Membrane Process Development for small particle removal in CMP slurry and Post-CMP Cleaning

SangHyeon Park[1] Jaewon Lee[1], Eungchul Kim[1] and Taesung Kim[1, 2*]
[1] School of Mechanical Engineering, Sungkyunkwan University, Suwon, South Korea,
[2] SKKU Advanced Institute of Nano Technology (SAINT), Sungkyunkwan University, Suwon, South Korea

INTRODUCTION

In the dielectric chemical mechanical polishing (CMP) process, ceria is widely used due to its high polishing performance and selectivity. However, it is difficult to remove the ceria particles in the cleaning process due to the chemical bond formed with SiO_2 wafer surface, which becomes more difficult as the ceria particle size decreases [1]. In this study, while maintaining the CMP performance of the ceria slurry, the tangential flow filtration (TFF) system was applied to separate small ceria particles before entering the CMP process.

BACKGROUND

CMP is conducted using an abrasive slurry consisting of nanosized (<100 nm) alumina, ceria, or amorphous silica particles, and many other chemical agents for the particular wafer application [2]. The quantity of wastewater generated per wafer undergoing CMP polishing may typically exceed 10 or more liters [2]. A typical wafer production step might involve the application of between 0.2 and 0.8 liter of CMP slurry, 1-2 liter of rinse water and another 5 or more liters of pad cleaner and rinse water [3]. Some reports indicate the CMP processes account for 30-40 percent of the total water used by a Fab. [2].To improve cleaning performance and keep the CMP performance, reducing of small size inactive abrasive particles was studied.

EXPERIMENTAL

The schematic of TFF system and particle separation mechanism are shown in Figure 1. Since the types of forces applied in the TFF system are diverse. It is important to understand the particle separation mechanism to minimize the loss of large particles and improve the separation rate of small particles in slurry. In the TFF system, particles were transported to the membrane surface by convection force, and transported from the membrane by Brownian-motion, shear-induced diffusion, or a combination of these two mechanisms [4]. 0.05, 0.1 and 0.2um size flat sheet PES(Polyethersulfone) membrane was applied to cell tester with 92x47mm face area to separate slurry particles.

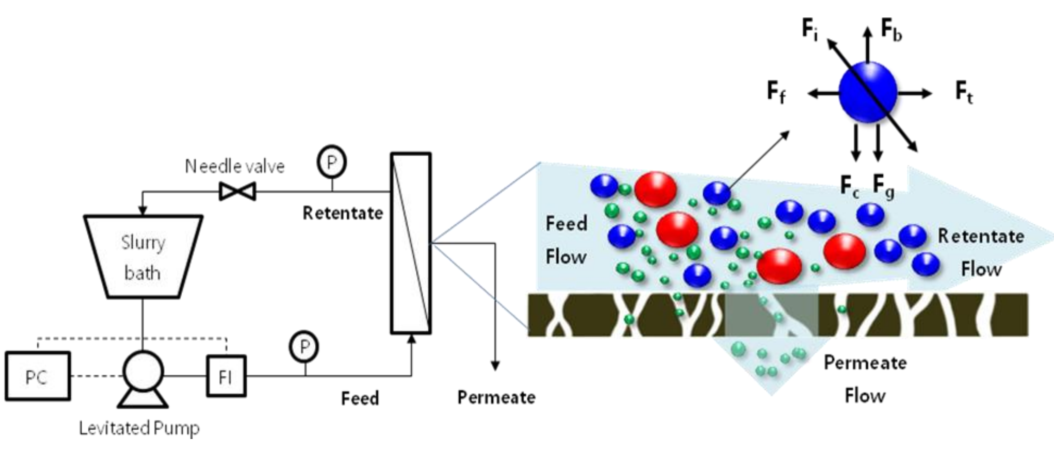

Fig.1 Schematic of the tangential flow filtration system and the mechanism of small particle separation.

DISCUSSION

Figure 2 shows the CMP performance of ceria slurry with and without application of TFF system. Through application of the TFF system, the total number of ceria particles in the slurry was decreased, however, the concentration and properties were maintained. In addition, the TFF system reduced the performance deviation while maintaining the average of SiO_2 removal rate of ceria slurry, which is determined as a result of the particle size distribution being stabilized. Furthermore, the TF system improved the cleaning efficiency of the ceria slurry, which proving that small ceria particles (< 50 nm) can act as a contaminant after the CMP process.

