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Study on scribing characteristics of wafer with precision of ground scribing wheel

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Abstract
Needs of cutting-off or dicing are increasing for semiconductor wafers of sapphire, Si and SiC and cover glasses used in LCDs and smart phones. They are conventionally processed by dicing with a diamond wheel (blade) or laser. However, there are some problems in these processes. In the case of dicing, cutting efficiency is low, kerf loss due to blade width is excessive, and a cleaning process is indispensable because of coolant usage. In the laser cutting process, thermal damage cause residual stress. In order to overcome these problems, the scribing process is proposed for cutting-off of the wafers and the cover glass. In the scribing process, a shallow groove or scratch is created on the substrates by the sharp diamond wheel, the groove propagates along the pre-groove by applying a bending stress, until the wafer is cleanly cut. Therefore, the cutting efficiency is high, the kerf loss is almost zero, and the cleaning process is unnecessary. In this study, the polycrystalline diamond wheel (PCD) was ground by the diamond wheel and the grinding characteristics were studied by varying the wheel grain size, the wheel rotation, and depth of cut. Finally, the scribing characteristics were measured and evaluated by varying the radius, the surface roughness, the roundness of the wheel edge, and the scribing load.

Keywords: cutting-off, scribing wheel, wafer, cover glass

1. Introduction

High precision and high efficiency cutting-off technologies for hard and brittle materials are required for semiconductor wafers and for cover glasses used in LCDs and smart phone displays. The dicing or grinding process with diamond blades and laser processing is generally used for cutting off. However, there are some problems in the conventional processes. In the dicing process, cutting efficiency is low, kerf loss due to blade width is excessive, and a residual stress is caused by heat energy. In the laser cutting process, thermal damage causes residual stress [1]. In recent years, a scribing process using a scribing wheel was proposed to overcome these problems, and this scribing process was chosen for cutting of cover glasses. However, the details of scribing process were not clear, and the effects of the shape and the surface roughness of the scribing wheel on the scribing results were unknown. In this study, polycrystalline diamond the scribing wheel (PCD) was ground to prepare different cutting edges of the PCD wheel, and the effect of the shape of the scribing wheel on the substrate was evaluated.

2. Scribing / Cleaving process

The scribing / cleaving process is shown in **Fig. 1**. First, in the scribing process, a scratch is created by rotating the scribing wheel on the substrate. In this process, a ductile mode of "scratch" is formed by applying a load onto the substrate surface in contact with the wheel. Second, in the cleaving process, the initially generated scratch progresses deeply due to a bending stress and the substrate is cleaved [2, 3].

Fig. 2 shows an image and a schematic illustration of the scribing set-up used in this experiment. The rolling wheel rotates on the substrate while applying a constant load. Scribing conditions are shown in **Table 1**. The scribing wheel was made of PCD, with a diameter of ϕ 2 mm. Three different cutting edge shapes with different tip radius R were ground for trial. In the scribing test, alkali free glasses with a thickness of 0.3 mm were affixed to the stage by a vacuum chuck and were scribed manually with the three types of wheels.

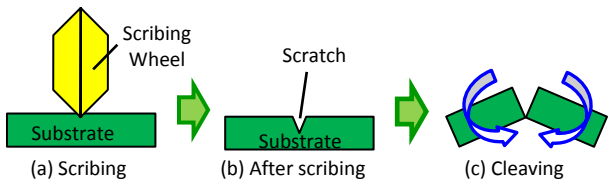

Figure 1. Scribing and cleaving process

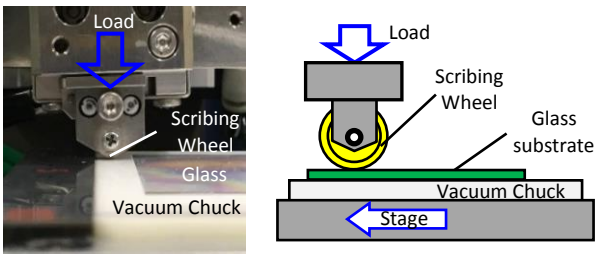

Figure 2. Scribing set-up

Table 1 Scribing conditions

Scribing wheel Outer diameter Cutting edge angle Edge radius	PCD (Poly Crystalline Diamond) Φ2 mm 100 ° R= 1.3, 1.5, 1.6 µm
Workpiece Thickness	Alkali free glass 0.3 mm
Load	2, 3, 4 N

3. Results of scribing experiments

Fig. 3 shows an evaluation method of chipping ratio. The chipping ratio was evaluated by removing the curve from the raw data of the ridge line and the chipping was defined as an edge lack of more than 1 µm in size. **Fig. 4** shows a measured chipping rate on the ridgelines of the cutting edge in the scribing wheel. With an edge radius of 1.3 and 1.5 µm, chipping was not observed, but with an edge radius of 1.6 um, chipping was observed. **Fig. 5** shows measured surface roughness on the ridgeline. The significant change of the surface roughness was not observed according to the edge radius, and the obtained surface roughness was 1.07 µm *Rz*. **Fig. 6** shows measured surface roughness of grinding surfaces. The surface roughness obtained by the edge of R = 1.3 µm showed 0.22 µm *Rz*.

