# High-sensitivity, High-speed, Dark-field Wafer-inspection System

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*OVERVIEW: In regard to semiconductor fabrication processes, the use of copper interconnection, high- or low-dielectric-constant materials, and new processes such as planarization by CMP (chemical-mechanical polishing) is steadily complicating processing. Under these circumstances, it is important to improve or maintain process yield in the early stage of a line start-up by means of detecting particles and defects that occur during processing and taking prompt action to remedy them. Having developed and installed the IS2700 dark-field inspection system for patterned wafers on the production line, Hitachi Group has made it possible to perform high-speed, high-sensitivity monitoring of defects and particles produced by beyond-90-nm-node processes. With the IS2700 it is possible to detect defects, such as particles, scratches, pattern short circuits, and cracks, on patterned wafers at a sensitivity of 0.10 μm. It can inspect all product wafers of 300-mm diameter wafer at high speed, namely, a throughput of 37 wph (wafers per hour). In addition, its user-friendly operation makes recipe creation easy, and it is equipped with an interface that provides defect analysis functions, automatic DFC (dark-field classification), and analysis through high-resolution DUV (deep ultraviolet) defect-review optical system and SEM (scanning electron microscope) defect data link.*

## INTRODUCTION

IN line with the progress toward the 90-nm node, major changes concerning further progress in finer processes, introduction of new materials and processes, and use of large-diameter (i.e., 300 mm) wafers are all ongoing. These circumstances make it especially important that however fast new plants and lines are set up, stable production must be maintained.

To improve the utilization rate of costly facilities and equipment, and maintain yields while inspecting for the particles and defects resulting from even finer and an increased number of processes, high-speed inspection systems providing all-product wafer inspection must be implemented in production lines (see Fig. 1).

To meet the demands of leading-edge semiconductor fabrication processes, a groundbreaking dark-field inspection system—called the IS2700—has been developed. The major advantage of this system is that it can maintain high process throughput while detecting particles and parts of shape defects on the surface as well as between lines and at the bottom of contact holes.

The following sections describe the features of the IS2700, a dark-field inspection system for detecting defects and particles on patterned wafers.

## REQUIREMENTS FOR PATTERNED WAFER INSPECTION SYSTEM

As the production of system LSIs (large-scale integrations)—which have a comparatively short product cycle—increases, the demands concerning the production yield have become higher than ever before. And with the introduction of new equipment to handle even finer processes as well as new processes and materials, there has been a rapid increase in the factors that degrade the yield. Under these circumstances, methods that rely on our current experience and know-how are becoming inadequate.

To improve yield in the early process stage, many measurements on as many wafers as possible under actual processing (i.e., in-process wafers) should be taken. This data should then be analyzed so that abnormalities in the process or equipment can be quickly detected and corrected by feedback control.

In light of these circumstances, an inspection system must meet the five requirements listed below:

