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Long-term stability and uniformity of water films prepared using a water-film chuck

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Abstract

A water-film chuck exploiting surface tension has been developed to flatten highly warped concave wafers and achieve high TTV (total thickness variation) values within ±100 nm. The water film is formed by spinning the chuck at high speed after water is sandwiched between the chuck and the specimen. This paper describes the spin conditions required to form a water film having a thickness of up to 100 nm and long-term stability and uniformity. For a spinner revolution speed of 5000 rpm and a revolution time of 600 s, the thickness of the water film drops below 100 nm over the entire surface of a 300-mm-diameter wafer. The water film becomes thinner and more uniform with increasing revolution speed and time. Such ultrathin films prove to be extremely stable for more than one month. Water films thinner than 100 nm maintain their uniformity over the long term, while thick films become thinner and more uniform with time.

Water film, Surface tension, Backgrinding, Wafer thinning, Water film thickness, TTV

1. Introduction

The semiconductor wafers used for fabricating IC cards and smartphones become thinner every year. The thickness of DRAM is currently limited to 4 µm and one device layer is less than 10 µm. It has been demonstrated that a multi-device can be constructed with the through-silicon via (TSV) technology [1]. The manufacturing process requires a ultra-flat vacuum chuck and a support wafer. The total thickness variation (TTV) needs to be less than 0.3 µm. However, a thinning grinding machine uses a porous vacuum chuck with pores that are larger than 100 µm and a backgrinding tape with a thickness variation of 1 µm. Therefore, it is too difficult to fabricate a thinning wafer with a TTV of less than 1 µm. To solve these problems, a water-film chuck has been developed. This chuck, which has a holding force of more than 70 kPa, utilizes the meniscus force of water [2]. A water film was formed by spin-coating. The thickness was less than 300 nm for a 300-mm-diameter wafer. After grinding, TTV was less than 1 µm [3]. The present paper describes the various spinning conditions needed to form an ultrathin water film with long-term stability and uniformity for a 300-mm-diameter wafer.

2. Formation method of ultrathin water film

An ultrathin water film was formed by the following procedure. ① Water was suffused on a silicon wafer and a glass wafer was slid obliquely across the water surface. It is important to avoid the bubbles in the water. ② This wafer pair was set to the spinner table. The water film grows thinner upon spinning the table. The thickness of the water film was measured with a thin-film analyzer (F20, Filmetrics Co.), and an air slider was used to continuously measure the entire 300-mm-diameter wafer, as shown in Fig. 1. The formation conditions of the ultrathin wafer film are given in Table 1. The revolution time was varied from 60 to 600 s, and the spinner revolution speeds ranged from 2000 to 5000 rpm. During the grinding process, the silicon wafer was affixed directly to the chuck table by using a water film. In the experiment, it is necessary to use a transparent material to measure the thickness of the water film. Thus, borosilicate or quartz glass wafers were used. The diameters of the silicon and glass wafers were 300 mm, and their thicknesses were 775 µm and 1 mm, respectively.

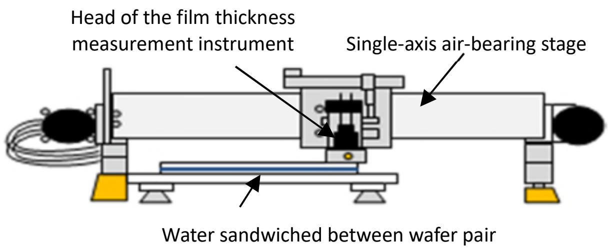


Figure 1 Water film thickness measurement system.

Table 1 Formation conditions of the water film.

Spinner	Spin coater KRC-300SV1 (Kanamex Co.)		
	Revolution speed (rpm)		2000, 3000, 5000
	Revolution time (s)		60, 180, 300, 600
Specimen	Water film material		Pure water
	Glass material		Borosilicate, Quartz
	Size	Diameter (mm)	300
		Thickness (mm)	1

3. Uniformity of ultrathin water film

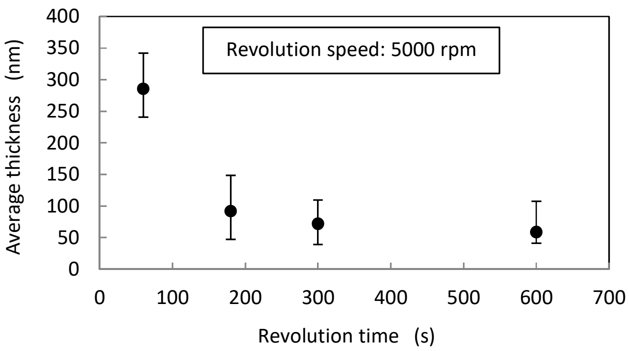
An ultrathin water film was formed to evaluate the uniformity of the water film thickness by using the above-mentioned method. Figure 2 plots the average thickness and the thickness variation (max to min) of a water film versus the revolution time and speed. As seen in Fig. 2(a), the average thickness decreases with revolution time and is saturated after 300 s. The change in average thickness is small with revolution time. However, the variation in the case of revolution speed is very large below 3000 rpm, and at 5000 rpm it is reduced by a factor of four, as shown in Fig. 2(b). The revolution speed influences the uniformity more strongly than the revolution time. It is necessary to set the revolution time to more than 300 s in order to obtain a uniformity of better than ±50 nm. The thickness distributions of the water film are shown in Fig. 3. A very high uniformity is obtained at 5000 rpm and 600 s. Thus, if the water film is formed under these conditions, a flatness of better than 100 nm may be achieved in the grinding process.

