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Porous chuck without vacuum for wafer grinding and polishing

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Abstract

In the grinding and polishing processes for thin substrates such as wafers, a chucking system is essential for a high-precision machining. Vacuum porous chucks are generally used for the grinding and polishing of wafers. However, their surfaces easily wear and they are difficult to clean inside. Additionally, the thinner the wafer, the more difficult it is to clamp without causing deformation above each pore of the porous chuck owing to the vacuum pressure. Therefore, a water-film chuck that does not allow direct contact between the wafer and the chuck has been developed. Our previous study showed that a water film with a size below 0.3 µm was required to obtain a lateral restraint force applicable to polishing. This paper describes a new chucking system that uses a water-film porous chuck without a vacuum. The adoped porous material has considerably smaller grains than those used in a standard porous chuck. Porous materials facilitated the formation of ultrathin water films. In addition, an ultrathin and uniform water film was formed via control of the atomizer application time. According to the experimental results, this chucking system generated a lateral restraint stress greater than 25 kPa, and could be used for polishing at the pressure of 30 kPa.

Keywords: grinding and polishing, porous chuck, water film, lateral restraint stress, sapphire wafer

1. Introduction

A vacuum porous chuck is a standard devices for clamping of a wafer for processing. The vacuum pressure generates a sufficient uniform clamping force over the entire wafer. The use of vacuum also facilitates the wafer attachment and detachment. However, the porous chuck suffers from surface wear owing to repeated contact with the wafers and it is difficult to clean the dust inside. Therefore, the chuck must be replaced. Additionally, the vacuum pressure causes deformation of the areas of the wafer located above in each pore of the porous chuck, as the wafers are expected to become thinner. Therefore, a chucking method without a vacuum is required.

This study describes a new chucking system using a water-film porous chuck, its clamping characteristics, and the results of a polishing experiment on a sapphire wafer.

2. Water-film porous chuck

To overcome the problems related to the vacuum porous chuck, a water-film chuck, which uses the adsorption of an ultrathin water film and does not allow a direct contact between the wafer and chuck, was developed as a unique clamping method without a vacuum. A thinner water film provides larger vertical and lateral restraint stresses that are attributed to the meniscus force generated by the water film [1–3]. When the thickness of the water film is less than 0.3 µm, the lateral restraint stress is above 30 kPa. However, thinning of the water film and detachment of the wafer are not straightforward because the chuck surface is a high-precision flat surface that is mirrored. These issues are caused by the difficulty of moving water in the water film within the small gap between the wafer and chuck, and supplying air between the wafer and chuck for detachment of the wafer. Therefore, we propose a water-film porous chuck with improved practicality compared to a water-film chuck.

2.1. Porous material

The porous material used in this experiment was manufactured via sintering 3.5 − 4.5 µm alumina ceramic grains and had the porosity of 40%. In addition, the diameter of the material was 100 mm with thickness of 5 mm. The material surface was mirror-polished to a flatness of 0.7 µm over its entire surface and roughness of lower than 10 nm (*Ra*) on the grain surface. Figure 2 shows a magnified image and calculated contact area (green area) of the porous material surface. The contact ratio was calculated by the height distribution measured by a laser scanning confocal microscope assuming that the area within 0.4 µm from the top of the grain surface contacts the wafer. The minimum size of the pores was 2 µm. This is considerably smaller than that of a standard vacuum porous chuck. The contact ratio calculated as 35.4%.

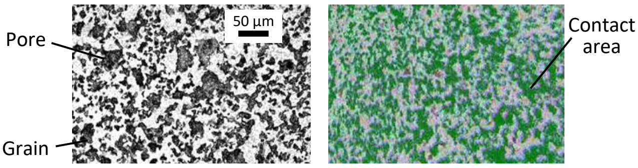

Figure 1. Magnified porous surface and calculated contact area.

2.2. Ultrathin water film formation method

A small amount of water supply is required for the water film formation method. An atomiser that generates mist water containing water particles (4 − 11 µm) was used in this experiment. Water mist was applied to the surface of the rotating wafer. A water film was formed after placing the wafer on the porous material and pressing it at the pressure of 7.5 kPa. Finally, a thinner water film forms as the water moves into the pores of the porous material via capillary action. The thickness of the water film could be adjusted based on the application time of the mist water. Figure 2 shows the sapphire wafers with diameters of 100 mm clamped using a water film under a white-light-emitting diode (LED). In Figure 2(a), interference fringes are observed when the amount of water applied is excessively large. As shown in Figure 2(b), no interference fringes were observed over the entire wafer surface. The water film thickness in this case was smaller than 0.3 µm, as measured by the thin-film thickness measuring instrument. This clamping state was maintained for at least 2 h without drying out.

