Polishing pad properties for achieving high edge surface flatness

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Abstract

As the substrates of semiconductor devices, silicon wafers are required to be highly flat for increasing the integration density of the devices. Especially edge roll off, which occurs during polishing process and seriously deteriorates edge surface flatness, is strongly demanded to be reduced. To investigate polishing pad properties required for decreasing edge roll off, an edge profile generating model was proposed based on the elastic contact theory. On the basis of the model, thin polishing pads with small deformation were developed. Polishing experiments showed that the developed polishing pads improved surface flatness near the edge.

1 Introduction

In the semiconductor industry, demand for improving the performances and the productivities of semiconductor devices has rapidly increased. For improving the performances, design rules are constantly miniaturized to increase the integration density of the devices. This requires extremely high flat surfaces of silicon wafers as the starting materials of the devices. However, it is well known that surface flatness significantly deteriorates near the wafer edge, namely, edge roll off (ERO) occurs in polishing process as the final stage of the wafer manufacturing processes [1]. To solve the problem, many theoretical and experimental studies of the polished edge surface profiles have been conducted [2-4] and several countermeasures for ERO have been proposed [3, 4]. However mechanism of the ERO generation has yet to be clarified exactly, which makes it difficult to meet the practical demand.

In this study, based on the elastic contact theory, an ERO generating model was proposed considering the effect of existing ERO on obtained edge surface profile. On the basis of the model, thin polishing pads with small deformation were newly developed for decreasing ERO. The corresponding polishing performances were also evaluated.

2 ERO generating model

Polished surface profiles, that is, the material removal rate profiles on the workpiece surface are basically proportional to the contact stress distribution on the surface. Several analytical models have been proposed for predicting the surface profiles by calculating the contact stress distribution based on wafer/pad contact mechanics [2-4] and fluid hydrodynamics [2]. The results obtained in the models typically indicate that the ERO generation is strongly dependent on the wafer/pad stress concentration at the edge. The above models, however, have the serious problem of applying to only a part of the actual polishing performances, namely, they cannot account for the improvement of edge surface flatness in polishing workpieces having large ERO.

To overcome the problem, the ERO generating model was newly proposed based on the elastic contact theory. Contact between workpiece and polishing pad was considered that between highly rigid plate and elastic body in the contact theory. In the case of the workpiece surface without ERO, the contact stress concentration occurs at the edge and smaller pad thickness significantly suppresses the stress concentration [5]. On the other hand, in the case of the workpiece surface with ERO, the contact stress decreases with the approach of the workpiece edge and the smaller the settlement of the workpiece is, the smaller the stress occurred at the edge is [6]. As mentioned above, the proposed model considered the effect of existing ERO on obtained edge surface profile. From the proposed model, thin polishing pads with small deformation were expected to be effective in decreasing ERO.

To verify the validity of the model, six types of polishing pads having different thickness and hardness were prepared and the deformation properties of the pads and the polishing characteristic were evaluated. Deformation properties of the pads were measured using an indentation tester (Shimadzu Corp., MST-I). Polishing experiments were conducted on silicon wafers using a single-sided polishing machine

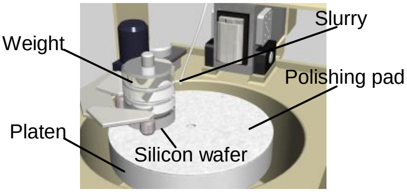


Fig. 1: Schematic of single-sided polishing process

Table 1: Polishing conditions

Workpiece Rotation	Silicon wafer 5'' 40 rpm
Polishing pad Diameter Rotation	 420 mm 40 rpm
Slurry Supply rate	Colloidal silica 25 mL/min
Polishing pressure	13.8 kPa

(Lapmaster Corp., LP-15F), as illustrated in Fig. 1. Table 1 lists the polishing conditions. The obtained ERO was quantitatively evaluated by the roll-off amount (ROA), which is defined as the vertical displacement from the level line to the measured wafer profile at a position 1 mm from the wafer edge.

