# Improvement of Rounding Effect in Chemical Mechanical Polishing Process for Nano-Scale Manufacturing

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In the present work, the rounding effect in the CMP process was examined in the process conditions such as the head pressure, platen and head speed, and deposition thickness. The rounding effect according to each process condition is measured from SEM and compared with each other. From the experimental results, CMP process condition to reduce the rounding effect is determined and the rounding effect has been improved from 55nm to 29nm, which is about 47% reduction.

**Key Words :** Rounding Effect, Chemical Mechanical Polishing, Head Pressure, Platen and Head Speed, Deposition Depth

## 1. Introduction

Recently, chemical mechanical polishing (CMP) process becomes more important for the device manufacturing using deep submicron process (Eom and Oh, 2003 ; Shin et al., 2004), Especially, in the technologies below 0.18 $\mu$m, the local and global planarization within wafer having the patterned dies is required to secure a sufficient process margin, such as depth of focus (DOF), in the photolithography (Seo, 2003). The aspect ratio of the step height and pitch in the patterned area, where the step height of multi-metalized cell area compared with un-metalized peri-area is higher than 100 nm (Park et al., 2004), is increased according to the design rule of under 0.1 $\mu$m isolation critical dimension (CD), but the DOF is decreased according to shortening of laser wavelength used in the photolithography process. Dielectric materials such as tetraethylorthosilicate (TEOS), high density plasma (HDP), and boron phosphorus silicate glass (BPSG) are deposited by chemical vapor deposition (CVD) on the patterned area. According to step height by multi-metalization, dielectric materials have a prominence and depression as shown in Fig. 1. This step height is globally planarized somewhat by CMP process. But in the view of local planarization, the rounding effect, which is combined with dishing and thinning (Miyashita et al., 2003 ; Seok, 2004 ; Seok, 2003 ;Cho et al., 2002), exists on the boundary of cell area and peri-area as shown in Fig. 2. The rounding effect is increased according to stiffening of aspect ratio as design rule is shrunk. This rounding effect results in poor dielectric characteristics, low yield of these elements and degradation in their level of reliability (Boning et al., 1999 ; Miyashita et al., 2001). Regarding the device manufacturing trend to smaller isolation CD, CMP process condition achieving both of the global and local planarization is required for improving the rounding effect.

In this work, the rounding effect is examined according to the change of process conditions such as pressures applying on membrane, retainer ring, and inner tube, speeds of platen and head, and deposition thickness in the same polishing pad. By using Taguchi experimental method, the

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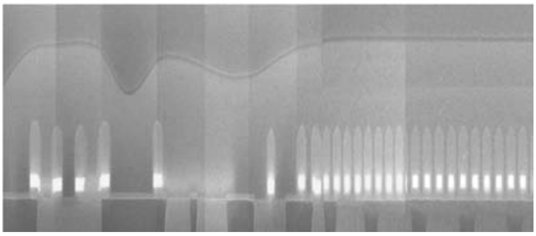
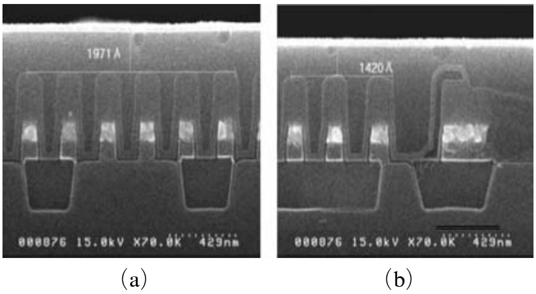


**Fig. 1** Cross-sectional SEM panorama view for the patterned wafer after deposition of a dielectric material



(a) (b)

**Fig. 2** Cross-sectional SEM view after inter-layer dielectric CMP process: (a) cell area and (b) cell area adjacent to a peri-area

process condition improving the rounding effect in CMP process is determined. The surface profiler, scanning electron microscope (SEM), and thickness measurement equipment are used to determine the best process condition, and to verify the improvement of the rounding effect by applying the determined process condition.

## 2. Experimental

In this experiment, a test vehicle employing 0.16 $\mu$m design rule for memory device is used as a sample of CMP process. A rotary table type polisher (Mirra/Applied Materials) and cleaning unit (On-Trak/Applied Materials) are used for polishing and cleaning of test patterned wafer. Rodel IC 1010/SUBA stacked polishing pad is applied in the polisher. In order to investigate the improvement of rounding effect in the CMP process according to the process conditions, we changed the pressures applying on membrane, retainer ring, and inner tube, platen and head speed, and deposition thickness in a same polishing pad. The polishing residue and micro dishing induced during the CMP process were quantitatively reviewed with cross-sectional SEM (S-2600/Hitachi).