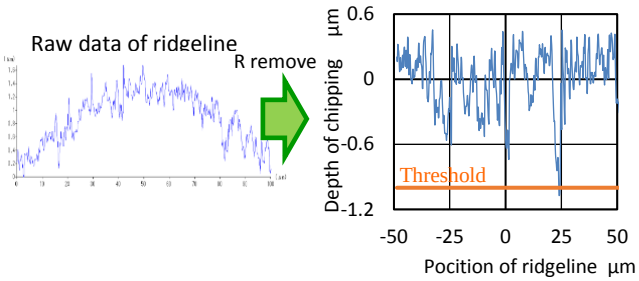

Figure 3. Evaluation method of chipping ratio

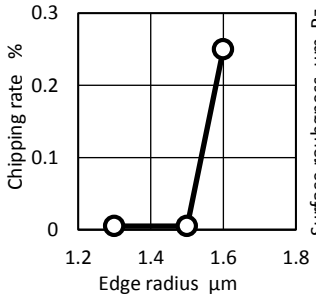

Figure 4. Chipping rate

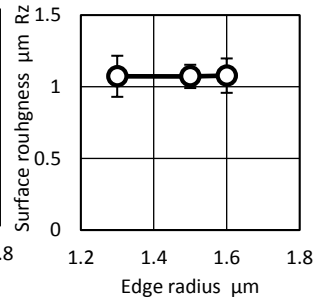

Figure 5. Surface roughness on ridgeline

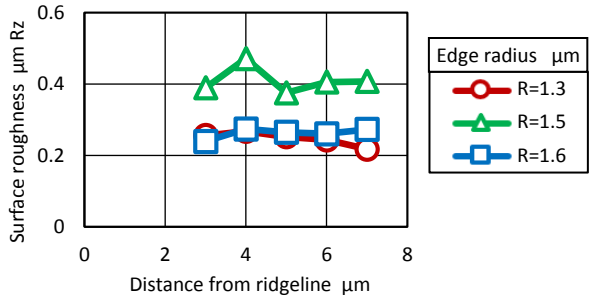

Figure 6. Surface roughness of grinding surface

4. Experimental results of scribing / cleaving

A surface image of the scribed glass substrate is shown in **Fig. 7**. An image of the cross section of the cleaved glass substrate is shown in **Fig. 8**. **Fig. 9** shows the depth of a scratch on the scribed glass substrate, which was measured with a non-contact type of laser probe scanner. The depth of the scratch increased as the scribing load increased.

The residual stress can be estimated by measuring the phase difference. In this experiment, the phase difference was evaluated using birefringence equipment. **Fig.10** shows the phase difference on the scribed glass substrate. The phase difference was decreased as the edge radius decreased, and the phase difference increased as the scribing load increased.

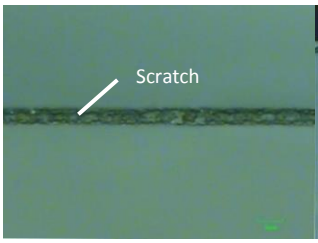

Figure 7. Sarface image of scribed glass

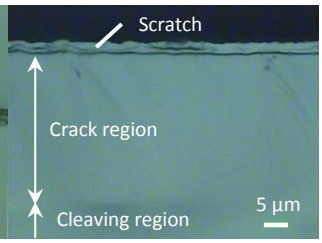

Figure 8. Cross section of cleaved glass

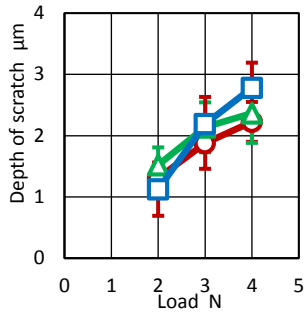

Figure 9. Scribing scratch depth

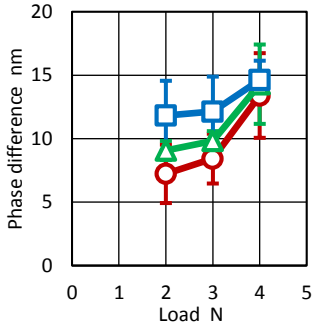

Figure 10. Evaluation of residual stress

Fig. 11 shows the surface roughness of a crack region on the broken glass surface after cleaving. **Fig. 12** shows the surface roughness of a cleaving region on the broken glass surface after cleaving, which was measured with a non-contact type measuring instrument. A significant change of the surface roughness was not observed according to the scribing load and scribing wheel condition.

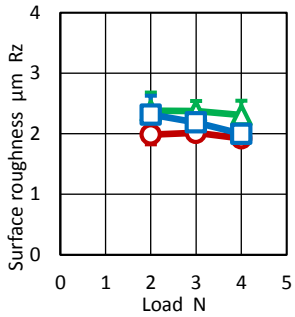

Figure 11. Surface roughness of crack region

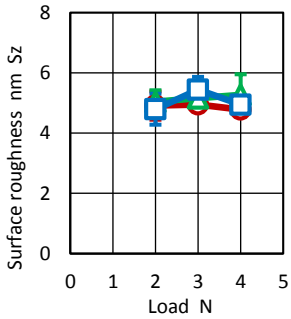

Figure 12. Surface roughness of cleaving region

5. Conclusion

In this study, PCD scribing wheels with different cutting edge shapes were prototyped by grinding, and the edge radius, chipping and surface roughness were measured. In addition, a glass substrate was cut by the scribing / cleaving process with the PCD scribing wheel, and the depth of scratch, surface roughness and residual stress were measured. From the experimental results, it was found that the depth of the scratch and residual stress increased as the load increased, and the phase difference was decreased as the edge radius decreased.

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