Governing Factors of Processing Quality for the Silicon Wafer Thinning Process

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Abstract

High processing quality is required for the silicon wafer thinning process. “Equipment configuration” and “processing conditions (including the processing point)” are some of the governing factors that influence the processing quality in the thinning process. This paper shows that optimization of the processing point has a larger impact on the processing quality than equipment configuration for the silicon wafer thinning process.

1. Introduction

One of the manufacturing processes for silicon-based semiconductor devices is wafer backgrinding, where a grinder is typically employed as the equipment. The processing quality of backgrinding is evaluated using indices such as TTV (Total Thickness Variation), saw marks on the front side, and die strength. As the backgrinding process directly contributes to the yield and reliability of the device, a high processing quality is required even for the thinning process of general silicon wafers. From the “equipment configuration” perspective, spindle deformation and vibration of the grinding equipment are known as some of the factors that affect processing quality. For example, if spindle deformation is reduced by increasing the rigidity of the grinder, TTV improvement can be expected (Figure 1). However, in reality, spindle deformation cannot be completely eliminated, and a highly rigid grinding equipment cannot be installed easily in the cleanroom due to its weight. Here, another method to improve the TTV is optimization of the processing point, which is the area where the abrasive grinding wheel comes into contact with the workpiece. In this paper, with a focus on the silicon thinning process, the processing quality of DISCO’s grinder polisher (DGP8762), which is widely adopted for the silicon thinning process, was investigated to show that a high processing quality can be achieved by optimizing the processing point.

2. Effect of spindle deformation on TTV

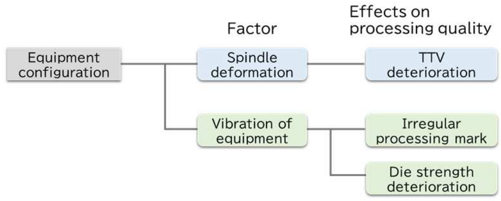

Figure 1 The relationship between equipment configuration and processing quality

2.1 Evaluation method

The key to understanding the effect of spindle deformation on wafer TTV is understanding the positional relationship between the grinding axis (spindle) and the chuck table (C/T). In a general grinder with a cantilevered structure, the segments of the grinding wheel pass through the center position of the C/T because the center axis of the spindle is not aligned with the center of the C/T (Figure 2 (a)). Therefore, depending on the processing load acting on the C/T, the direction of inclination of the spindle is an arc in the upward

