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# Physical and Chemical Characteristics of the Ceramic Conditioner in Chemical Mechanical Planarization

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**Abstract.** The purpose of this study was to characterize a new pad conditioning disk in terms of corrosion resistance and CMP performances, such as removal rate, non-uniformity, and contamination of metals and particles on wafers. The new conditioning disk was manufactured using a pattern process on ceramic substrates and a diamond CVD on patterned substrates. The point size and numbers were easily controlled by the pattern process and a uniform diamond film growth was achieved by the CVD process. Conventional conditioning disks often encounter problems such as scratches due to the diamond segregation and the metal contamination, which is due to the dissolution of Ni during the CMP process. The new conditioning disk eliminated the sources of microscratch and metal contamination from diamond segregation and metal dissolution. It also exhibited a high corrosion resistance when treated with corrosive chemicals, such as $H_2O_2$ and KOH. No differences in removal rate and non-uniformity were measured, unlike those with the conventional conditioning disk. Also, the defects and particles on polished wafers were reduced using the new conditioning disk.

## Introduction

Pad conditioning during CMP (Chemical Mechanical Planarization) is a necessary process for the constant removal rate and non-uniformity [1]. The structure and properties of polishing pad are important in determining the polish rate and planarization ability of the CMP process [2]. During CMP, the change of pad surfaces is not uniform, thus the micro pores on the pad surface can be easily blocked by slurry residues [3].

The conditioning process of the CMP pad is a necessary to maintain constant removal rate and uniformity during CMP [4]. Commonly used conditioning disks are composed of electroplated Ni on SS (stainless steel) substrates to combine abrasive diamonds. These conventional conditioning disks cause problems such as scratches because of the diamond segregation and the metal contamination resulting from the dissolution of Ni surface during CMP [5]. Sintering and CVD methods have been studied and developed in order to solve these problems [6]. However, these conditioning disks were still prone to scratches and metal contamination on polished surface especially in the acidic metal CMP processes.

In this study, the ceramic based conditioning disk was introduced to eliminate the scratches and the metal contamination during CMP. The change of removal rates and defects on polished surfaces were evaluated with the corrosion resistance in various acidic and alkaline chemicals.

## Experimental Materials and Procedure

The $Si_3N_4$ ceramic based conditioning disk was manufactured by a pattern of ceramic and the diamond CVD processes. The grooves on the ceramic substrate were generated by Hunatech precision

milling machine (HNT-G-W150) and the shape and density of patterns were adjusted for the optimization of pad conditioning. The diamond film was deposited thick enough to protect $Si_3N_4$ patterns and enhance the performance of conditioner. A thermal CVD process, accomplished using Hunatech CVD equipment (HNT-CVD-1200), was used for the diamond film deposition.

The corrosion resistance of the ceramic conditioner was evaluated in acidic and alkaline solutions with various pH values using $H_2O_2$ (30 wt%) and KOH (45 wt%) chemicals. After dipping the disks in these chemicals for a week, the surface morphology were observed using FESEM.

Strasbaugh polisher (6DSSP) was used for the polishing test and commercial polyurethane pads (IC 1000, Rodel Co.) and ILD slurry (Cabot SS-25) were used for the experiments. Eight inch 8000Å-thick USG wafers were used for the oxide CMP. The polishing parameters were set accordingly ; head pressure 7 psi, conditioner pressure 3 psi, platen speed 20 rpm, head speed 25 rpm and slurry flow rate 125 ml/min. The polishing and conditioning time were set from 1 to 5 minutes. The removal rate of USG wafers was measured by an ellipsometer (FE-IIID, Rudolph Co.). Defects on the patterned wafers were analyzed by KLA 2132 after post CMP cleaning. Particulate contamination was measured using laser surface particle scanner (SFS-6200, Tencor Co.).

## Results and Discussion

In the ceramic conditioner, every point of groove patterns acts as a diamond abrasive in a conventional conditioning disk. The many parameters, such as point size and number of points, were controlled to optimize the conditioning disk as shown in Table 1. In order to evaluate the polishing performance, the removal rate and non-uniformity of USG wafers for both the ceramic and conventional conditioners were measured and compared. Figure 1 shows the schematic structure of the pattern used for polishing test.

