A Basic Study on Slurry Actions and Slicing Characteristics of Multi-wire Saw

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1. Introduction
The silicon wafers as the base plate of IC or LSI are mass-produced by large sized ingot. The mass-production of silicon wafers bears one part of development of electronics industry. The multi-wire saw is one of the slicing methods for semiconductor materials. This slicing method uses tensioned thin wire and slurry (mixed working fluid of abrasive grains). And, this slicing method has some problems on the slurry characteristics and actions and slicing accuracy in case of the slicing of large sized silicon ingot. There are some papers for slurry characteristics on multi-wire saw [1]. Although the slurry actions during the processing affect the large effect for slicing efficiency and accuracy, authors have known few papers for the slurry actions.

Therefore, authors direct our attention to the slurry action to enter into processing area in case of the work descent type of multi-wire saw. And, this study aims to clear the slurry actions on the thin wire tool, the relation between the slurry action and slicing efficiency, and the mechanism of processing. In this paper, the high speed camera observed the slurry actions on the wire, and the slurry amounts on the wire were measured. And, another report [2] described about multi-wire saw used low frequency vibration. This wire saw system vibrates the wire to improve enter of carried slurry in slicing area. The report was clear that the slicing efficiency showed increase of 50-100%. Therefore, in this paper, the slurry actions in case of vibrated wire are observed, and the vibration effects are considered from viewpoint of slurry actions.

2. Experimental apparatus and methods
2.1 Slurry amount and actions
Figure 1 shows the measurement method of slurry amount on the wire. Here, the slurry amount is defined by total slurry amount on the wire at the separate point of 50 mm from...
supplied point of slurry. At the measurement of the slurry amount, the slurry is supplied on the wire, and the wire runs. The sponges caught the slurry on the wire at the measurement point, and the slurry amount is measured.

Figure 2 shows the method to observe slurry actions on wire. The observation method applies the slurry on wire and observes the slurry action on wire at the arbitrarily point from supplied point.

Table 1 shows the experimental conditions of slurry actions.

### 2.2 Slicing method

Figure 3 shows the mechanism of multi-wire saw. This wire saw is the descent type of the workpiece. The slurry is supplied continuously and uniformly on the wire. In case of the vibration slicing, the wire vibrates by the four eccentric grooved rollers at the processing area. And, this wire saw has a characteristic that the frequency of wire changes with the wire running speed.

Table 2 shows the experimental conditions of slicing.

### 3. Slurry actions and slicing characteristics in non-vibration slicing

Figure 4 shows relationship between slurry amount and wire running speed. When the wire running speed is less than 60 m/min, the slurry amount increases linearly with accelerating of wire running speed. And, at the area of 60 m/min over, the increase of slurry amount shows very small value. Figure 5 shows the observation results of slurry actions by
high-speed camera. As shown in Figure 5-(a), the slurry in case of 20m/min of wire running speed becomes like small balls at observation point of L=80 mm. And, in case of 100m/min, the slurry film under the wire is observed at the same point. In case of high wire speed, the carried slurry in the processing area observes uniformly film to compare with the case of low wire speed. On the other hand, the slurry film under wire is observed at L=0 mm (this slurry film defines as bottom film.). This bottom film brings by supplied slurry and carried slurry for wire running direction. Therefore, authors expect that the carried slurry amount in processing area is increase to get widely bottom film.

The two slurry nozzles is prepared to increase the carried slurry in the processing area. And, these nozzles are set over the wire for wire running direction. The slurry amounts on the wire measure by changing the length between two slurry nozzles. Figure 6 shows relationship between length of two nozzles and slurry amount. As shown in Figure 6, the slurry amount on the wire increases by using two nozzles. But, it is clear that the over-length of two nozzles decreases the carried slurry amounts.

Figure 7 shows the behavior of slicing efficiency by two type of supply method. It is clear that the cutting efficiency in case of improved supplying slurry nozzles shows the value efficiency of 1.2 times to compare with the previous supplying with the case of A: one slurry pipe, B: 2mm, C: 4mm, D: 7mm, E: 10mm. Fig. 6 slurry amount of two nozzles Fig. 7 Behavior of slicing efficiency by two type of supply method.
4. Slurry actions and slicing characteristics in vibration slicing

Figure 8 shows the slicing efficiency in case of non-vibration and vibration slicing. The slicing efficiency in vibration slicing is larger than one of non-vibration. When the wire running speed is 200 m/min, the difference of slicing efficiency between non-vibration and vibration slicing shows 32 µm/min, and the difference of slicing efficiency at wire running speed of 400 m/min is 123 µm/min. These difference values are in proportion to increasing rate of wire running speed. This vibration effect is occurred by the change of frequency.

The slurry actions on vibrated wire observe by high speed camera to be clear vibration effect. Figure 9 shows the observations of slurry action. The experimental conditions are wire running speed: 60 m/min, amplitude: 1.0 mm, frequency: 60 Hz. In case of non-vibration, the carried slurry in processing area is hung under the wire. But, in case of vibration, the carried slurry rounds on the wire for up and down direction. As the slurry on the wire moves, the carried slurry amount in processing area increases to compare with non-vibration.

5. Conclusions

The slurry actions and slicing efficiency are studied, and the followings are clear.
1. When the two slurry nozzle for wire running direction is used, the amount of carried slurry in the processing area increases. And, the slicing efficiency shows the increase of approximately 10%.
2. The amount of carried slurry in the processing area is affected by bottom film under wire.
3. As the results of vibration wire saw, the hanged slurry rounds on the wire by vibration acceleration, and the amount of supplied slurry increases.

Reference