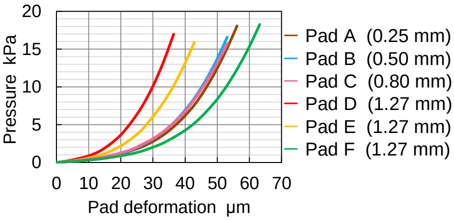
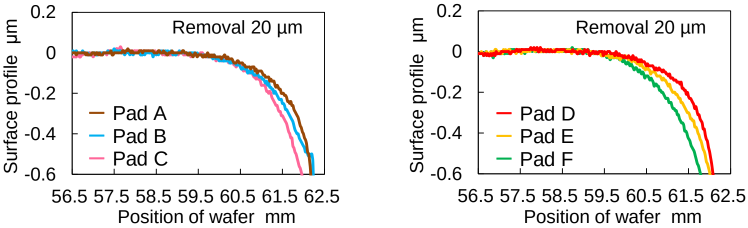


Fig. 2: Thickness and deformation properties of polishing pads

Fig. 2 shows the thickness and the deformation properties of the polishing pads. Figs. 3 (a) and 4 (a) confirm that thinner polishing pads decreased ERO in the case of the same deformation of the pads. As for the deformation of polishing pads, it is confirmed that small deformation brought small ERO in the case of the same pad thickness (Figs. 3 (b) and 4 (b)). From the above experimental results, the validity of the proposed ERO generating model was verified.

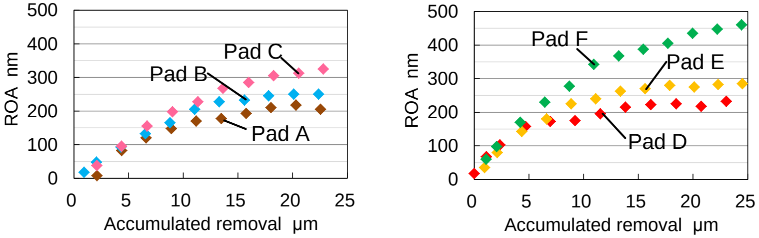
3 Newly developed polishing pads

On the basis of the above findings, thin polishing pads with small deformation were newly developed. Fig. 5 shows the deformation properties of the developed polishing



(a) Effect of pad thickness (b) Effect of pad deformation

Fig. 3: Edge surface profiles of polished wafers



(a) Effect of pad thickness (b) Effect of pad deformation

Fig. 4: Change in ROA with accumulated removal

pad (thickness 0.16 mm) and reference commercial polishing pad (Nitta Haas Inc., SUBA800, thickness 1.27 mm).

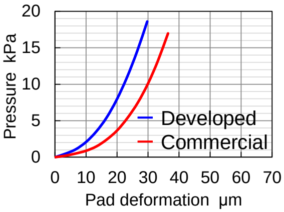
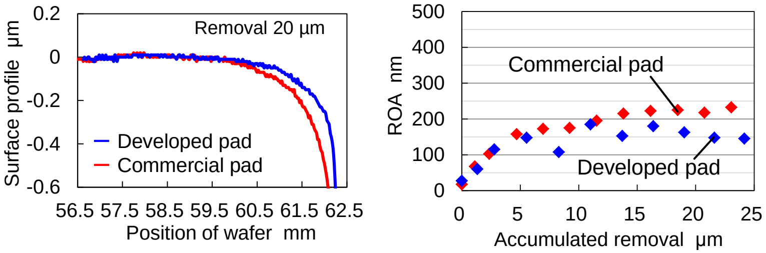


Fig. 5: Deformation properties of polishing pads



(a) Edge surface profile (b) Change in ROA

Fig. 6: Polishing performances of developed polishing pad

Fig. 6 confirms that surface flatness at the wafer edge was improved using the developed polishing pad. As for the finishing efficiency, the removal rate was improved by 1.2 times with stability. This was possibly because the material used in the developed pad, namely, extra-fine fiber had high abrasive holding ability.

4 Conclusion

To decrease the ERO of a workpiece, edge profile generating model was proposed on the basis of the elastic contact theory. Based on the model, thin polishing pads with small deformation were developed in the hopes of decreasing ERO. Experimental results on silicon wafers showed that the developed polishing pads improved surface flatness at the workpiece edge and finishing efficiency.

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