Development of a freezing pin chuck for fabricating a nonwarped substarate: Peeling due to thermal stress during polishing and deformation during fixing

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Abstract

It is difficult to fabricate a nonwarped wafer substrate, because a thin wafer cannot be held during the polishing process without deformation occurring. To resolve this problem, a freezing pin chuck was developed. This paper describes the peel strength of frozen liquid due to the thermal stress forming during polishing and deformation in the fixing process. The experimental result of the tensile and shear strengths of the frozen liquid were compared with the calculation result by the finite element method (FEM). When a few-hundred-micron-warped wafer is fixed with the freezing pin chuck, the profile change is one-tenth of that for a plane chuck. In addition, polishing both sides with the freezing pin chuck reduces the warpage to less than 1 micron.

1 Introduction

Liquid crystal masks and extreme ultraviolet lithography (EUV) masks require nonwarpage and very high flatness. Especially, a flatness tolerance of 10 μm including the warpage is required for the tenth-generation quartz mask. It is difficult to achieve high flatness in a short time. A freezing chuck has been used practically to hold these nonmagnetic substrates. The freezing chuck has difficulty in holding a thin substrate without deformation. Here, the development of a nondeforming freezing chuck is investigated. The target is to fabricate a nonwarped substrate by polishing.

2 Tensile and shear strengths of a frozen liquid

The process for fabricating a nonwarped substrate is shown in Figure 1. Expansion in the solidification process causes the freezing liquid to flow into the spaces

between the pins (see ①). The substrate is fixed without deformation. Next, the warpage is removed by polishing (see ②). The substrate is inverted and held with a vacuum pin chuck (see ③), and the back surface of the warped surface is polished again (see ④). The tensile and shear stresses in the frozen liquid caused by the thermal deformation were measured to check the peeling tolerability. A 10-mm-square, 6-mm-thick quartz glass specimen and a silicon-carbide pin chuck were used. The chuck has a pin diameter of 0.58 mm and a pin pitch of 1 mm. The pin tops were lapped with GC#400 abrasive grain to improve the peel strength after coating with an oil repellent film to pile the thick freezing liquid on the pin tops, as shown in Figure 2. After the freezing liquid was applied, the specimen was fixed at 5°C. Figure 3 shows the measured tensile and shear strengths. The average tensile strength exceeds 1800 kPa and the average shear strength is 1200 kPa.

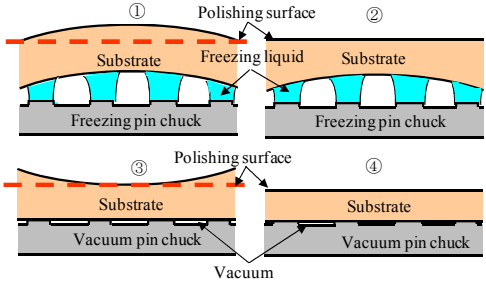

Figure 1: Process for fabricating a nonwarped substrate.

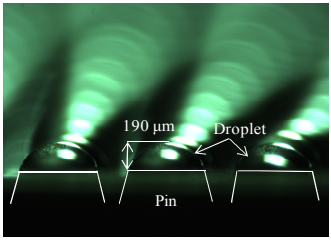

Figure 2: Droplets of freezing liquid formed on pins with a diameter of 0.5 mm.

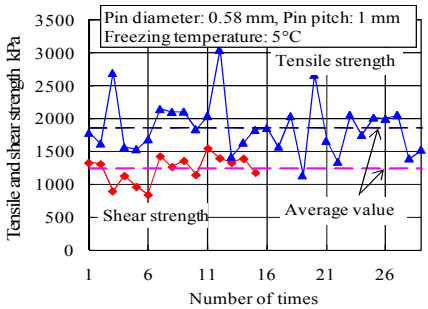

Figure 3: Tensile and shear strengths of freezing liquid fixed at 5°C.

3 Stress distribution in frozen liquid due to thermal deformation from FEM

As the difference of the temperature between the upper and the bottom surface of the wafer, thermal deformation occurs. The tensile and shear stresses due to this deformation were calculated by FEM under the conditions listed in Table 1. Since the mechanical characteristics of the freezing liquid were unknown, their values for

ice at -5°C were used. Figure 4 shows the maximum and minimum tensile and the maximum shear stresses acting on each pin arranged in a reticular pattern for wafers 40 mm and 80 mm in diameter, when the temperature difference between the upper and bottom surfaces is 25°C and the pin pitches are 1, 2, and 3 mm. The maximum tensile and shear stresses are 1700kPa and 1200 kPa for the 1 mm pitch, respectively. The tensile strength has a sufficient margin for peeling, but the shear strength is close to the allowable value, even if a 1-mm-pitch pin chuck is used when the temperature difference is 25°C.