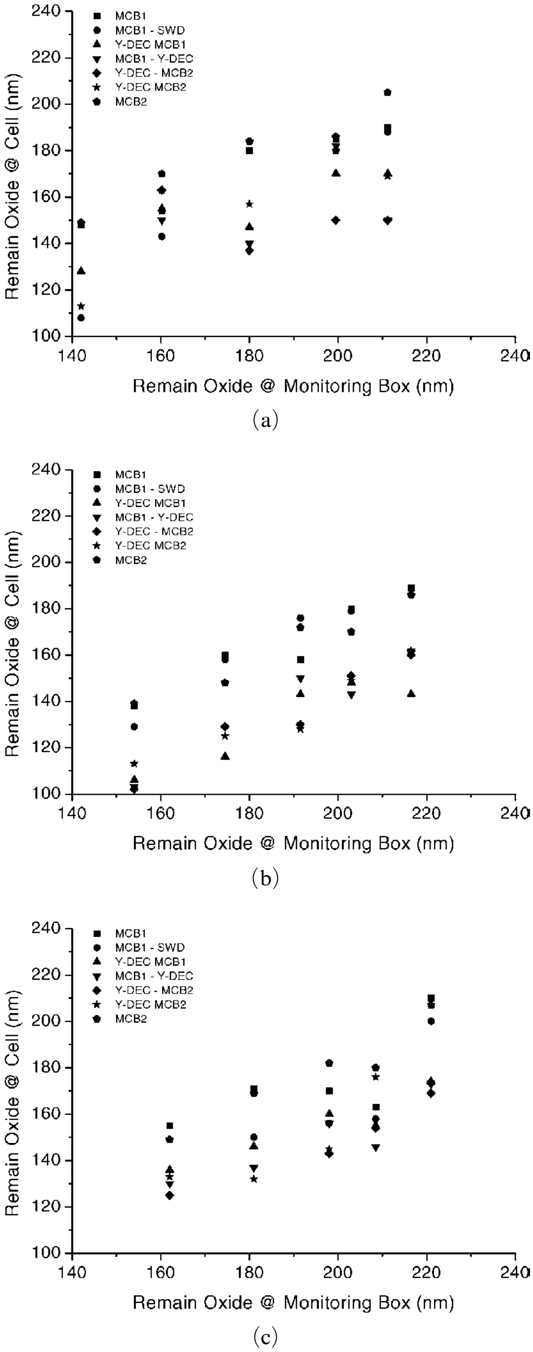
The base condition used in the inter-layer dielectric CMP process is that pressures acting on membrane, retainer ring, and inner tube are 4.5/5.5/5.0 psi, speeds of platen and head are 53/47 rpm, and deposition thickness is 600 nm. The within die (WID) rounding in the base condition is 55 nm on the average.

## 3. Results and Discussion

The rounding effect is defined by difference in the remained oxide between cell area and peri-area in the patterned wafer as shown in Fig 2. The remained oxide thickness on the gate hard mask nitride at the cell is measured with cross-sectional SEM, and the remained oxide thickness at the monitoring box is measured with thickness measurement equipment (Optiprobe/Thermawave). In the patterned wafer, the monitoring box is prepared in each die.

### 3.1 Head pressure

Figure 3 shows the WID rounding according to the pressures applying on membrane, retainer ring, and inner tube, respectively in the base process condition such as platen and head speed 53/47 rpm and deposition depth 600 nm. In Fig. 3, cross-sectional SEM is measured at the seven positions across a line, which is constituted with 1st main cell block, 1st main cell block adjacent to a sub word line, 1st main cell block adjacent to a Y-decoder, 2nd main cell block adjacent to a Y-decoder, and 2nd main cell block. In the pressure condition of 4.5/5.5/5.0 psi, which is base condition, the maximum WID rounding is 55 nm, and average WID rounding is 41.2 nm for five dies. In the pressure condition of 3.0/5.0/3.0 psi, the maximum WID rounding is 48 nm, and average WID rounding is 42.4 nm for five dies. In the pressure condition of 3.0/4.0/3.0 psi, the maximum WID rounding is 41 nm, and average WID rounding is 36.6 nm for five dies. From these experiments, we determined the pressure condition as 3.0/4.0/3.0 psi.



