficient observation and analysis (see Fig. 5).

Foreign-body-classification Function

As a result of improving detection sensitivity, the number of items that can be detected has been significantly increased. Since not all detected defects and foreign bodies are of a critical nature, however, to employ effective countermeasures on the production line, it is necessary to extract only the critical defects and foreign bodies. The IS3000 is equipped with a function called easy dark-field classification for classifying the detected defects and foreign bodies in real time. A screen shot of classification set-up is shown in Fig. 6. By utilizing an algorithm for automatically selecting specific amounts for classification, the classification performance and simplicity of outputting conditions are improved.

Example of Detected Foreign Bodies and Defects

Examples of foreign bodies and defects detected by the IS3000 are shown in Fig. 7. It is clear that although detection is difficult with conventional dark-field inspection equipment, it is possible to detect defects and foreign bodies on wafer patterns as well as small void defects in steps with the IS3000.

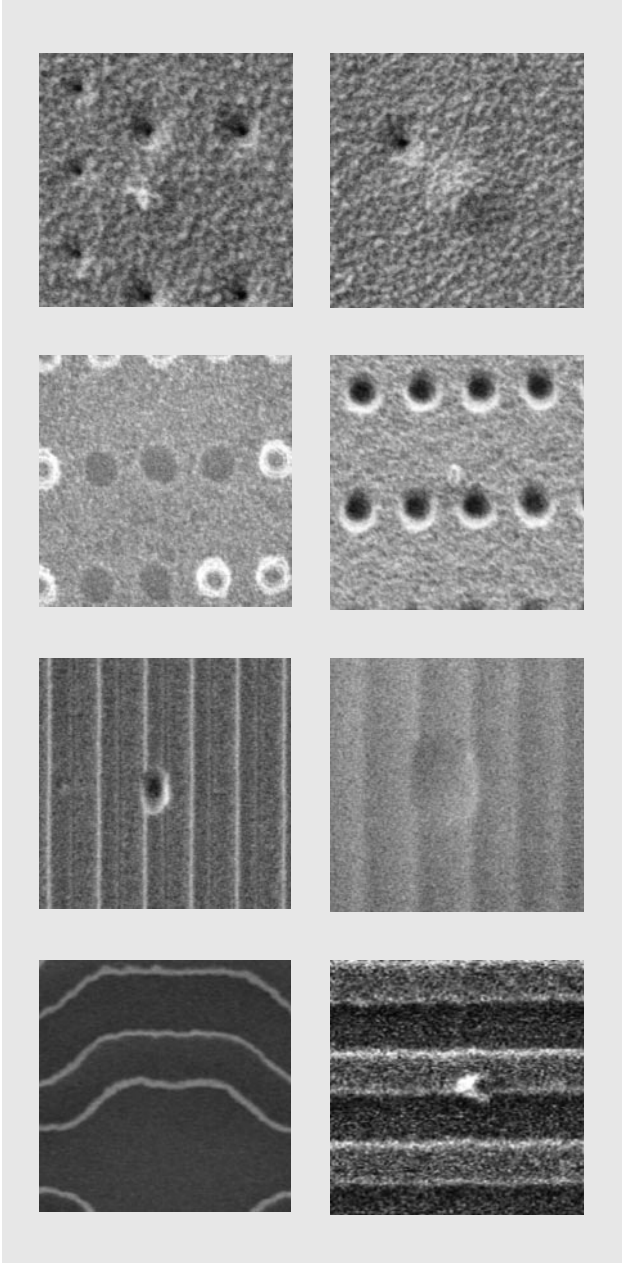


Fig. 7—Examples of Detected Foreign Bodies and Defects. With a conventional dark-field inspection device, detection was difficult; however, with the new method, detection of small foreign bodies and defects on the pattern, as well as small voids on steps, is possible.

CONCLUSIONS

A dark-field-type wafer-pattern-defect inspection system was developed. Speeding up start up of factory production and development of cutting-edge semiconductors makes inspection technology ever more important. From now onwards, with this

importance in mind, Hitachi will strive to develop and continuously improve high-speed and high-sensitivity inspection systems in line with the demands of our customers.

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