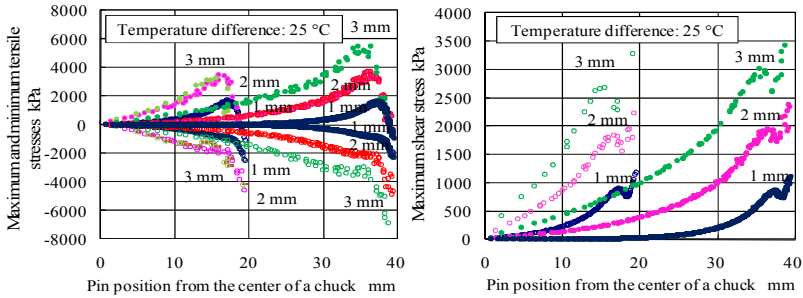

Figure 4: Maximum and minimum tension and maximum shear stresses acting on each pin arranged in a reticular pattern of various pin pitches for wafers 40 mm and 80 mm in diameter.

4 Profile changes during fixing

Profile changes for quartz wafers 300 mm in diameter and 1.2 mm in thickness during fixing were measured using the freezing pin chuck with a pin diameter of 0.5 mm and a pin pitch of 1 mm. The initial warpage amounts for the concave and flat wafers are 250 µm and 10 µm, respectively. The changes were measured in a similar manner to compare them with a plane chuck without pins. Figure 5 shows the profile changes of the concave and flat wafers held using the plane chuck. The profile difference before and after infusing the freezing liquid reaches 180 µm for the concave wafer, and the profile difference before and after fixing is very small, less than ±5 µm. The values for the flat wafer are 15 µm and ±1 µm, respectively. The results using the freezing pin chuck are shown in Figure 6. The profile changes before and after applying the freezing liquid for the concave wafer decrease to less than one-tenth, because surface tension between the wafer and the chuck is reduced

by grooves between pins. The change for the flat wafer decreases to one-third. It is possible to reduce the warping to less than ±1 µm by polishing both sides.

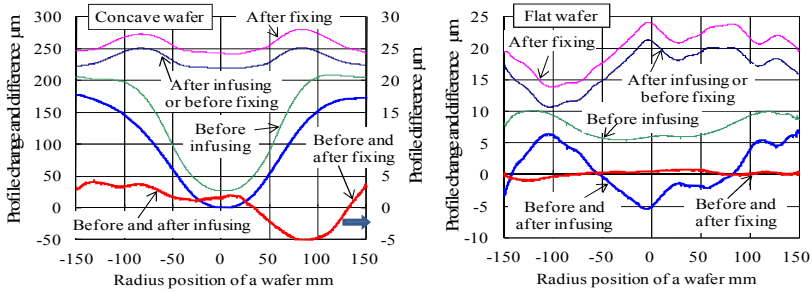

Figure 5: Profile changes for concave and flat wafers fixed using a plane chuck.

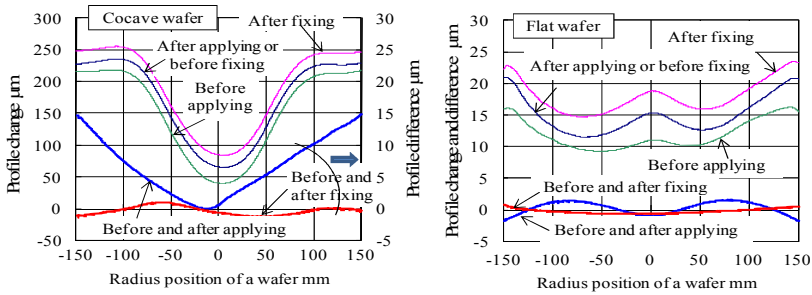

Figure 6: Profile changes for concave and flat wafers fixed using a freezing pin chuck.

5 Conclusion

The possibility of fabricating a nonwarped quartz wafer with a freezing pin chuck was studied. The tensile and shear stresses caused by thermal deformation were calculated by FEM. It was clarified that the wafer does not peel by polishing at 30°C, because the calculation values are smaller than those of the experimental results. In addition, it was shown that the profile changes for a few-hundred-micron-warped wafer during fixing can greatly decrease by using the freezing pin chuck.

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