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Ultra-Uniform CMP Using a Hydro Film Buffered Chuck (Hydro Chuck)

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Abstract A new wafer-chuck featured by hydro film buffer has been developed for ultra uniform CMP. The chuck is made of quarts glass with fully-flat water-support surface, and water is continuously supplied to form hydro film between the surface and the wafer. This hydro film suppresses the slurry penetration between the quarts glass surface and the wafer, origin of local polishing defects such as abnormally-polished spots. Using the new wafer chuck, uniformity of ± 200 A in 6" wafer is realized for CVD-SiO_2 polishing.

1. Introduction

For CMP application to modern ULSI fabrication such as interlayer dielectric film planarization and shallow trench isolation formation [1-3], polishing speed, cleaness and uniformity are essential factors. Recently, high speed polishing with low contamination has been achieved by developing neutral silica slurry with ammonium salt [4]. To realize high uniformity, improvement in a wafer-chuck is necessary. Purpose of this work is to develop a new wafer-chuck accomplishing wafer-scale uniformity without local polishing defects. The chuck is featured by direct wafer mounting on the quarts glass plate with a hydro film buffer (Hydro chuck).

2. Experimental

Three kinds of wafer-chucks were fabricated, and the effects of the chuck structures on the polishing characteristics were examined. Figure 1 illustrates two chucks of ordinary structures; a vacuum chuck and a backing-pad chuck. The vacuum chuck was made of a quarts glass plate, whose surface was precisely flattened by optical-lens polishing technique (Fig. 1(a)). Narrow trenches of concentric circles were fabricated in the chuck. Wafer was mounted directly on the rigid quarts glass plate by vacuum pumping. In the backing-pad chuck (Fig. 1(b)), a backing-pad such as a porous soft-polymer film was bonded on a fully-flattened quarts glass plate. During CMP, a wafer was held on the backing-pad by surface tension of water immersed in the backing-pad. A retainer ring was attached on the quarts glass plate peripheral area to prevent the wafer flying out.

Figure 2 illustrates a new wafer-chuck, referred as to hydro chuck. The Hydro chuck was also made of fully-flattened quarts glass plate with several water-supplying holes. A retainer ring was put on the chuck perimeter. Wafer was directly mounted on the rigid quarts-glass-plate, and water was supplied through the holes to form a thin hydro film between the quarts glass plate and the wafer. The water supplying rate was approximately several milliliters per a minute.

Using these wafer-chucks, 1 μ m-thick CVD-SiO_2 film on 6" wafer was polished under a fixed polishing condition, where the polishing pressure was 0.4 kg/cm^2 and the rotation rates both of the chucks and the polishing plates were 35 rpm. A two-layered polishing pad was used, in which a hard polymer sheet was stacked on a soft one. Neutral silica slurry without KOH was introduced on the pad at a rate of 50 ml/min.

After a Post-CMP cleaning, the SiO_2 film thickness was measured at 49 points in the wafer except for the 10mm-perimeter (edge-cut: 10mm). The average polished thickness as well as the thickness fluctuation in the polished-wafer were calculated. The thickness fluctuation was defined as the difference between the maximum and the minimum thicknesses in the wafer. Particle number on the wafer-reverse surface, which was faced to the wafer-chuck, was measured by a laser particle counter. Here, the mirror-polished surface of 6" wafer with 0.1 μ m-thick thermal silicon-oxide was tentatively mounted to the wafer-chuck.

3. Results and Discussion

3-1. Vacuum chuck

Fig. 3 shows a photograph of 6" wafer after

5min-CMP using the vacuum-chuck. Several spots of circular fringes were observed on the wafer. These spots reflected local thickness fluctuation of the polished SiO_2 film, or essentially local polishing defects such as the abnormally fast-polished spots. On the reverse surface of the wafer, several dried- and agglomerated-silica particles, which had been dispersed in the slurry, were attached. The positions of the particle on the wafer reverse coincided with those of the local polishing defects on the wafer surface .

Namely, the slurry is aspirated and dried between the wafer and the chucking plate, resulting in the rigid agglomerated-silica particles. The rigid particles locally bend the wafer toward the polished surface, generating the local defects of abnormally fast-polished spots.