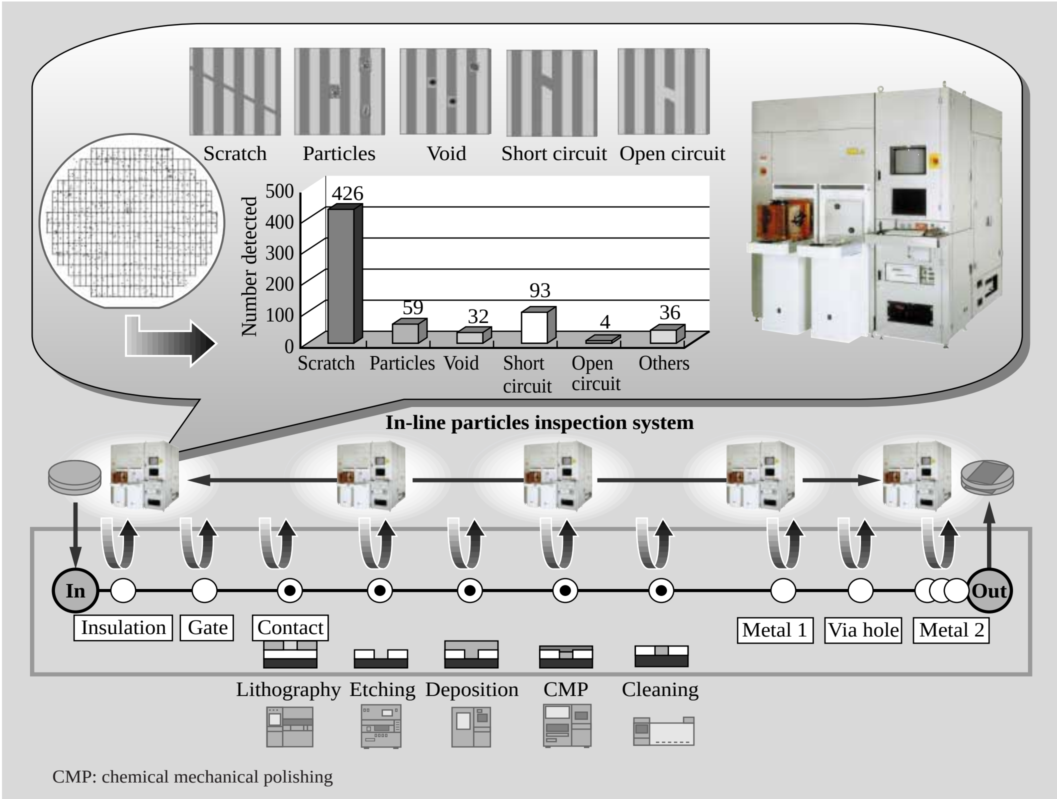


*Fig. 1—Application Example of High-sensitivity, High-speed Wafer Inspection System "IS2700."*
*The IS2700 is equipped with a new optical system and high-speed stage, as well as a high-speed data-processing function, that enable all product wafer inspection of beyond-90-nm-node in-line processes at high sensitivity and high throughput.*

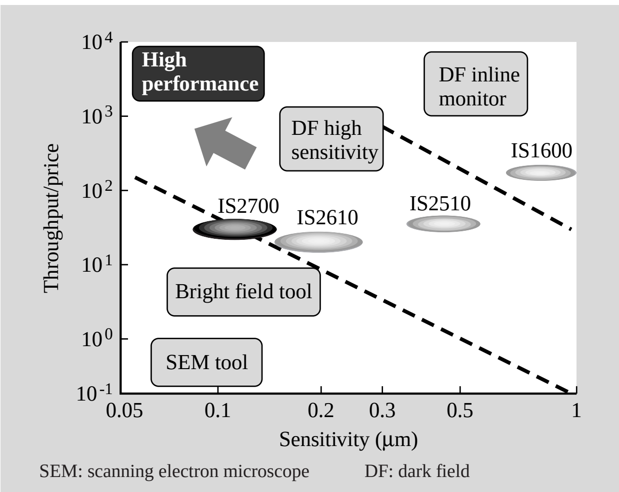


*Fig. 2—Throughput/price vs. Sensitivity for IS Series.*
*The IS2700 combines high sensitivity and high throughput while lowering inspection cost.*

(1) High inspection sensitivity
(2) Inspection of all product wafers at high throughput
(3) Easy-to-use operation for fabrication staff
(4) Low dependence of sensitivity on kind of LSI (e.g., memory LSIs or system LSIs)
(5) Outstanding CoO (cost of ownership)

As an extension of the conventional IS series, the development of the IS2700 was aimed at combined high-speed and high-sensitivity inspection together with good cost performance (see Fig. 2).

## TECHNOLOGICAL TARGETS

Upon developing the inspection system, in addition to combining high sensitivity and high throughput together with improving the replacement ratio concerning particles and defects, we set an objective to improve inspection performance regarding defects generated during new processes (see Fig. 3).

### High-sensitivity Defect-detection Techniques

To obtain high sensitivity for discriminating between light scattered from a wafer pattern and that from particles and defects, the techniques listed below were developed:
(1) Reduced inspection pixel size
(2) Laser illumination angle for inspection target

Applying the above techniques enables defects and particles produced by below-90-nm-node processes to be detected at high sensitivity and contributes to maintaining and improving process yields.

### High-speed Defect-detection Techniques

(1) High-speed-inspection stage

The IS2700 is equipped with an inspection stage

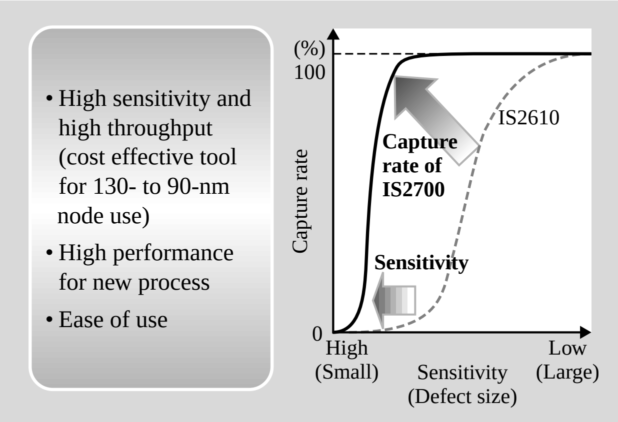


*Fig. 3—Concept behind Development of IS2700.*
*The IS2700 is aimed at improving performance regarding new processes and defect capture ratio.*

that can move the wafer in the X- and Y-directions so that the whole area of the wafer's surface can be inspected. To reduce inspection time, it was necessary to speed up the scan time and shorten the acceleration time of the stage in the X-direction as well as the movement time in the Y-direction. To accomplish these two tasks, the operation of the IS2700 is significantly faster in comparison to previous systems; consequently, it can perform high-speed inspection at a rate of 37 (300-mm diameter) wph (wafers per hour).

