Investigation of shape measurement method for large-diameter silicon wafer with additional support

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Keywords: Silicon wafer, Warp, Shape measurement

Abstract

When the warp of a 450 mm silicon wafer is measured with the inverting method, the displacement sensor with a sufficiently wide dynamic range has to be used to measure the wafer shape because of the significant gravity induced deflection, which would lead to a decrease in the measurement accuracy. In order to solve this problem, a measurement method of warp shape for thin-large panels like 450 mm silicon wafers with four supports was proposed and its effectiveness was verified experimentally.

1. Introduction

Although the warp measurement for 450 mm wafers is required from the production site, precise measurement methods have not been established yet. One reason is that the wafer deflection due to gravity during the shape measurement process with the three-point-support inverting method [1] increases significantly comparing with that of a 300 mm wafer. This deflection deteriorates the measurement accuracy because a wider dynamic range has to be used. In this study, a four-point-support inverting method was proposed to reduce the gravity induced deflection and improve the warp's measurement accuracy for thin-large panels.

2. Measurement principle

2.1 Principle of three-point-support inverting method

Fig.1 shows the schematic of the principle of the three-point-support inverting method [1]. The front surface shape $f(x, y)$, expressed by Eq.(1), is measured when the wafer is supported horizontally with three balls which are positioned every 120° on a circle concentric with the wafer center.

$$f(x,y) = w(x,y) + g(x,y) + \frac{t(x,y)}{2} + \frac{s_t(x,y)}{2} \quad (1)$$

where, $w(x,y)$ is the warp, $g(x,y)$ is the deflection due to gravity, $t(x,y)$ is the thickness distribution, and $s_t(x,y)$ is the inclination correction. After measuring the front surface, the wafer is inverted around the y-axis and the back surface is measured in a similar way. Since the sign of the x-coordinate is reversed, the back surface shape $b(x,y)$ of the wafer can be expressed by Eq.(2).

$$b(x,y) = -w(-x,y) + g(-x,y) + \frac{t(-x,y)}{2} + \frac{s_t(-x,y)}{2} \quad (2)$$

From Eq.(1) and (2), the warp shape can be obtained with Eq.(3) by deleting the deflection due to gravity and the thickness deviation.

$$w(x,y) = \frac{f(x,y) - b(-x,y)}{2} \quad (3)$$

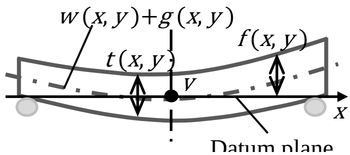

Fig.1 Schematic of three-point-support inverting method

2.2 Principle of four-point-support inverting method

When the shape measurement of a 450 mm wafer is carried out with the above inverting method, the increased deflection due to gravity is reduced by raising the wafer center with a fourth support. In order to eliminate the influence of the additional support, the same force is applied to raise the wafer before and after inverting. The raising amount is set so that the dynamic range of the measurement sensor needed in the surface shape measurement becomes the smallest. The deflection at the wafer center, expressed by Eq.(4) obtained from Eq.(1) and (2), can be calculated from the measured results of $f(0,0)$, $b(0,0)$ and $t(0,0)$ when neglecting $s_t(0,0)$ since it's too small comparing with other items. When the front surface is set upward, the raised amount at the center is adjusted with the additional support and observed with a displacement sensor. When the raised amount becomes nearly equal to the value obtained by Eq.(4), the raising force is determined and used for both shape measurements of the front and back surface. Because the deflections due to gravity before and after inverting decreases equivalently by the same raising force, the warp shape can be obtained from Eq.(3).

$$g(0,0) = \left(f(0,0) + b(0,0) - t(0,0) - s_t(0,0)\right)/2 \qquad (4)$$

3. Experimental verification for four-point-support inverting method

In order to verify the effectiveness of the proposed four-point-support inverting method, a thin rectangle beam was measured when supported by two cylindrical rollers at both ends (equivalent to the three-point method) and by three cylindrical rollers at both ends and center (equivalent to the four-point method). By comparing the measurement results of the warp, the effectiveness of newly proposed four-point method was verified.

3.1 Experimental method

A milling machine was used instead of the surface shape measurement machine. The displacement sensor was mounted on the spindle of the milling machine, and the beam was measured when supported on the table of the milling machine. The schematic of the measurement set up is shown in Fig.2. Supports were positioned ±150 mm in the X-direction from the beam centre. A three axis stage and a rotating stage whose rotating axis was z-axis were fixed on the machine table. The support for raising the central part of the beam was mounted on those stages. Moreover, the deflections of the beam were measured along its central line in the X-direction which is the longitudinal direction of the beam. After the front surface was measured, the beam was inverted around this central line.

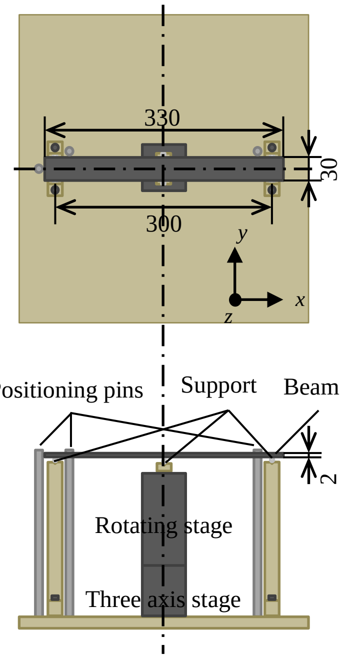

Fig.2 Schematic of measurement set up

3.2 Experimental results

The measurement results of the deflections of the traditional three-point method and the central-support (four-point) method are shown in Fig.3. The deflections of the front and back surfaces are shown respectively. The beam centre was raised by a force of 0.261 N with the fourth support. Fig.3 shows that the deflections of the front and back surfaces at the central part with the central-support method were about 105 μm smaller than that with the traditional method. The front surface shape and the back surface shape were symmetrical to the datum plane. Fig.4 shows the warp shapes obtained from deflection data of the traditional and the central-support method. Although the deflection shapes of the front and back surfaces were different with these two methods, the obtained warp shapes were nearly the same.

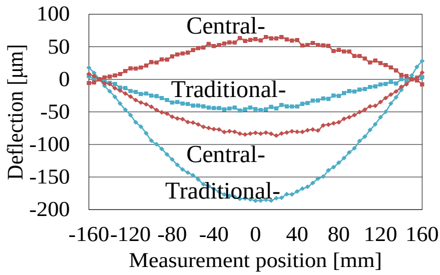

Fig.3 Measurement results of

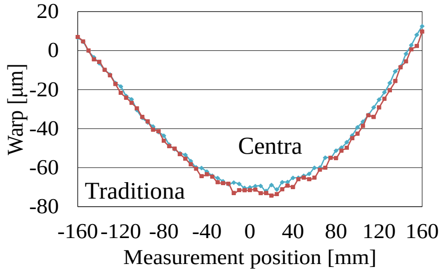

Fig.4 Measurement results of

4. Conclusions

In this study, an accurate warp measurement method for thin-large panel which deforms easily due to gravity was proposed and its principle was explained. In shape measurement, a raising force was applied equivalently to the panel center in order to reduce the deflection due to gravity. It was confirmed by experiments that the warp shape can be accurately measured by the proposed four-point-support inverting method using the measured results of the surface shape.

References:

[1] Y. ITO, W. NATSU and M. KUNIEDA 2011 Simultaneous Measurement of Warp and Thickness of Large-Diameter Silicon Wafer Using Three-Point-Support Inverting Method *Proceedings of the 11th euspen International Conference* 1 166-170