Development of a freezing pin chuck for polishing to fabricate a nonwarped substrate: Fixing characteristics to polish a quartz glass wafer

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Abstract

Precision polishing of thin, large substrates is essential in order to realize the manufacturing of green devices. However, most substrates warp and so cannot be fixed during polishing without deformation occurring. As such, fabricating a nonwarped substrate is difficult. In order to solve this problem, a freezing pin chuck for polishing has been developed. The present paper describes the fixing characteristics for polishing a quartz glass wafer using the development chuck. The experimental results showed that the chuck surface is cooled to less than 5°C, at which point the freezing liquid fixes the wafer firmly and the wafer profile is changed no more than 1 μm. The polishing experiment revealed that the wafer did not peel from the chuck for 60 minutes, and the fixing strength of the freezing pin chuck was determined to be sufficient for polishing. In addition, the coolant filling the space between the pins was revealed to greatly improve the fixing strength of the wafer.

1 Introduction

A liquid crystal mask requires a flatness tolerance of 10 μm, including warpage. This mask has been growing in size and satisfying this requirement is becoming increasingly difficult. Mask substrates are polished multiple times in order to remove warpage because fixing a thin substrate without deformation through conventional chucking methods is difficult. Thus, it is difficult to achieve high flatness in a short time. The freezing chuck, which is a conventional chuck, has been used practically to fix nonmagnetic substrates. This type of chuck deforms the profile of the substrate when the freezing liquid solidifies. Based on the principle of the freezing chuck, we have developed a freezing pin chuck that can fix a thin substrate without deformation[1)]. The goal is to fabricate a nonwarped substrate by polishing. The present paper describes the mechanism and fixing characteristics of the newly developed freezing pin chuck for polishing.

2 Freezing pin chuck for polishing

The experimental process for fabricating a nonwarped substrate is shown in Fig. 1. Expansion in the solidification process causes the freezing liquid to flow into the spaces between the pins (see ①). Therefore, the substrate is fixed without deformation. Next, the upper surface is planarized by polishing (see ②). The substrate is then inverted and fixed with a vacuum pin chuck (see ③).The opposite surface is planarized by polishing and a substrate with no warpage is fabricated finally (see ④). When the freezing pin chuck is used for polishing, the freezing liquid must bear the friction heat and force resulting from polishing, which requires that the freezing liquid on the pins be cooled efficiently. The developed chuck has a mechanism to flow coolant among the pins, as shown in Fig. 2. Figure 3 shows a photograph of the freezing pin chuck for polishing. The chuck has pins, one coolant inlet, and eight coolant outlets on the face of the chuck. The diameter and height of the pins are 0.5 mm and 0.8 mm, respectively. The pin area is 300 mm in diameter, and the pin pitch is 2 mm. The chuck is made of silicon-carbide, which has high thermal conductivity. Figure 4 shows an infrared image of the chuck, into which a quartz glass wafer of 300 mm in diameter was placed. The cooling mechanism of the freezing pin chuck cooled the entire surface of the wafer, to which the freezing liquid fixed the wafer firmly, to less than 5°C. Figure 4 shows the profile changes of a quartz glass wafer fixed to the chuck. The difference in the initial profile and the

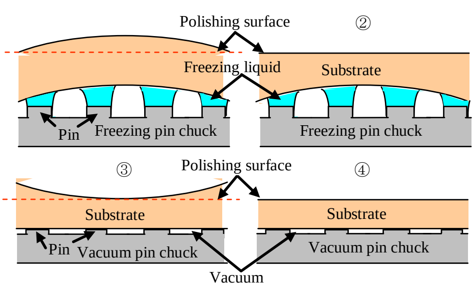

Figure 1: Experimental process for fabricating a nonwarped substrate.

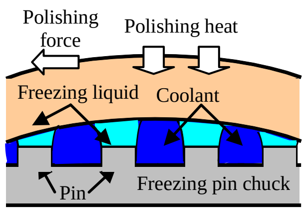

Figure 2: Principle of cooling around a freezing liquid in the presence of friction heat and force generated by polishing.