(2) High-speed image processing

To attain high sensitivity, the size of the detection pixels is reduced in comparison to the conventional size. As a result, the number of pixels in proportional to pixel size is increased. And combining a faster image-processing system clock with parallel processing makes it possible to detect particles and defects within the wafer scan time, thereby high throughput is realized.

## FEATURES OF IS2700

(1) High-sensitivity, high-speed inspection

By addressing the above-mentioned technological issues, Hitachi Group has succeeded in developing a commercial high-level inspection system that combines high sensitivity with high throughput. The main specifications of this system—namely, the IS2700—are listed in Table 1.

(2) Defect classification function

Although the improved sensitivity has led to a big increase in the number of detected defects, it is important to determine whether all of these defects have influences on the yield.

The IS2700 is equipped with a function called DFC

TABLE 1. Specifications of IS2700 System
*The IS2700 can perform inspection of all product wafers at high sensitivity of two lots/h.*

| Item | Specification | | Note |
|---|---|---|---|
| Wafer size | 300 mm | 200 mm | — |
| Detection sensitivity | 0.10 µm | | High-sensitivity mode |
| | 0.15 µm | | High-throughput mode |
| Throughput (patterned wafer) | 25 wph | 38 wph | High-sensitivity mode |
| | 37 wph | 55 wph | High-throughput mode |
| Analysis functions | DUV microscope, DFC | | (Option) |
| External interface | Ethernet* (FTP), SECS, GEM | | (Option) |

FTP: file transfer protocol
* Ethernet is a trademark of Xerox Corp. in the U.S.A.

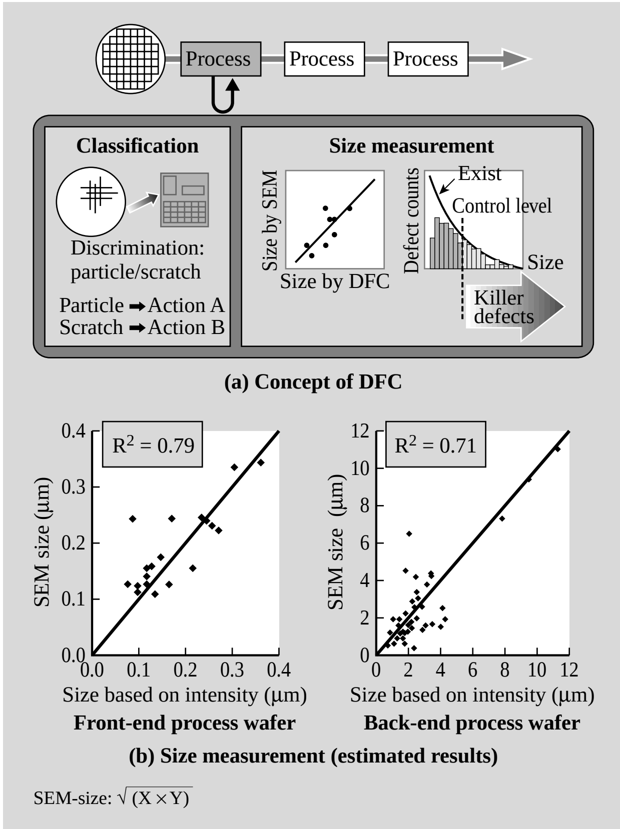


*Fig. 4—Defect Classification Function.*
*A DFC function enables defects such as particles and scratches to be classified. The particles sizing function gives an excellent correlation factor of 0.70 between SEM size and standard luminance size.*

(dark-field classification) that can classify detected particles and defects and calculate their sizes in real time. The concept of DFC is illustrated in Fig. 4. According to the detected defect mode and size, different actions are taken as feedback to the process. The category and size of the defects are then displayed and an accurate forecast of the process yield can be

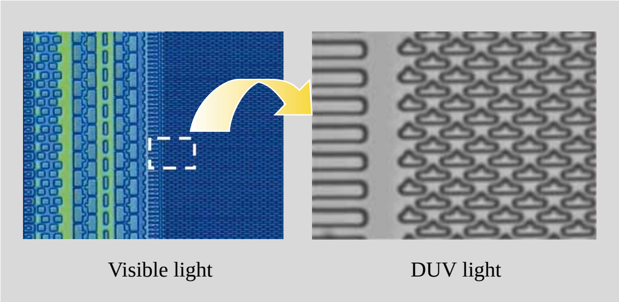


*Fig. 5—Defect Observation Function.*
*Both visible light and DUV light provide high resolution; therefore, they offer high-performance particle and defect observation.*