During grinding and polishing, the lateral restraint stress of the chucking system must be larger than the friction stress generated between the wafer and the grinding wheel or the polishing pad. Figure 3 illustrates the measurement instrument for the lateral restraint force. In the experiment, an optical flat with the thickness of 10 mm was used to avoid cracking, and the maximum load was limited to 200 N. This corresponds to 25.5 kPa for a wafer with a diameter of 100 mm. Figure 4 presents the measurement results for the water-film porous chuck and vacuum porous chuck. For the water-film porous chuck, the lateral restraint force was 197 N, which was almost at the measurement limit. The clamping force for a standard thickness wafer is expected to be considerably larger because its deformation follows the chuck surface profile. In contrast, the lateral restraint force of the vacuum porous chuck, whose frictional force was determined by the friction coefficient and real contact area, was 90 N corresponding to 11.5 kPa.

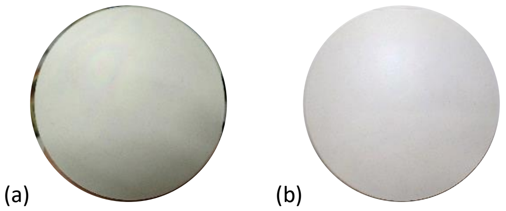
(a) (b)

Figure 2. Interference fringe images of sapphire wafers clamped by the water-film porous chuck.

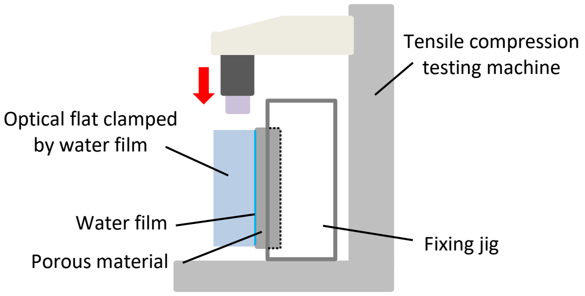

Figure 3. Measurement apparatus for the lateral restraint force.

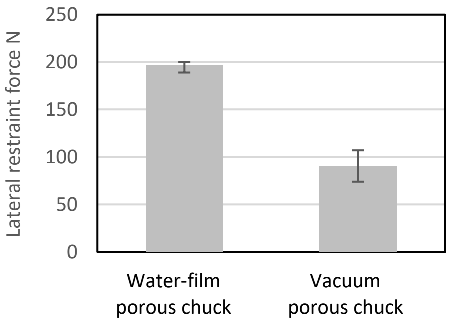

Figure 4. Lateral restraint forces generated by the water-film porous chuck and vacuum porous chuck.

3. Polishing experiment

A polishing experiment using the porous material mentioned above as a water-film porous chuck was conducted under the conditions listed in Table 1. The initial roughness of the wafer was 0.67 µm (*Ra*). Figure 5 shows the variation in the horizontal load applied to the polishing head over time. The water film exhibited sufficient clamping performance against the frictional force generated by the polishing. The periodic change in the load was caused by the oscillating motion of the polishing head. The average horizontal load was 242 N, which was greater than the lateral restraint force obtained in the experiment. The roughness of the polished wafer was 0.33 µm (*Ra*). According to the observation after polishing, the slurry did not seep between the wafer and the chuck. Therefore, the water-film porous chuck can polish a wafer without causing wafer detachment under standard polishing conditions.

Table 1 Polishing conditions.

Polishing machine	Fujikoshi Machinery Corp., SLM-140CY	
Wafer	Sapphire wafer	
Polishing pad	NITTA DuPont Inc., MH-S15A	
Rotational speed	Wafer	100 min^{-1}
	Polishing pad	100 min^{-1}
Polishing pressure	30 kPa	
Oscillation speed	60 mm/min	
Slurry	Colloidal silica, 50 mL/min	
Polishing time	60 min	

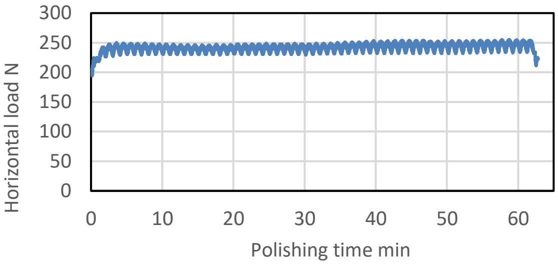

Figure 5. Variation in horizontal load of polishing head during polishing.

4. Conclusion

To overcome the problems related to the vacuum porous chuck, a water-film porous chuck that clamps a wafer without a vacuum was proposed. The main characteristics of the chucking system are the usage of the porous material with pores of 2 µm minimum and forming method of a thinner water film using the mist water. According to the experimental results for the optical flat with diameter of 100 mm, the formation of the water film with a size below 0.3 µm was achieved, and a lateral restraint force of approximately 200 N was obtained. Furthermore, the water-film porous chuck can polish a wafer at the pressure of 30 kPa. Future studies should aim to clarify the grinding and polishing characteristics of the thinning process using this chucking system.

Acknowledgments

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