Table 1. Pattern structures of ceramic conditioners used for polishing

| | Point size(㎛) | Valley (㎛) | # of point | Channel(㎛) | Channel pitch(㎛) |
|---|---|---|---|---|---|
| 1 st | 0.04 | 0.3 | 46158 | 0.5 | 2.5 |
| 2 nd | 0.04 | 0.5 | 13279 | 1 | 4.3 |
| 3 rd | 0.03 | 0.5 | 2816 | - | 4.3 |

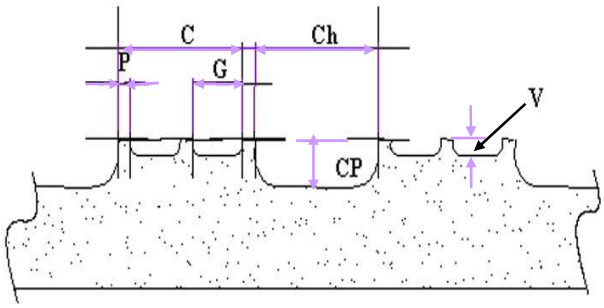
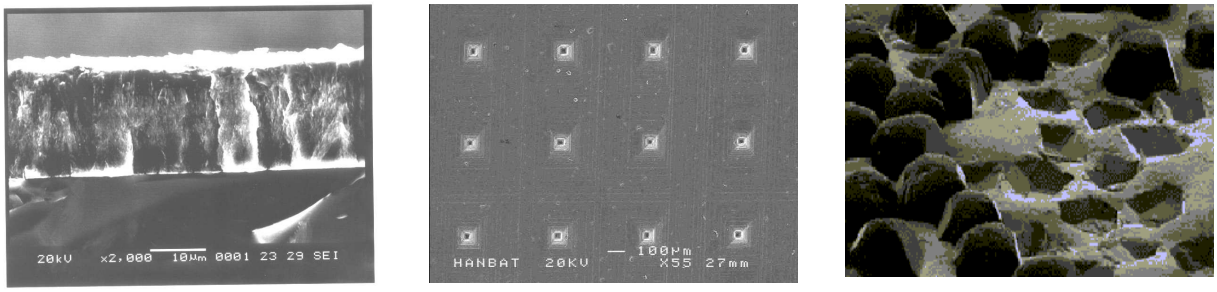



Figure 1. The schematic structure of a pattern used for polishing test ; P : Cutting Point, C : Cell Size, V : Valley(Point to Point), G : Groove(Cell to Cell), Ch : Channel(Cell Block to Cell Block), CP : Channel Pitch(Channel Height)

Figure 2 (a) shows the SEM cross sectional image of diamond film grown on ceramic substrate. The TTV (total thickness variation) of grown diamond film was below 10 %. Figure 2 (b) shows the SEM images of grooved ceramic point and the patterned grooves on ceramic substrate after the CVD process. Point size and point positions were uniform compared with conventional conditioning disk

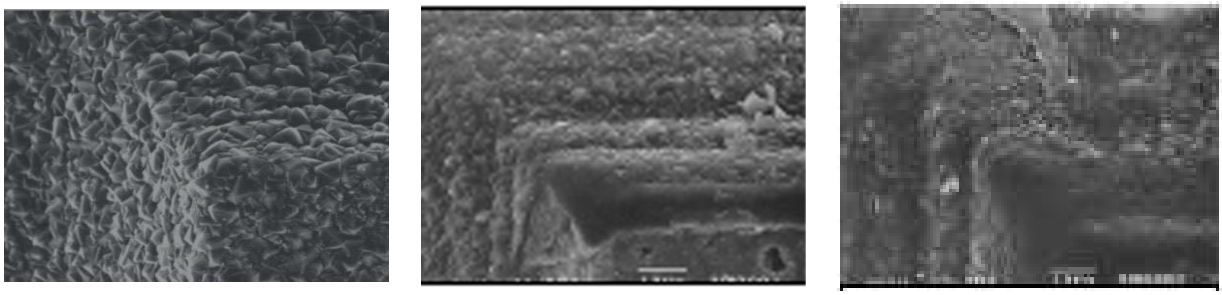
as shown in Fig. 2(c). It was considered that the contact area between pad and disk could be controlled by the pattern structure and point size.




(a) (b) (c)

Figure 2. SEM images of (a) deposited diamond film on the $Si_3N_4$ surface, (b) CVD diamond coated on $Si_3N_4$ patterns and (c) conventional conditioning disk with electroplate technology

The corrosion resistance of ceramic conditioner was measured in acidic and alkaline chemicals, such as $H_2O_2$ at pH 4.6 and KOH at pH 12. Figure 3 shows SEM images of the ceramic disk after dipping in chemicals for a week. No changes in surface morphology were observed on conditioners treated in chemicals.