(a)

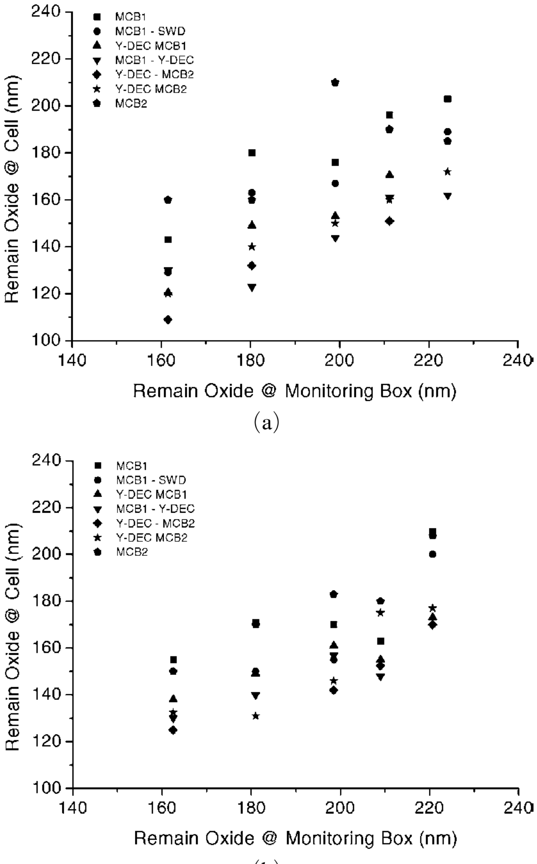
(b)

(c)

**Fig. 3** WID rounding according to the pressures applying on membrane, retainer ring, and inner tube, respectively in the base process condition: (a) 4.5/5.5/5.0 psi, (b) 3.0/5.0/3.0 psi, and (c) 3.0/4.0/3.0 psi

### 3.2 Platen and head speed

Figure 4 shows the WID rounding according to the speed of platen and head, respectively in the process condition such as pressures acting on membrane, retainer ring, and inner tube 3.0/4.0/3.0 psi and deposition depth 600 nm. In Fig. 4, cross-sectional SEM is measured at the seven positions as defined in Fig. 3. In the speed condition of 63/57 rpm, the maximum WID rounding is 66 nm, and average WID rounding is 52.0 nm for five dies. In the speed condition of 53/47 rpm, which is base condition, the maximum WID rounding is 41 nm, and average WID rounding is 36.6nm for five dies. From these experiments, we determined the speed condition as 53/47 rpm, which is the same speed as used in the base condition.



(a)

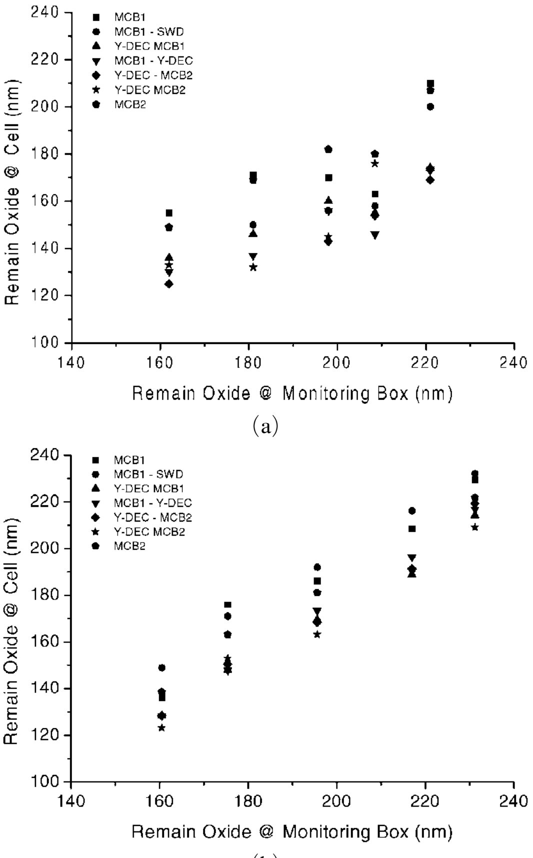
(b)

**Fig. 4** WID rounding according to the speed of platen and head, respectively in the process condition: (a) 63/57 rpm and (b) 53/47 rpm

