Development of water-film chuck utilizing surface tension

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Abstract

Porous vacuum chucks are susceptible to becoming contaminated by grinding fluid and chips, and are also incapable of flattening highly warped concave wafers. To overcome these problems, a water-film chuck utilizing surface tension has been developed [1]. The present paper describes its chucking performance, the method for forming a uniform ultrathin water film, and its application to grinding. The lateral restraint force and the tensile strength for the water-film chuck is found to increase rapidly when the water film becomes thinner than 1000 nm. For a 300-nm-thick water film, values greater than 35 kPa and 70 kPa can be achieved, allowing the chuck to be used for polishing. However, spin coating and spraying methods cannot form a uniform water film with a thickness of less than 1000 nm. Therefore, a new method is developed in which the chuck is spun at high speed after water is sandwiched between it and a specimen. This method can apply to wafers of less than 15 nm Ra and produce a uniform water film with a thickness of less than 200 nm over the entire surface of a 300-mm-wide chuck. It is shown to be capable of backgrinding a silicon wafer to a thickness of 80 μm with a total thickness variation of less than 2 μm.

1. Introduction

Silicon wafers used for fabricating IC cards and smartphones are thinned by backgrinding to a thickness of a few tens of microns and then subjected to chemical mechanical polishing. A porous vacuum chuck is typically used to hold the wafer flat during such machining processes. However, it is difficult to completely clean a chuck that has been soiled due to machining, or to flatten a concave wafer with a large degree of warpage. To solve these problems, a water-film chuck has been developed [1], which involves the wafer and the chuck being held together by a thin water film. This paper describes the performance of the water-film chuck, the method for forming a uniform ultrathin water film, and its application to grinding.

2. Lateral restraint force and tensile strength of water-film chuck

A large lateral restraint force is required to fix a wafer during grinding and polishing. This force was therefore measured using a push-pull gauge for various water film thicknesses, specimens and chucks. The water film thickness was determined using a multichannel photodetector (Otsuka Electronics Co.). The specimens used were quartz glass and silicon wafers with an area of 40 mm square and a thickness of about 1 mm. The silicon specimen was polished or ground with a SD#8000 or SD#2000 vitrified grinding wheel to examine the influence of surface roughness. The roughnesses of the specimens were 3, 5, and 15 nm Ra. The chucks had a diameter of 300 mm, and were made from polished SiC or Pyrex glass. Figure 1 shows the dependence of the lateral restraint force on the water film thickness. It is seen to be zero for a thickness of greater than 2000 nm, and to increase rapidly as the thickness decreases below 1000 nm. For a film thickness of less than 500 nm, it exceeds 10 kPa. Although this restraint force is sufficient for grinding, polishing requires a force of more than 25 kPa (pressure 50 kPa × friction coefficient 0.5). From Fig. 1, it can be seen that a water film with a thickness of less than 300 nm produces a force of more than 35 kPa, which is suitable for polishing. Although there is a relatively large degree of scatter in the data points, all are located near the solid curve. This indicates that for a surface roughness of less than 15 nm, the type of substrate or chuck material has little influence on the lateral restraint force.

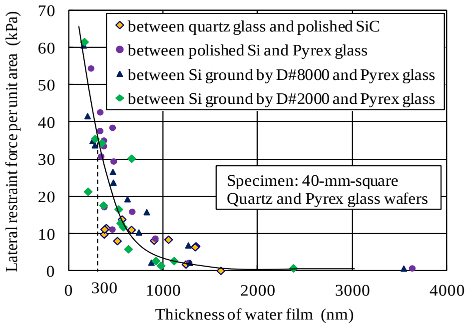

Fig. 1 Relation between lateral restraint force and thickness of water film.

To flatten a highly warped wafer, a strong adhesion force between it and the chuck is required. A push-pull gage was therefore used to measure the tensile strength for a 10-mm-

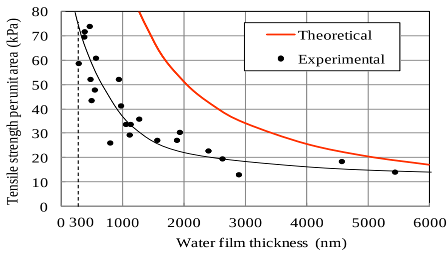

Fig. 2 Relation between tensile strength

square quartz glass specimen with a thickness of 4 mm, where the chuck was also made from quartz glass. The experimental results are shown as black circles in Fig. 2. The theoretical curve represents the negative Laplace force due to the water film, and is proportional to both the surface tension of the water and the film area, and is inversely proportional to the radius of curvature [2]. The experimental values are smaller than the theoretical ones, possibly because of the limited size of the specimen. The experimental values are seen to increase rapidly as the water film thickness decreases below 1000 nm, similar to the case for the lateral restraint force. In contrast to the lateral restraint force, the tensile strength is still more than 10 kPa for a film thickness of greater than 2000 nm. For a thickness of 300 nm, the tensile strength is more than 70 kPa, which is comparable to that produced by a porous vacuum chuck, and is sufficient to flatten a highly warped wafer.