(a) (b) (c)

Fig 3. SEM image of CVD diamond coated ceramic disk after treated in (a) $H_2O_2$ and (b) KOH for a week

Figure 4 shows the removal rate and non-uniformity of USG wafers using three types of ceramic conditioning disk with different number of points as shown in Table 1. The removal rate of wafers was observed to be dependent on the number of cutting points. As the number of points decreased from 40,000 to 2800, the removal rate increased from 1,400 to 1,600 Å/min and the stability of polishing performance improved. This is because when the number of points decreased, the down force per unit point increased and the ability of conditioning improved. The polishing performance could be effectively improved by controls of point number and pattern shape of the conditioning disk.

Figure 5 shows the removal rate and non-uniformity of USG wafer with a ceramic conditioning disk having optimized point numbers and pattern shape. The polishing test was performed for 130 hours and the pad was changed once during the polishing test. The reference tests with a conventional disk were performed for comparison. The removal rate was 1,700 Å/min, while non-uniformity was about 6 % during the polishing. Also, the stable removal rate and good WIWNU (With in Wafer Non-Uniformity) and WTWNU (Wafer To Wafer Non-Uniformity) were observed when wafers were polished continuously.

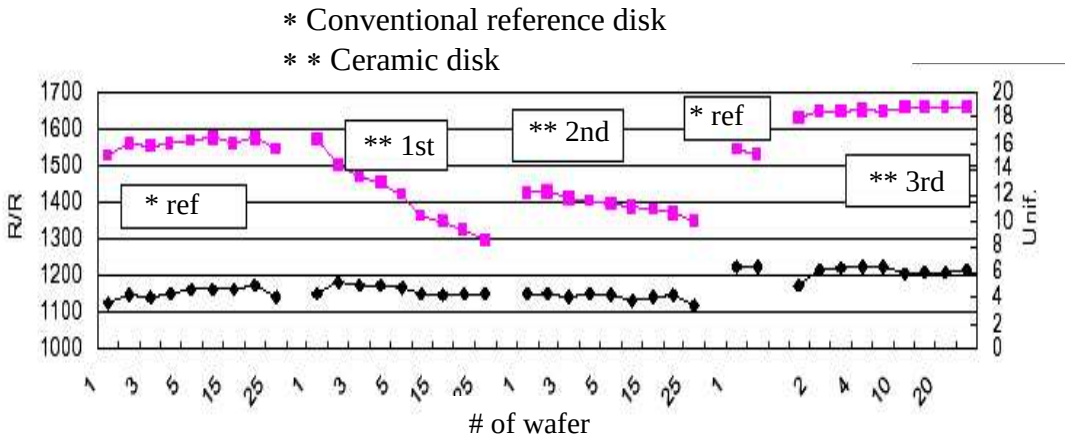



Figure 4. Effect of groove patterns on polishing performance

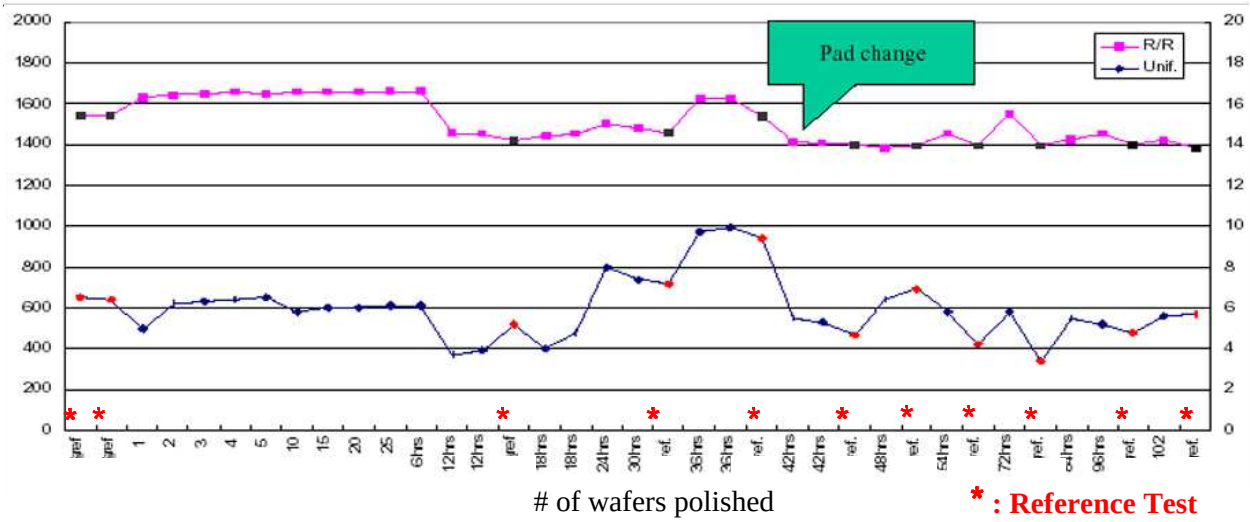



Figure 5. Removal rate and non-uniformity of polished oxide through the ceramic conditioner