### 3.3 Deposition thickness

Figure 5 shows the WID rounding according to the deposition thickness in the process condition such as pressures acting on membrane, retainer ring, and inner tube 3.0/4.0/3.0 psi and platen and head speed 53/47 rpm. In Fig. 5, cross-sectional SEM is measured at the seven positions as defined in Fig. 3. In the deposition thickness condition of 600 nm, the maximum WID rounding is 41 nm, and average WID rounding is 36.6 nm for five dies. In the deposition thickness condition of 700 nm, the maximum WID rounding is 29 nm, and average WID rounding is 26.6 nm for five dies. From these experiments, we determined the deposition thickness condition as 700 nm.

Table 1 lists the summary of the WID rounding according to the change of process condition such as pressures applying on membrane, retainer ring, and inner tube, speeds of platen and head, and deposition thickness in the same polishing pad. From Table 1, the process condition to improve the rounding effect is determined as pressure condition of 3.0/4.0/3.0 psi, speed condition of 53/47 rpm, and deposition thickness condition of 700 nm, respectively. By changing of process condition, the WID rounding is improved from 55 nm to 29 nm, about 47%. Fig. 6 shows the cross-sectional SEM view after inter-layer dielectric CMP process using new process condition at the cell area and cell area adjacent to a peri-area. In Fig. 6, the rounding effect is improved compared with that shown in Fig. 2. Fig. 7 shows the map of the removed oxide measured at the monitoring box for patterned wafer according to process condition. In Fig. 7, there is no difference in the characteristics of the two maps, which is the edge past in the oxide removal rate.



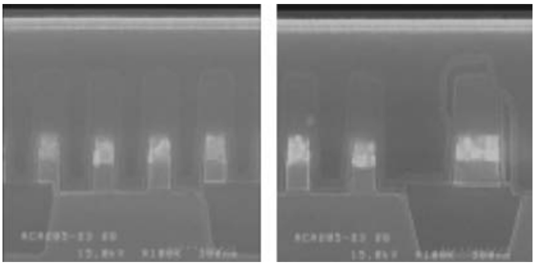
(a)

(b)

**Fig. 5** WID rounding according to the deposition thickness in the process condition : (a) 600 nm and (b) 700 nm

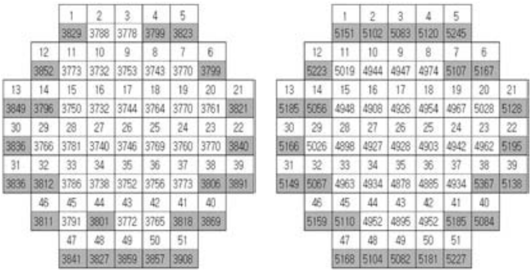
**Table 1** WID rounding according to the change of process condition

| Polishing Condition (Pressure, Speed, Deposition Thickness) | WID Rounding | Unit |
|---|---|---|
| 4.5/5.5/5.0 psi, 53/47 rpm, 600 nm | 55 | nm |
| 3.0/5.0/3.0psi, 53/47 rpm, 600 nm | 48 | nm |
| 3.0/4.0/3.0 psi, 53/47 rpm, 600 nm | 41 | nm |
| 3.0/4.0/3.0 psi, 63/57 rpm, 600 nm | 66 | nm |
| 3.0/4.0/3.0 psi, 53/47 rpm, 700 nm | 29 | nm |



(a) (b)

**Fig. 6** Cross-sectional SEM view after inter-layer dielectric CMP process using new process condition : (a) cell area and (b) cell area adjacent to a peri-area



(a) (b)

**Fig. 7** C Map of the removed oxide measured at the monitoring box for patterned wafer according to process condition : (a) base and (b) new

## 4. Conclusion

In this work, the rounding effect is examined according to the change of process condition such as pressures acting on membrane, retainer ring, and inner tube, speeds of platen and head, and deposition thickness in the same polishing pad. From the experiments, the process conditions to improve the rounding effect is determined to pressure condition of 3.0/4.0/3.0 psi, speed condition of 53/47 rpm, and deposition thickness condition of 700 nm, respectively. By changing of process condition, the WID rounding has been improved from 55 nm to 29 nm, which is about 47% reduction. From the comparison of removed oxide map for base and new process condition, we conclude that new process condition improves the rounding effect without change the removal characteristics.

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