3. Formation of uniform ultrathin water film

Methods for producing a uniform water film with a thickness of less than 300 nm were next examined. The first approach was to coat the chuck with water by spinning or spraying, and then to bring the specimen into contact with it. However, it was found to be difficult to produce a uniform water film thinner than 1000 nm. An attempt was then made to remove excess water by pressing the specimen against the chuck, so that water escaped around the edges and was allowed to evaporate over a long period to decease the film thickness. However, it was found that when the film thickness became less than 500 nm, the water disappeared from the periphery. The final approach was to spin the chuck and specimen at high speed after a water film was sandwiched between them. This was found to be capable of producing a uniform water film with a thickness of 100 to 200 nm, as shown in Fig. 3 for orthogonal directions x and y.

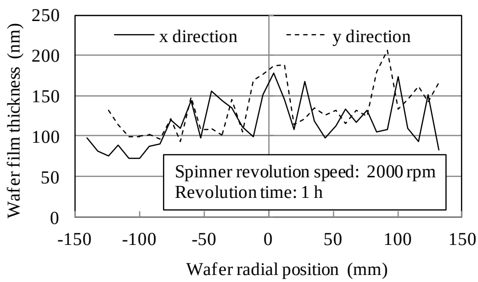

Fig. 3 Thickness profiles for water film between specimen and chuck.

4. Wafer thinning by backgrinding using water-film chuck

The proposed water-film method was next tested by using it to thin a silicon wafer from 725 to 80 µm. The resulting thickness uniformity was compared with that for an accurate wafer thinned using a porous vacuum chuck. The grinding conditions are given in Table 1. Grinding was carried out using a GDM300 grinding machine (Okamoto Machine Tool Works, Ltd.), and SD#500 and SD#8000 vitrified wheels were used for coarse and fine grinding, respectively. Figure 4 shows the thickness variation for the thinned wafers measured using a F50 thin-film measurement apparatus (Filmetric Co.). For the water-film chuck, the thickness variation is within ±0.5 µm and is equivalent to that for the wafer directly attached to the porous vacuum chuck. In addition, it is less than that for the case when a porous vacuum chuck and backgrinding tape were used. Figure 5 shows the thickness distribution over the entire surface of a 300-mm wafer, following thinning using the water-film chuck. The total thickness variation (TTV) is less than 2 µm, which indicates that the water-film chuck is promising for practical use.

Table 1 Grinding conditions.

		Coarse grinding	Fine grinding
Machine		GDM300 (Okamoto Machine Tools Co.)	
Grinding wheel	Stone	SD#500	SD#8000
	Size	ϕ 300 mm×t5 mm	
Rotational speed	Wheel	2600 rpm	2300 rpm
	Workpiece	-200 rpm	299 rpm
Infeed rate		150 µm/min	20 µm/min
Grinding fluid		City water	

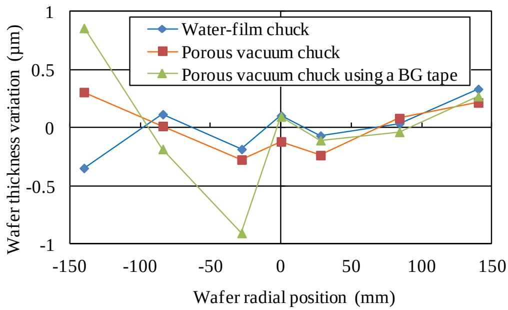

Fig. 4 Thickness variations in wafers ground under various conditions.

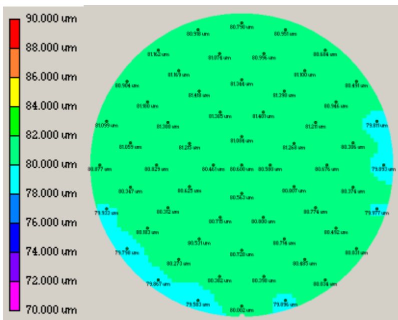

Fig. 5 Thickness distribution in wafer thinned using the water-film chuck.

5. Conclusion

A water-film chuck utilizing surface tension was developed. It was found that grinding and polishing were possible when the thickness of the water film was less than 300 nm. Such a uniformly thin water film was produced by first sandwiching water between the chuck and the specimen, and then subjecting them to high-speed spinning. This method can apply to wafers of less than 15 nm Ra. It was demonstrated that using the water-film chuck, it was possible to thin a 300-mm silicon wafer from 725 to 80 μm with a TTV of less than 2 μm.

Reference

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