Effect of radial grooves pads on copper chemical mechanical polishing

Chulwoo Bae[1], Shinil Oh[2], Juhwan Kim[2], Sunjae Jang[3], and Taesung Kim[1,2,*]
[1] SKKU Advanced Institute of Nano Technology (SAINT), Sungkyunkwan University, Suwon, South Korea, chalres11@naver.com
[2]School of Mechanical Engineering, Sungkyunkwan University, Suwon, South Korea,
[3] Material Development Team, Semiconductor R&D Center, Samsung Electronics, Hwasung, South Korea
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ABSTRACT

In this study, the effect of radial grooves (RG) pads used in the Cu chemical mechanical polishing (CMP) process was investigated, to improve the Cu CMP performance. Four types of pads were selected according to the number of RGs; the numbers of RGs were 0, 8, 16, and 32. Simulation and CMP test were performed to confirm the effect of the number of RGs. When simulating the effect of the radial groove pad, it shows a higher new slurry mass fraction than the conventional circular groove (CG) pad. These results show more improved performance in the Cu CMP test. As the slurry move faster towards the Cu wafer total area, the removal rate increases, and non-uniformity is improved. As the old slurry quickly outflows, the contaminants and pad debris contained in the old slurry are discharged, thereby improving the roughness.

INTRODUCTION

As the size of semiconductor chips decreases, the semiconductor manufacturing process is subdivided and requires sophisticated process technology. The CMP process also requires a higher polishing rate and a process technology that can improve various defects[1, 2]. This technique can be improved through a variety of CMP consumables. Although CMP consumables have different effects on CMP performance, their synergistic effect can improve CMP efficiency[3, 4].

Many research teams are studying the CMP pad groove[5-7]. They studied the slurry utilization efficiency according to the width of the pad groove and the evaluation of CMP performance according to various grooves were studied. Among the characteristics of the pad, the size, shape, number of grooves, etc. of the groove are one of the important factors that can affect the removal rate of the film. Also, it is possible to improve wafer defects by controlling the outflow/inflow of the slurry using the characteristics of the groove.

In this study, we conducted the Cu CMP process by adding RG to the CG by number and studied the effect of the Cu CMP process according to the number of RGs. Through the simulation, the new slurry mass fraction according to the number of RGs was compared, and the improvement in removal rate and roughness was checked through Cu CMP test.

EXPERIMENTAL

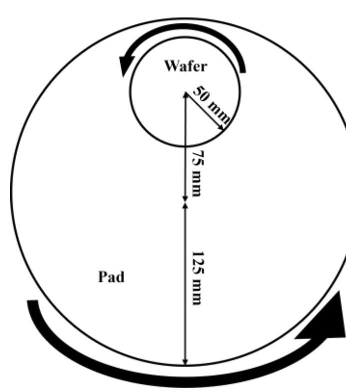

Figure 1. Configuration of CMP simulation.

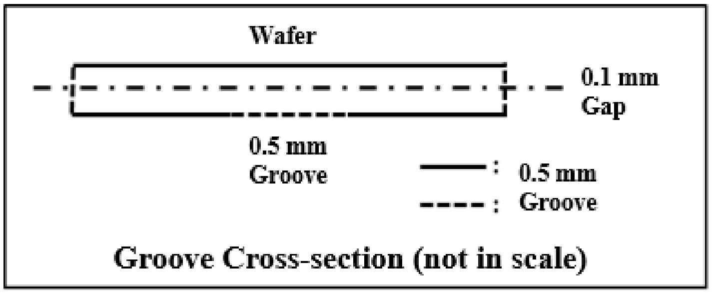

Figure 2. Computational model of wafer and CMP pad.

ANSYS FLUENT v.20 was used for the numerical analysis. The steady-state mass conservation (continuity equation) and momentum equations were used for Newtonian, and incompressible fluids (Navier Stokes equation) were used to analyze the fluid flow.

Figure 1. shows the configuration of Cu wafer and pad size and rotation direction used in the simulation test. In the simulation model, it is assumed that the wafer and pad are flat, and the groove width is set as shown in Figure 2. The rotation speed of the head and wafer was set to 90 rpm, and the number of radial grooves was 0, 8, 16, or 32.