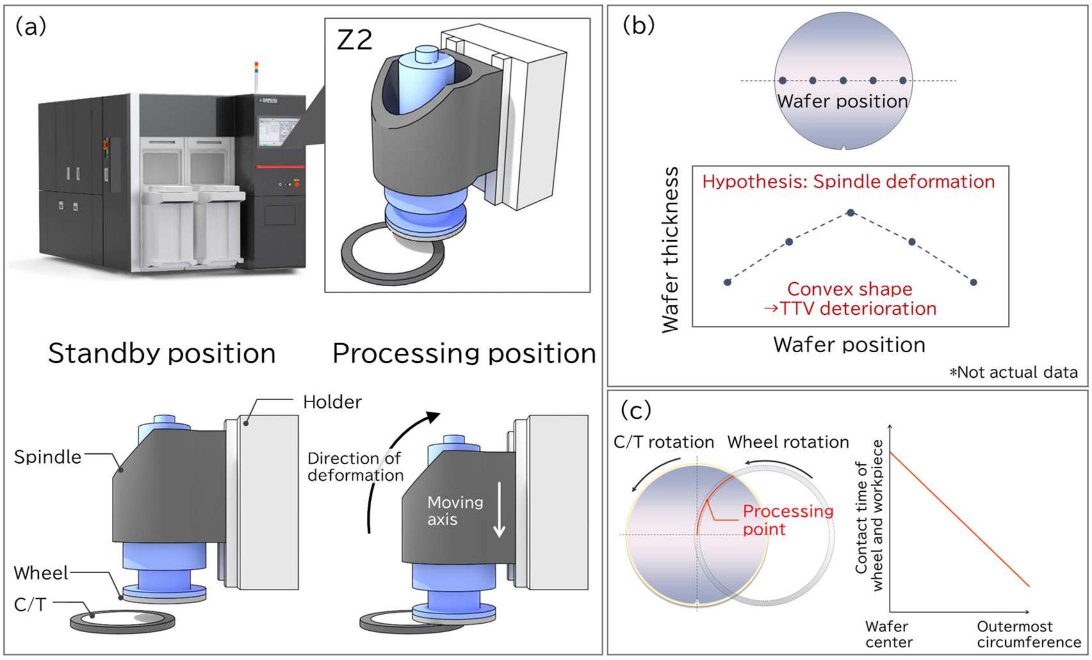

Figure 2 (a) Grinder appearance and spindle configuration in the standby and processing positions, (b) Assumed image of TTV data in case of spindle deformation, (c) Rotation direction of the C/T and wheel during in-feed grinding and contact time of wheel with workpiece during one rotation

direction with the holder as the center (indicated by the black arrow in Figure 2 (a)). If the spindle tilts in this direction, the processed wafer shape will become convex, hypothetically causing the TTV to worsen (Figure 2 (b)).

The surface planarization of the C/T (self-grinding) is widely carried out in advance of the wafer thinning process, which makes it possible to cancel out the mechanical error between the spindle and the C/T in the standby position. This means that the only mechanical error that affects the wafer TTV is the spindle deformation during the grinding process. Considering this, the TTV of wafers processed under self-grinding conditions (same wheel type and processing recipe as self-grinding) directly after self-grinding was measured

(a)

	Wheel	Processing recipe	C/T inclination
(1)	SD600-VS (For self-grinding)	Self-grinding conditions	No adjustment after self-grinding
(2)	SD600-VS (For self-grinding)	Grinding conditions	Adjusted after self-grinding

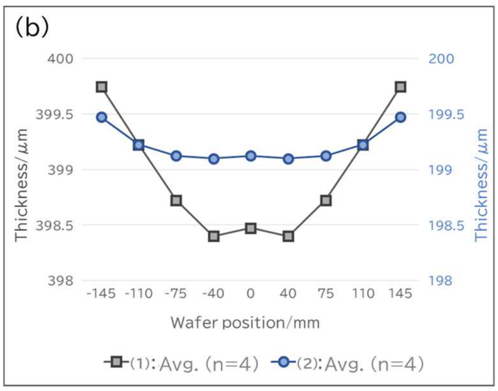

Figure 3 (a) Processing conditions of (1) and (2), (b) Radial dependency of wafer thickness processed under each set of conditions in order to study the relationship between processing quality and spindle deformation.

2.2 Results

The average measured value of the thickness dependence in the radial direction (n=4) of wafers processed under self-grinding conditions directly after self-grinding (Figure 3 (a)-(1)) was plotted. The resulting TTV was approximately 1.3 µm, and the wafers were concave after the thinning process (Figure 3 (b), solid gray line). These results were the opposite of the hypothesis that the wafer shape should be convex when the grinding spindle is deformed due to processing load in the vertical direction. The concave shape suggests that there is a difference in the amount of work done by the grinding wheel at the center and at the circumference. In in-feed grinding, where both the wheel and C/T rotate at a position where the spindle overlaps with half of the wafer, the amount of time that the wafer and grinding wheel are in contact becomes longer the closer the position is to the center (Figure 2 (c)). Due to this, it is thought that the center of the wafer is ground more, resulting in a concave shape. For comparison, the thickness dependence in the radial direction of a wafer processed with the same wheel as self-grinding but with a processing recipe and adjusted C/T inclination (Figure 3 (a)-(2)) was measured. The TTV improved to approximately 0.3 µm, and the wafers showed a relatively flatter shape (Figure 3 (b), solid blue line. These are reference values when processing without tape, and does not apply to tape grinding). From this, it can be concluded that spindle deformation due to processing load in the vertical direction is not a governing factor of wafer processing quality, and that optimization of the processing point (adjustment of processing conditions and C/T inclination) can achieve a high level of planarity and a TTV of 1 µm or less in general grinders such as DGP8762.

3. Effect of equipment vibration on processing marks and die strength

3.1 Evaluation method

In addition to spindle deformation, vibration of the equipment is another known factor that has a negative effect on the processing quality. A slight vibration of the processing spindle may cause irregular processing marks or decrease the die strength. Here, the processing marks of wafers processed using a normal DGP8762 and a DGP8762 with induced vibration were compared. The processing marks were observed using an appearance inspection equipment.

