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Application News

No. V28

High-Speed Video Camera Hyper Vision HPV-X2

3D-DIC Analysis in Impact Test of Silicon Wafer

As the main material for semiconductor devices, silicon wafers (hereinafter, Si wafers) are the most important basic material in the electronic industry. Si wafers are manufactured by applying polishing, heat treatment and other processes to thin sheets (wafers) sliced from single crystal ingots of silicon (Si).

In recent years, demand for semiconductor devices such as flash memories and LSIs has increased explosively, and higher throughput is also required in the manufacturing process in order to satisfy this continually-increasing demand. Use of larger-diameter Si wafers is progressing with the aim of increasing the number of devices that can be manufactured from each Si wafer, and this has made large contributions to both higher throughput and cost reduction.

However, recent Si wafers have reached a size of φ300 mm but have a thickness of only 1 mm or less, and great care is necessary in handling these hard, brittle Si wafers.

An accurate knowledge of the size and distribution of strain at the wafer surface until a Si wafer is destroyed is necessary in order to improve wafer handling technologies, but because destruction of Si wafers is a high-speed phenomenon, adequate information could not be obtained with the conventional techniques.

In this example, high-speed deformation of Si wafers was visualized by 3D-DIC analysis*1 by observing the destruction of Si wafers from two directions using two Hyper Vision HPV-X2 high-speed video cameras.

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*1 DIC (Digital Image Correlation) analysis:
Technique for investigating the amount of pattern movement at the surface of an object by comparing a random pattern before/after deformation. Three-dimensional measurement (3D-DIC) from images taken from two directions is also possible.

Measurement System

In a puncture test using a High-Speed Puncture Impact Testing Machine HITS-P10, destruction was observed with two Shimadzu Hyper Vision HPV-X2 high-speed video cameras. Because the two HPV-X2 cameras are connected with a synchronization cable, synchronized recording in which the phases of the recording frames coincide is possible. Recording from two directions enables highly accurate 3-dimensional measurement considering deformation in the out-of-plane direction.

The test equipment used in this example is shown in Table 1. Fig. 1 shows the arrangement of the test equipment, and Fig. 2 shows the condition of the test section. To observe the opposite side to punching side of the specimen by striker from the front of the device, a plane mirror is arranged at the bottom of the test section. Recording is triggered by detection of the position where the striker contacts the specimen so as to match the timing of recording.

As the images taken by the HPV-X2 cameras are analyzed by using the DIC software VIC-3D, it is possible to obtain the distribution of displacement. With VIC-3D, the HPV-X2 cameras are controlled directly by the DIC software, and as a result, the complicated calibration operation which is essential in 3D-DIC and data analysis at the time of measurement can be performed easily.

Table 1 Measurement Conditions

High-speed video camera	: Hyper Vision HPV-X2 × 2 units
Testing system	: High-Speed Puncture Impact Testing Machine HITS-P10
Lighting	: Strobe
DIC software	: VIC-3D (Correlated Solutions, Inc.)

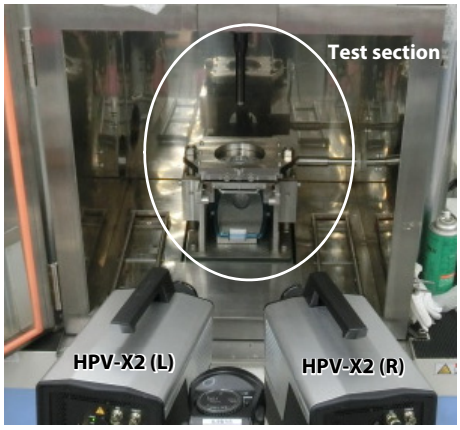

Fig. 1 Arrangement of Test Equipment

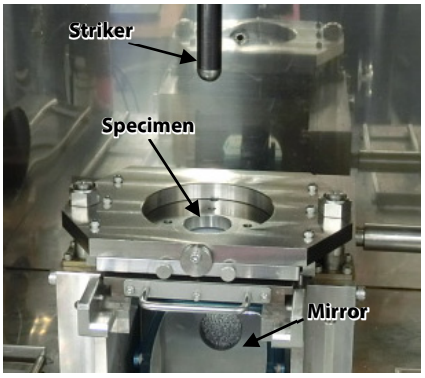

Fig. 2 Condition of Test Section

Test Conditions

A 3-inch Si wafer with a <100> crystal orientation was used as the test specimen. Table 2 shows the details of the specimen. A random pattern was drawn on the satin-finished surface of the Si wafer with a permanent (oil-base) marker (Fig. 3). The test conditions are shown in Table 3.