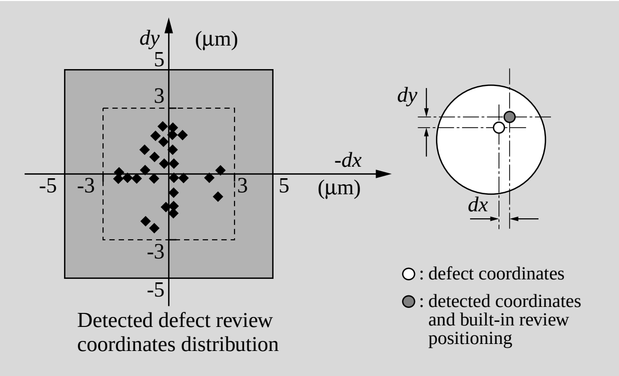


*Fig. 6—Coordinate Accuracy for Linked Analysis Devices.*
*The distribution of the coordinate precision is within a ±3 μm, and precisely linking the IS2700 with other defect-review and analysis devices leads to shorter defect-analysis time.*

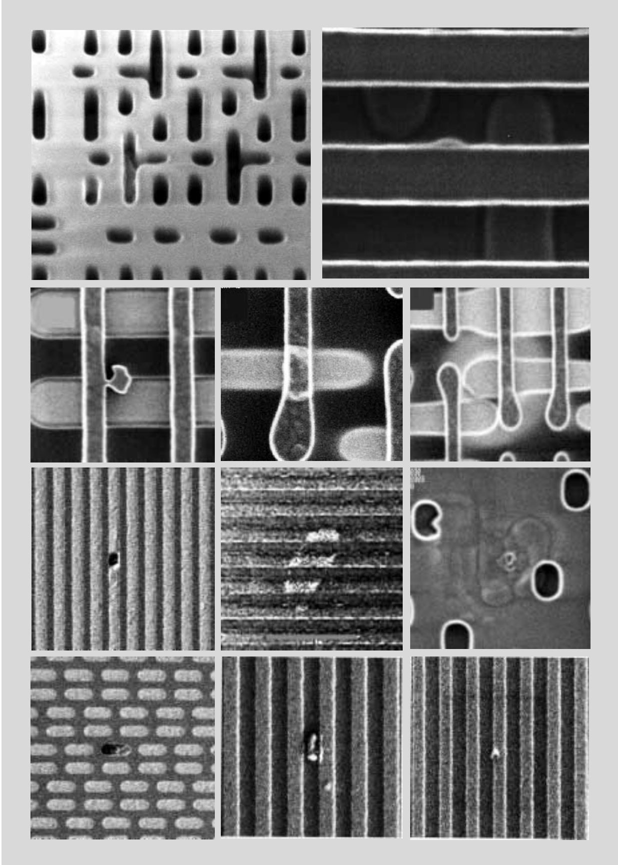

*Fig. 7—Examples of Detected Particles and Defects.*
*It can be clearly seen from the images that the IS2700 can detect objects, such as particles in the bottom of trenches and pattern defects, that were hitherto difficult to detect with conventional inspection systems.*

made.

(3) Simple operation

In accordance with the trend toward low-volume multi-product production of system LSIs, it has become a heavy burden to create the proper inspection conditions. As a result of this additional burden, the equipment up-time has decreased and the optimum sensitivity set according to the experience of the operator who sets the conditions may not be available. In light of these problems, the IS2700 is designed such that only two parameters are required to set the inspection sensitivity, namely, illumination condition and detection threshold. And since the system is also equipped with a function that automatically sets the conditions, the condition setting takes about 10 minutes.

(4) Linking of monitoring and analysis systems

The inspection results are displayed as an image called a particle map. Monitoring of detected particles and defects is carried out by the optical microscope equipped in the IS2700, which can either be operated according to the defect detection order or by clicking on particular particles on the map.

Furthermore, DUV (deep ultraviolet) can be selected as the light source, so monitoring can be switched between visible light and DUV light. This produces high performance in detecting particles or defects (see Fig. 5). In addition, according to the information about detected particles obtained by the DUV or visible-light inspection, even more efficient analysis can be performed with an attached defect-review SEM (model RS3000) (see Fig. 6).

(5) Examples of detected particles and defects

Some examples of actual particles and defects detected by the IS2700 are shown in Fig. 7. It is clear from the images that particles at the bottom of trench, pattern defects, and minute particles—all objects that are difficult to detect with a conventional dark-field-type inspection system—can be successfully detected by the IS2700.

## CONCLUSIONS

This paper has described a new dark-field wafer inspection system for detecting particles and defects in patterned wafers. As the scaling down of semiconductor devices continues to be spurred on more and more, Hitachi Group is committed to developing and commercializing inspection systems that meet the needs of our customers.


## ACKNOWLEDGMENTS

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