Slurry	Silica (80nm)
Rotation speed	93/87 rpm
Flow rate	150 ml/min
Pressure	3 psi
Number of radial grooves	0, 8, 16, 32

Table 1. Condition of Cu CMP process

Table 1. shows the basic condition of Cu CMP process, and 4 cm × 4 cm Cu coupon wafer was used for CMP process. The process was tested for 1 minute using GnP Poli-400 equipment. Using a 4-point probe, the removal rate was calculated from the difference in the thickness of the Cu wafer before and after. After the CMP process test, the roughness of the wafer was compared for each condition through AFM.

RESULTS and DISCUSSION

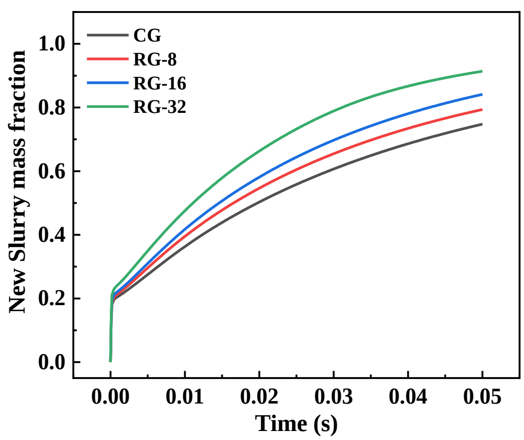

Figure 3. New slurry mass fraction according to the number of grooves.

Figure 3. shows the result of simulation test, as the number of radial grooves increases, the new slurry mass fraction increases. When comparing the RG-32 pad and the CG pad, the new slurry mass fraction differs by about 23%. As a result of the simulation, indirectly explain that the amount of slurry injected under the wafer for the same time is more, and a higher removal rate can be expected in the CMP test. In addition, as the amount of new slurry is larger, the discharge of old slurry is also higher for RG pad than CG pad. Therefore, it can be expected that the contaminants or pad debris, which is included in the old slurry, are discharged faster[8, 9].

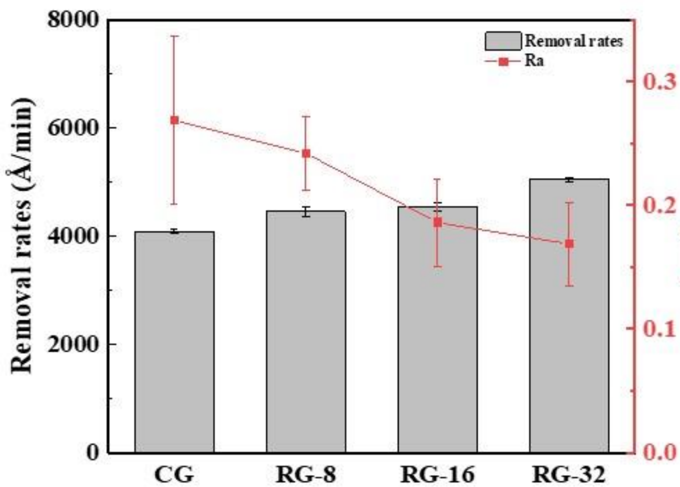

Figure 4. Removal rates and Ra values according to the number of radial grooves

Figure 4. shows the result of Cu CMP test. It shows a similar tendency to the simulation result and has the highest removal rates in RG-32 pad. As shown in the previous simulation results, this result is due to the amount of new slurry mass fraction. The tendency for the removal rate to increase as the new slurry is injected quickly and the slurry utilization efficiency increases. In addition, Ra value decreases as the number of radial grooves increases. As the old slurry is discharged quickly, contaminants, pad debris, or wafer fine fragments that can affect roughness are rapidly discharged together, helping to improve roughness.

Simulation and CMP test results show that RG can positively change the slurry flow during the CMP process. Also, the changed slurry flow contributes to increase the Cu CMP process efficiency, specifically, the removal rate increases and the roughness is improved.

CONCLUSIONS

In this study, the change in slurry flow when RG was added to CG was identified through simulation, and the effect of such slurry flow on the Cu CMP process was tested. When RG is added, more slurries are introduced in the same amount of time, which increases the polishing rate. Also, roughness is improved because by-products in the old slurry are discharged faster. That is, Cu CMP performance can be improved by adding RG.,

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Corresponding Author:
Taesung Kim
Tel: +82-31-290-7466
E-mail: tkim@skku.edu
Sungkyunkwan University (SKKU)
2066, Seobu-ru, Jangan-Gu, Suwon, 440-746, South Korea