Fundamental characteristics of a water-film chuck

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Abstract

Backgrinding wafers have large warpage, and it is particulary difficult to flatten a concave wafer with large warpage by using a vacuum chuck. Therefore, a water-film chuck utilizing surface tension was developed in this study. This paper describes the flattening characteristics of the water-film chuck. It was clarified that a quartz glass wafer 1.2 mm thick that has warpage of a few-hundred microns can be flattened to less than 10 µm over time. Then, a backgrinding silicon wafer with 1 mm warpage was flattened instantly below 100 µm by applying a fine water mist. In addition, the lateral restraint force per unit area was found to be over 0.8 kPa for a water-film thickness of less than 1 µm. Therefore, the water-film chuck can be used for not only wafer transfer but also grinding or light-load polishing.

1 Introduction

Silicon wafers for fabricating IC cards and smartphones must be less than a few tens of microns in thickness. After the wafer is thinned by backgrinding, the damaged layer is removed by chemical mechanical polishing (CMP) and dry polishing. A porous vacuum chuck is typically used to fix the wafer during machining. However, it is difficult to completely clean the porous chuck and to flatten a concave wafer with large warpage. To solve these problems, a water-film chuck is proposed. This chuck has a thin water film between the back surface of a wafer and the surface of the chuck. This paper describes the principle of the water-film chuck, the flattening characteristics of concave- and convex-warped quartz glass and backgrinding silicon wafers, and the lateral restraint force of the water-film chuck.

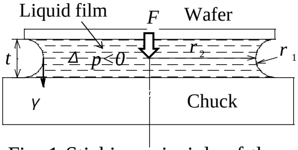

Fig. 1 Sticking principle of the water-film chuck.

2 Sticking principle of the water-film chuck

It is well known that liquid between two objects generates a meniscus force. The force F acting between two flat objects, as shown in Fig. 1, is the sum of Laplace negative pressure Δp and surface tension γ [1]. When curvature radius $r_1 << r_2$, Δp becomes dominant. As a result, F becomes equal to Δp and is directly proportional to γ and the film area πr_2^2, and inversely proportional to the film thickness t. This force sticks the wafer onto the surface of the chuck. The interfacial tension between the back surface of the wafer and the liquid flattens concave- and convex-warped wafers.

3 Flattening a quartz glass wafer and a backgrinding silicon wafer

After quartz glass wafers with warpage of a few hundreds of microns were put onto a pool of approximately 10 ml water, the profile changes were measured over a long time with a high-accuracy air-slider and a laser displacement sensor. The wafer diameter was 300 mm and the thickness was 1.2 mm. A concave or convex wafer was made by turning a wafer upside down. The proposed chuck had a flatness of 0.3 μm and was made of silicon carbide. Figure 2 shows the profile changes immediately after pressing. The concave wafer with 160 μm warpage is flattened to 60 μm, and to 30 μm when the water film is thinner. Accordingly, thinning the water film increases the flattening ability. The convex wafer with 260 μm warpage is flattened to approximately 100 μm.

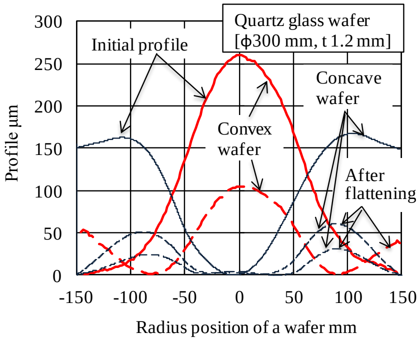

Fig. 2 Profile changes after pressing for concave and convex quartz glass wafers.

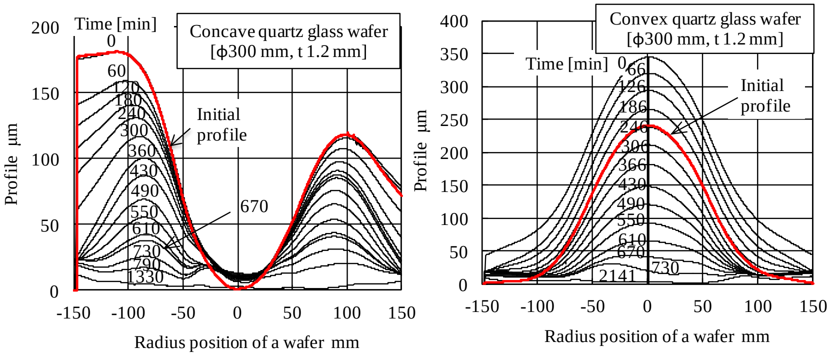

Fig. 3 Profile changes for concave (left) and convex (right) quartz glass wafers while left for a long time.

Figure 3 shows the profile changes over a long time. The high profiles on the left and right sides for the concave wafer (left plot) are unbalanced until 360 min because the wafer was set at a tilt. After 430 min or later, both high parts become the same height and decrease gradually. The central valley rises slightly after approximately 610 min. Then the wafer flattens with the decrease of the water-film thickness due to evaporation. Finally, the wafer is flattened to less than 11 μm after 1330 min. The convex wafer (right plot) does not deform until 66 min. After 126 min or later, the wafer flattens gradually, and is flattened to less than 10 μm after 2141 min. At this time, the water-film thickness was measured to be less than 5 μm by using a multi-channel photo detector (Otuka Electronics Co.). Enlarged views of the profiles at the final time for the concave and convex wafers are shown in Fig. 4.