Table 2 Details of Test Specimen

Test specimen	:	Si wafer Crystal orientation <100>, one-side polishing
Specimen dimensions (in)	:	φ3 inch (φ76 mm), thickness 380 µm

Table 3 Test Conditions

Test speed	:	10 m/s
Recording speed	:	500 kfps
Dimensions of test apparatus	:	Striker φ20 mm Inner diameter of specimen support φ40 mm

Fig. 3 Test Specimen Showing Random Pattern

Measurement Results

Fig. 5 shows the high-speed recording images before/after destruction of the Si wafer. The results of measurement of the displacement in the Z-direction (vertical direction from the page surface) obtained by DIC analysis of these images are shown in Fig. 4.

The condition of change cannot be observed visually in the recorded images. However, from the analytical results, it can be understood that displacement increases progressively in a concentric manner from the central part of the specimen.

Fig. 6 shows the displacement of the cross section along the diameter of the Si wafer in each frame. Displacement increases at a nearly constant rate until frame 72. The rate of increase in displacement is approximately 10-11 m/s, which is consistent with the test speed. At frame 73, a rapid increase in displacement can be seen in the right of center area; this is due to the occurrence of a vertical crack at the right side of the center of the specimen. Thus, it was possible to grasp the maximum displacement of the specimen and the occurrence of the crack in its initial phase by DIC analysis, even though these features cannot be understood from the recorded images alone.

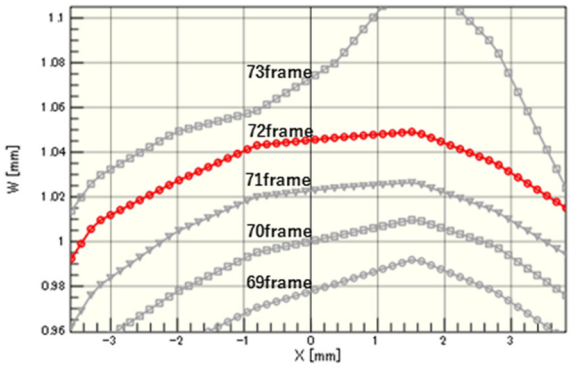

Fig. 4 Displacement of Cross Section in Z-Direction

Summary

In this example, the 3-dimensional displacement of a Si wafer before/after destruction was measured by 3D-DIC analysis of high-speed recording images taken from two directions using two HPV-X2 high-speed video cameras. Knowledge of the size and distribution of displacement before/after destruction can be useful for improving Si wafer handling technology.

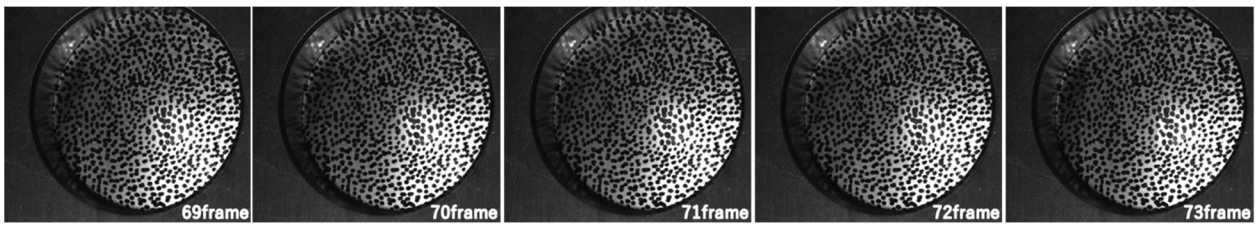

Fig. 5 Recorded Images Before/After Destruction (Taken by Camera on Right; the Time Interval Between the Images is 2 µs)

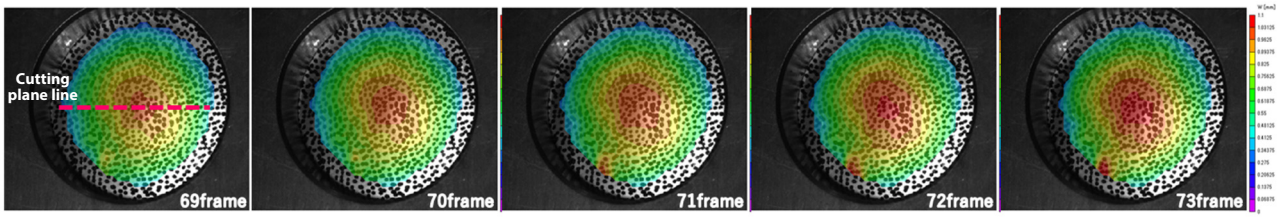

Fig. 6 Results of 3D-DIC Analysis of Images in Fig. 5 (Distribution of Displacement in Z-direction; the Size of Displacement is Indicated by the Color Bar at the Right)

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