3-2. Backing-pad chuck

Figure 4(a) shows the thickness fluctuations of SiO_2 film using the backing pad chuck. No local defect was observed on the polished surface. Global polishing uniformity, however, was not accomplished: the polishing rate near the wafer peripheral area was greater than that near the center. Figure 5 shows the changes in the average polished thickness and the thickness fluctuation as a function of the polishing time. In case of the backing-pad chuck, the thickness fluctuation increased with increasing the polishing time.

Namely, the backing-pad chuck itself had a fully flat and rigid surface, but a backing-pad is bonded on it. The backing-pad acts as a mechanical buffer layer, eliminating the local defects such as the abnormally fast polished spots. The backing pad, however, may not be shrunk uniformly under the polishing pressure, causing the polishing fluctuation.

3-3. Hydro-chuck

The hydro-chuck has an intermediate structural feature between the vacuum chuck and the backing-pad chuck: a wafer is mounted directly on fully-flat rigid quarts glass plate, and is held inside of a retainer ring only by surface tension of hydro (water) film. The polishing properties, however, were much better than those of the ordinary chucks.

Figure 4(b) shows the thickness fluctuations of SiO_2 film polished by the hydro chuck. No local polishing defect was observed on the polished surface, and excellent polishing uniformity across the whole wafer was accomplished. As shown in Figure 5, the thickness fluctuation of 400A ($\pm$200A) in the initial CVD-SiO_2 film was kept even after 7000A-polishing (7min-polishing) using the hydro chuck, while the fluctuation using the backing-pad chuck increased with increasing the polishing time. The direct wafer-holding on the fully-flat, rigid quarts glass plate (chucking plate) keeps the wafer flat, yielding the excellent polishing uniformity.

In Table 1 are summarized the particle number on the wafer reverse surface after Post-CMP cleaning. The particle number using the hydro chuck was much smaller than that using the backing-pad chuck. The hydro film suppresses the slurry penetration between the chucking plate and the wafer, and prevents the attachment of the dried-abrasive particles, which cause the local polishing defects. In addition, the chuck of the high purity quarts glass gives no chemical contamination to the wafer.

4. Conclusion

In ULSI device planarization such as a planarized shallow trench isolation, high polishing uniformity are very important to keep up the device fabrication reliability. In the new hydro chuck, the wafer was held directly on the fully-flat, quarts glass plate with hydro film buffer. The hydro film prevented the contamination of wafer reverse surface from the abrasive particle attachment, eliminating the local defects such as abnormally fast-polished spots. The direct wafer holding on the fully-flat and rigid plate accomplished excellent uniformity of $\pm$200A in 6" wafer for CVD-SiO_2 polishing.

References

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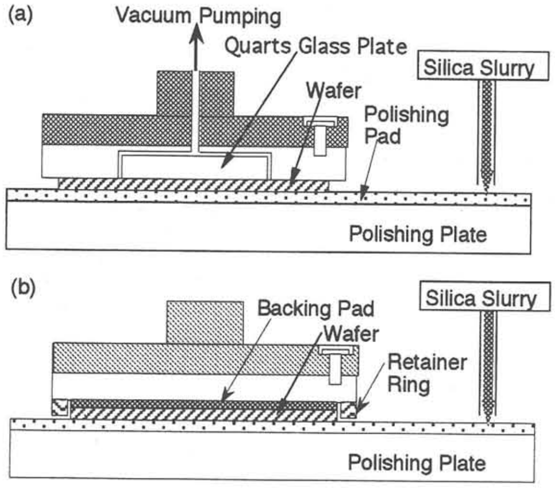

Fig. 1 Ordinary wafer-chucks in CMP equipments: (a) a vacuum chuck and (b) a backing-pad chuck. In the vacuum chuck, a wafer is held directly on the quarts plate by vacuum pumping during CMP. In the backing-pad chuck, a porous soft-polymer film as a backing-pad is bonded on the quarts plate. The wafer is held on the backing pad due to the surface tension of water in the pad. A retainer ring is attached on the quarts plate peripheral area to prevent the wafer flying away.