4. Long-term stability of ultrathin water film

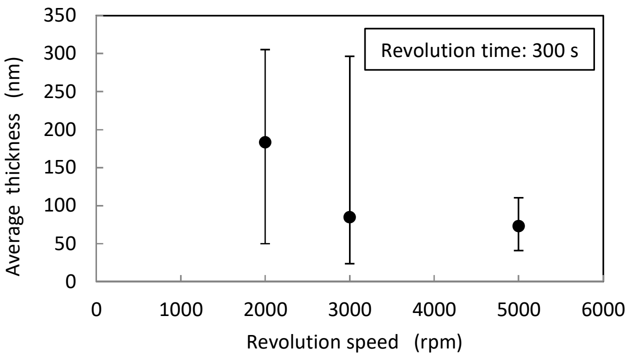
The water film sandwiched between two wafers becomes thinner with time owing to evaporation, and the warped wafer is corrected by the flat surface [2]. Then, the sticking force gradually increases.

Figure 4 shows the time evolution of the thickness distribution of a water film. The thickness after 2 h of spinning is relatively large. It is more than 300 nm at 2000 rpm or 3000 rpm. After eleven days, the thickness variation at 2000 rpm falls below ±50 nm (not shown in figure), and the distribution at 3000 rpm has large peaks. However, the variation drops below ±50 nm after twenty days. Thus, the thinning due to evaporation improves the uniformity of the thickness. Because the thinner water film increases the sticking force, the water in the thicker region moves to the thinner region.

Figure 5 shows the change in the interference fringe with time. The average film thickness is large for a revolution time of 60 s and small for 600 s at 5000 rpm. In the former case (60 s), the fringe is observed in the periphery of the wafer, which means that the water film is thick. The width of the periphery fringe gradually decreases, and the fringe almost disappears after 56 days. In the latter case (600 s), dust particles stick to the top surface of the wafer and the thickness is small. After 56 days, the fringe is observed only around the dust, the diameter decreases, and the thickness of the water film drops below 50 nm. Thus, it is concluded that the water film has long-term stability.



(a) Average water film thickness versus revolution time.



(b) Average water film thickness versus revolution speed.

Figure 2 Average thickness and variation in water film versus spinner revolution time and speed after one day of spinning.

5. Conclusion

It was demonstrated that a uniformity of better than ±50 nm can be obtained at 5000 rpm in a revolution time of more than 300 s. It was also shown that the non-uniformity of the average thickness drops below 100 nm after twenty days when the initial thickness exceeds 300 nm, and that ultrathin films can be kept for a long time, namely, at least two months.

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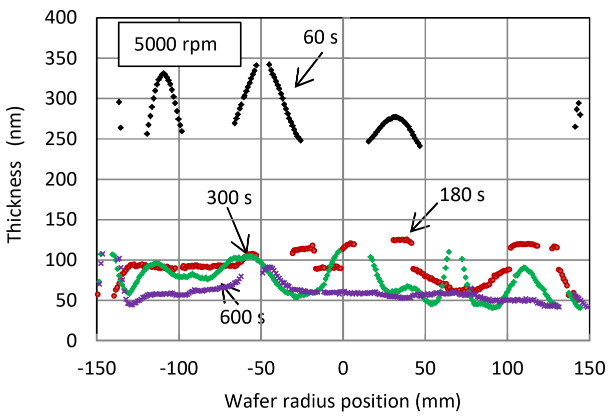

Figure 3 Thickness distributions of water film versus spinner revolution time and speed after one day of spinning.

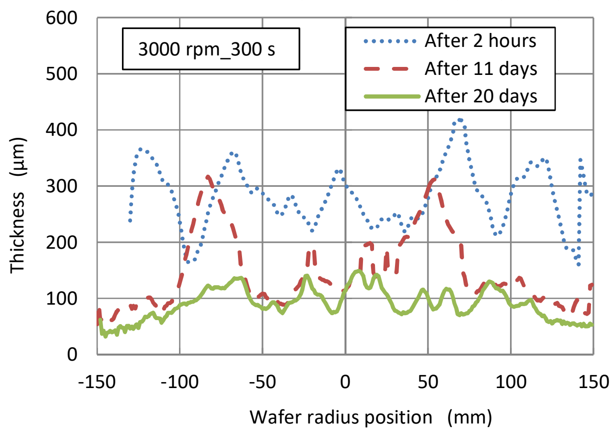

Figure 4 Time evolution of thickness distribution of a thick water film.

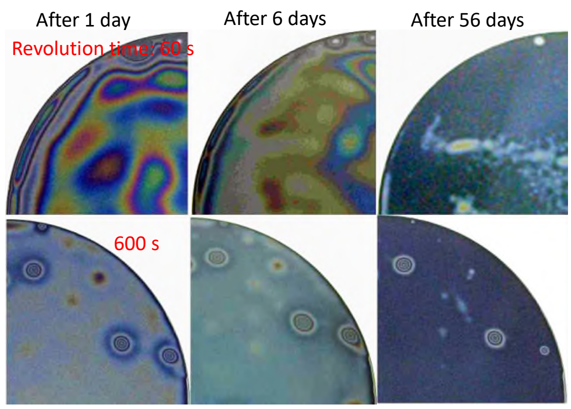

Figure 5 Long-term changes in interference pattern of water film.