Figures 6 and Figure 7 show the particles and total defects on USG wafers after polishing as a function of conditioning time. The sudden increase of the number of particles and defects was observed on polished wafers with the conventional disk when polished for 20 hours. Then particles and defects decreased and stabilized after polishing for 40 hours. When applied to the ceramic disk, the levels of particles and defects added were lower than those of the conventional disk. The particles and defects were stabilized within 12 hours.

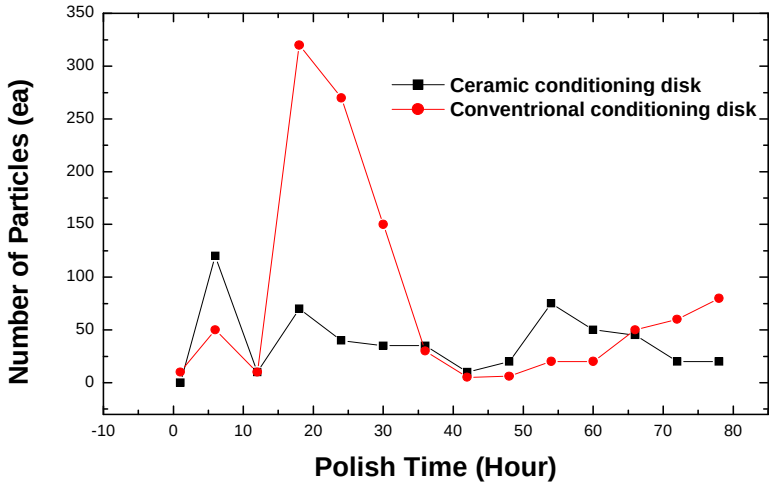



Figure 6. Number of particles added after polishing as a function of conditioning time

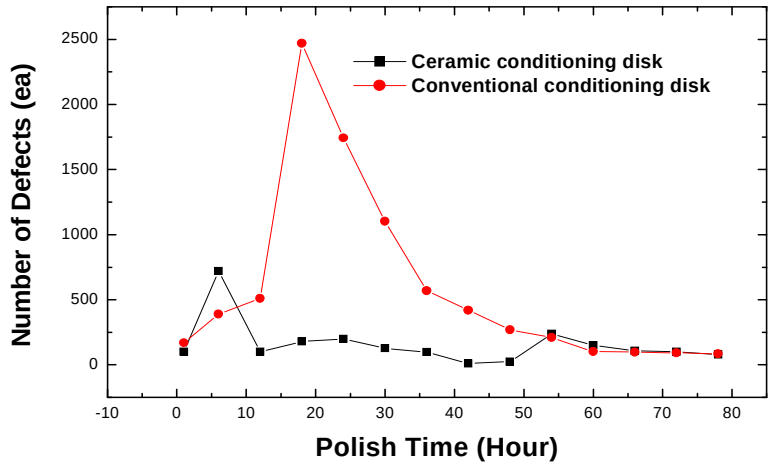



Figure 7. The number of total defects added after polishing as a function of conditioning time

## Summary

The new ceramic based conditioning disk was introduced and compared with the conventional Ni plated stainless steel conditioners. This disk was manufactured by the $Si_3N_4$ substrate patterning and CVD deposition of diamond film on the ceramic patterns. The new ceramic conditioning disk has many advantages such as flexibility for formation of pattern and excellent corrosion resistance. Although the ceramic disk was treated in severely corrosive solutions for a week, no damages on the conditioner of diamond surface were observed. The constant removal rate and good non-uniformity were also observed even if the conditioning process was performed over 100 hours. The number of particles and defects can be reduced using the new ceramic disk. No scratches were found on polished wafers due to the absence of diamond particles on the ceramic based conditioner.

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