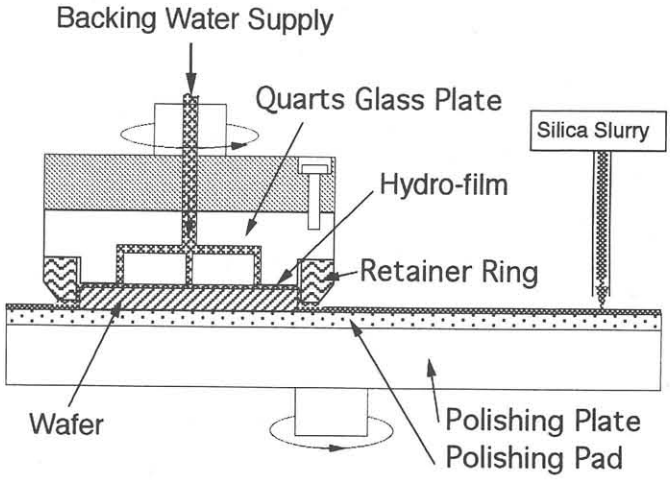

Fig. 2 Schematic illustration of the Hydro chuck. The chuck is made of quarts glass, and the surface is flatted by optical-lens polishing technique. During CMP, water is supplied at rate of a few milliliter per a minute to form a thin water film (a hydro-film) between the quarts glass plate and the wafer. The chuck is rotated at the same rate as that of polishing plate, and a neutral silica slurry without KOH is introduced on the polishing pad.

Fig. 3 Photograph of SiO_2-deposited wafer after 5 min-CMP using the vacuum chuck. The fringes correspond to the local thickness fluctuations of the SiO_2 film. During CMP, abrasive silica particles in the slurry were aspirated and dried on the wafer reverse or the chuck surfaces, resulting in local wafer deformations and polishing defects.

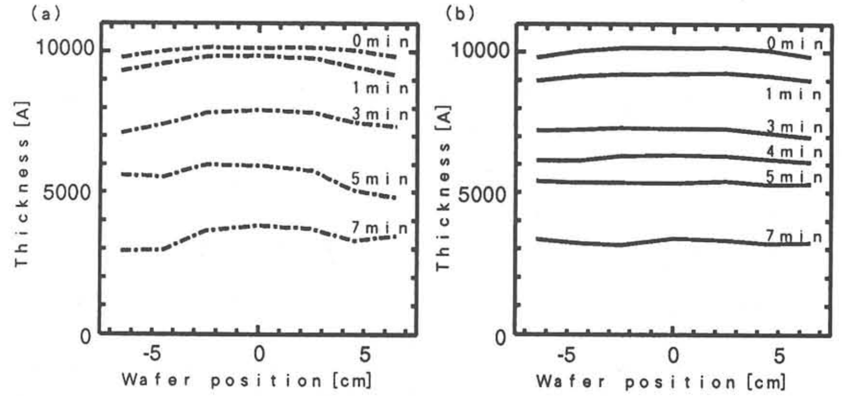

Fig. 4 Changes in SiO_2 film thickness fluctuation during CMP using (a) the backing-pad chuck, and (b) the Hydro chuck. The thickness fluctuation was measured on the wafer diameter line parallel to the wafer orientation flats (OF).

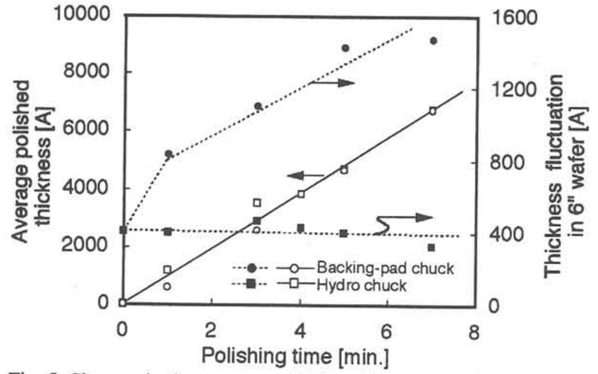

Fig. 5 Changes in the average polishing thickness and the thickness fluctuation as a function of polishing time. The film thicknesses were measured at 49 points within the wafers (edge-cut: 1cm). The film thickness fluctuation was defined as the difference between the maximum and the minimum film thicknesses measured in the wafer.

Table 1 Particle numbers on the wafer reverse surface

	Backing-pad chuck	Hydro chuck
Water supplement	No	Yes
Backing Pad	Yes	No
Holding structure	Backing pad /Wafer	Silica plate /Water film/Wafer
Particle number * $\phi \geqq 0.3\mu m$	680 / 6" wafer	220 / 6" wafer

* The particle number was measured after a Post-CMP cleaning (a chemical cleaning).