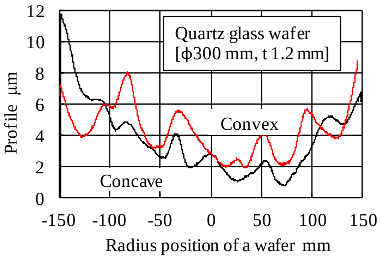

Fig. 4 Enlarged view of profiles at the final time for concave and convex wafers.

Every profile is flattened to less than approximately 10 μm, but the small-pitch irregularity of a few microns does not disappear. Accordingly, the water-film chuck is judged to have flattening ability for irregularities of a large pitch, but not of a small pitch. Figure 5 shows the deformations calculated by the finite element method

(FEM) for the above concave (left plot) and convex (right plot) wafers under various uniform pressures and when pressing against a rigid plate at a force of 20 N. These wafers are flattened to micron orders by the pressure of 1 kPa and 10 kPa, respectively. It is clear that flattening the concave wafer is easy.

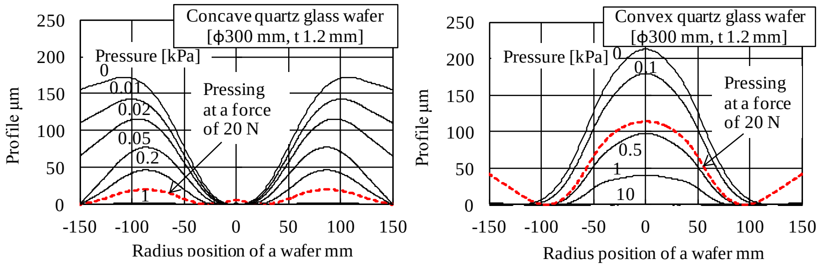

Fig. 5 Deformations calculated by FEM for concave (left) and convex (right) quartz glass wafers under various uniform pressures and when pressing against a rigid plate.

The profile changes shown in solid lines are similar to those in the experiment shown in Fig. 3. The concave wafer rises slightly in the central part and the convex wafer rises around the periphery, as shown by the dotted line when pressing against the rigid plate. Accordingly, the experimental results agree generally with the FEM results. Figure 6 shows the flattening by using the water- film chuck on a backgrinding silicon water with adhesive tape of 100 µm thickness and warpage of a few millimeters. A fine mist was used to thin the water film and to increase the flattening ability. After applying a fine mist to the side of the wafer or the adhesive tape, the wafer was put on the chuck. The the convex wafer 75 µm thick and concave wafer 45 µm thick are flattened immediately to less than 40 µm and 80 µm, respectively. It was clarified that the water-film chuck has excellent flattening ability for the thin wafer with large warpage as compared to the flattening ability of the vacuum chuck.

4 Lateral restraint force of the water-film chuck

A large lateral restraint force is required to grind and polish. Figure 7 shows the results measured with a push-pull gauge for various water-film thicknesses. The water-film thickness was measured with the photo detector mentioned above. The specimen is a quartz glass wafer 40 mm square and 1.2 mm thick. The lateral restraint force per unit area increases rapidly when the water-film thickness becomes less than 1 μm and more than 0.8 kPa.

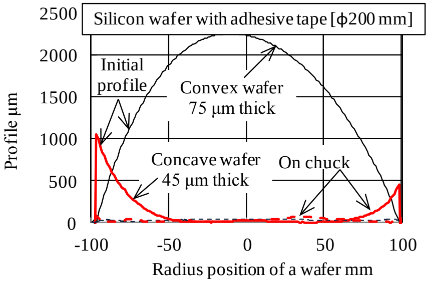

Fig. 6 Flattening using a thin-film spray method for concave and convex backgrinding silicon wafers.

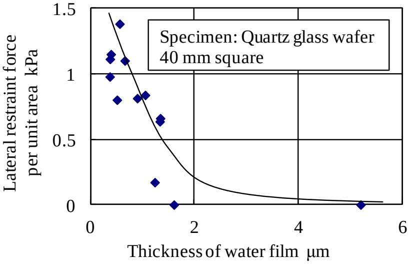

Fig. 7 Relation between lateral restraint force and water-film thickness for the water-film chuck.

5 Conclusion

The possibility of flattening a wafer with large warpage by using a water-film chuck was studied. The flattening abilities and the lateral restraint forces were measured. It was clarified that a quartz glass wafer 1.2 mm thick can be flattened to less than 10 μm under a water-film thickness of 5 μm. Backgrinding wafers with adhesive tape can be flattened to less than 100 μm regardless of the wafer profile, even if the wafer is warped to more than 1 mm. In addition, it was shown that a lateral restraint force per unit area of 0.8 kPa is obtained under a water film of less than 1 μm in thickness. Finally, this chuck can be used for not only wafer transfer but also grinding and light-load polishing.

Reference

[1] J. N. Israelachvili: Intermolecular and surface forces, Academic Press (1991).