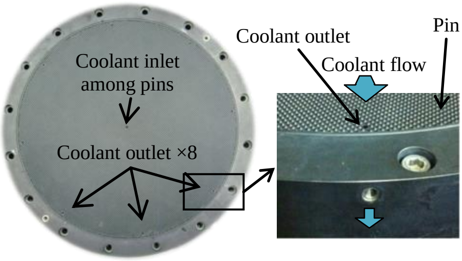

Figure 3: Overhead and close-up views of the freezing pin chuck

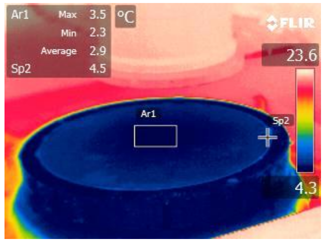

Figure 4: Infrared image of quartz glass on a freezing pin chuck.

profile after placement, which was same as that before solidification, as shown in the figure, was approximately 5 μm. Reducing this difference is difficult because the wafer is deformed by the meniscus force. On the other hand, the difference in the profiles before and after fixing by solidification was less than 1 μm.

3 Applying a freezing pin chuck to polishing

Figure 6 shows a schematic diagram of the polishing experiment using the freezing pin chuck. Oscillation polishing is one of the precision polishing methods used in planarization. Table 1 shows polishing conditions. The periphery of a wafer was grinded about 5 μm in order to measure the stock removal and the polishing experiment was carried out under the condition of non-oscillation polishing. In the polishing process, the rotation of the chuck is thought to have degraded the cooling capacity of the chuck, because the coolant was affected by centrifugal force. The flow condition of the coolant among the freezing liquid depends on the flow rate of the coolant and the number of coolant outlets. Experiments were conducted for the cases

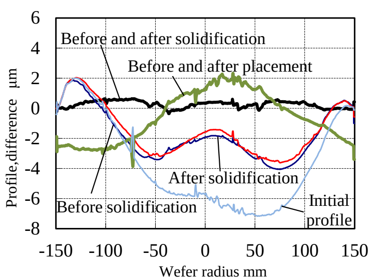

Figure 5: Profile change during solidification using the freezing pin chuck.

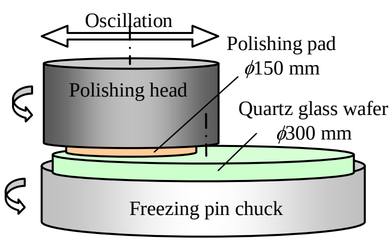

Figure 6: Schematic diagram of oscillation polishing.

Table 1: Experimental conditions

Rotational velocity	Wafer	50 rpm
	Pad	50 rpm
Polishing pressure		4.8 kPa
Oscillatiion position		65 mm
Slurry		CeO_2
Coolant flow rate		50 ml/min
Number of coolant outlets		1, 2
Polishing time		60 min

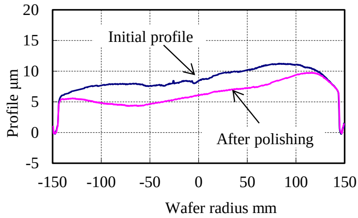

Figure 7: Profile change due to polishing in the case of one outlet.

of one and two coolant outlets. In the case of one outlet, the wafer did not peel for 60 minutes, and the stock removal was approximately 2 µm, as shown in Fig. 7. This result shows the possibility that the freezing pin chuck can be used for oscillation polishing. In the case of two outlets, the wafer peeled, except at the periphery of the wafer, after 60 minutes. No coolant remained among the pins in this case because the cross-sectional area of the coolant outlets was greater than that of the inlet. It is important to control the coolant flow condition in the rotational condition of the chuck. Based on these results, the coolant among the pins was shown to greatly improve the fixing strength of the wafer.

4 Conclusion

The possibility of fabricating a nonwarped quartz glass wafer with a freezing pin chuck was investigated. The newly developed freezing pin chuck for polishing was demonstrated experimentally to cool the wafer to 5°C in order to fix the wafer with freezing liquid. In addition, the experimental results suggest that the chuck can be used for the polishing of a quartz glass wafer by considering the coolant flow rate among the pins.

Acknowledgement

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References:

[1] Takehana, K. et al.: Development of a freezing pin chuck for fabricating a nonwarped substrate: Peeling due to thermal stress during polishing and deformation during fixing, Proc. of 12th euspen Int. Conf., (2012), pp.352-355.