3.2 Results

Inspection images clearly showed that there were no strong processing marks on the wafer processed using the normal equipment, whereas irregular processing marks appeared in a radial pattern on the wafer processed using the equipment with induced vibration (Figure 4). These results

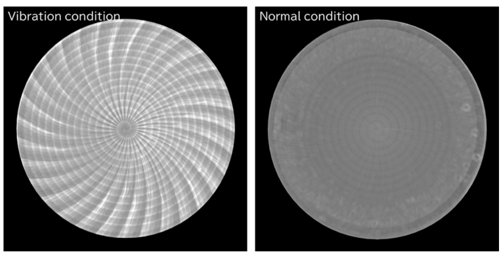

Figure 4 Inspection images of wafers processed using a normal grinder and a grinder with induced

indicate that equipment vibration of a normal DGP8762 does not affect the processing marks on the wafer surface.

In order to study the relationship between die strength and equipment vibration, we prepared two types of singulated die (thickness: 200 μm) from the wafers processed with a normal grinder and a grinder with induced vibration. The die strength was measured using the ball-point bending method in order to evaluate only the effect of grinding damage. The results indicated that the vibration of the equipment had no effect on the die strength of the singulated die, and the two types of singulated die showed the same level of die strength (Figure 5). Based on these results, it can be concluded that a high quality thinning process can be achieved by using DGP8762 in its normal condition.

4. Stability of processing

4.1. Evaluation method

The discussion on the processing quality of grinding (e.g., TTV or die strength) thus far has been based on a limited number of samples under specific conditions. In an actual semiconductor processing plant, continuous processing is carried out using several C/T on an equipment in order to maximize the productivity, which may cause the processing quality to deteriorate. Thus, the TTV transition of 25 wafers that were continuously processed using DGP8762 with an optimized processing point was investigated.

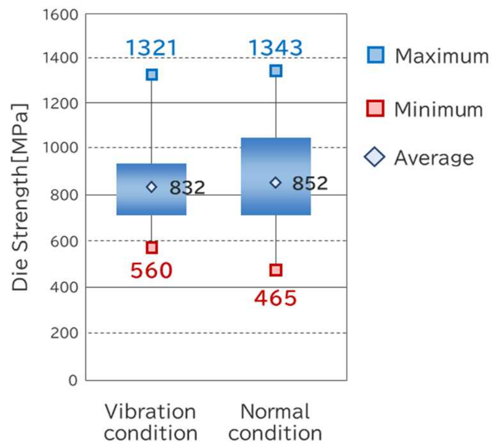

Figure 5 Die strength of die from wafers processed with a normal grinder and a grinder with induced vibration

4.2. Results

The TTV transition remained stable regardless of the C/T (C/T-A, B, C, D) used for processing (Figure 6). These results indicate that a grinder with an optimized processing point can achieve sufficient processing accuracy even during continuous processing.

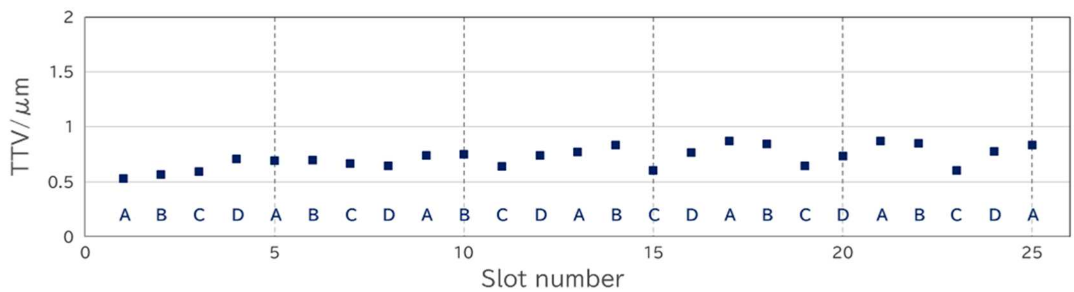

Figure 6 TTV transition and dependence of TTV on the C/T for wafers processed continuously using a grinder with an optimized processing point

5. Conclusion

The processing quality that is required in the general silicon semiconductor thinning process can be achieved using a general grinder with an optimized processing point. In addition to the steps taken to improve the processing quality as mentioned in this paper, DISCO is developing new technology to achieve low TTV grinding (e.g., installing an advanced measurement unit or customizing the equipment mechanism). Please feel free to contact a DISCO sales representative regarding any inquiries or test cut requests.