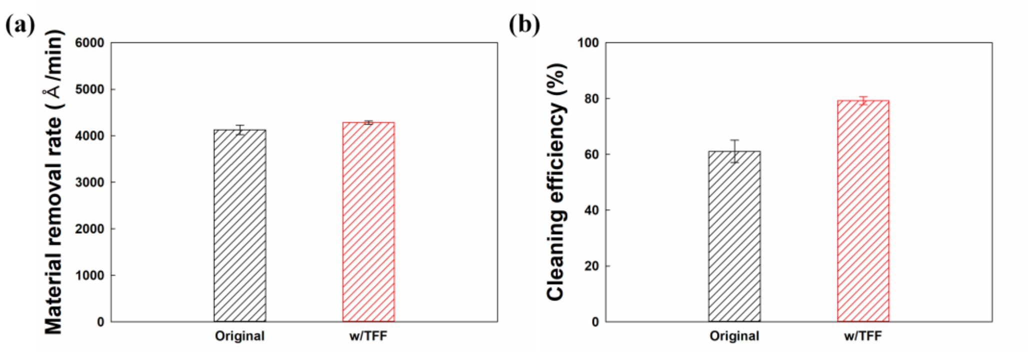

Fig.2 (a) Removal rate of SiO_2 film and (b) buff cleaning efficiency according to the application of TFF system for ceria slurry.

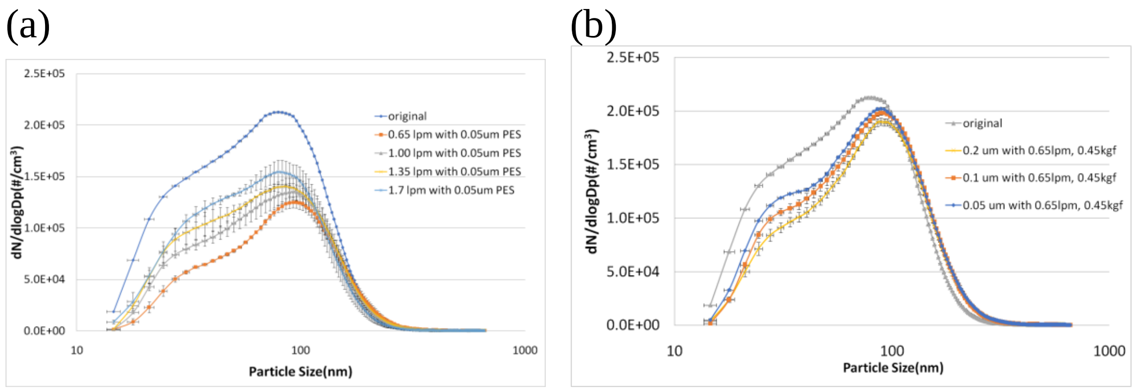

Fig.3 (a) Particle size curve by membrane pore size and (b) tangential flow velocity.

Table 1.50nm particle separation by flow velocity

	0.1 m/s	0.16m/s	0.21m/s	0.27m/s
<50 nm	61.4%	37.7%	21.0%	15.0%
>50 nm	17.2%	20.2%	6.3%	8.1%

Table 2.50nm particle separation by membrane pore size

	0.05um PES	0.1um PES	0.2um PES
< 50 nm	51.4%	52.1%	63.3%
> 50 nm	5.5%	16.1%	35.2%

Figure 3 shows the comparison of slurry particle size distribution of retentate measured by SMPS(Scanning mobility particle sizer) between original and other separated Ceria slurry by different tangential flow rate from 0.65 to 1.7lpm and membrane pore size.

Table 1 shows the separation efficiency on below and over 50nm size particle by tangential flow velocity from 0.1 to 0.27m/s. 0.1m/s(0.65lpm) condition has highest separation efficiency among other condition. Table 2 also shows the separation efficiency by membrane pore size. 0.05um PES membrane and 0.1m/s velocity condition has highest separation efficiency in terms of below and over 50nm particle selectivity.

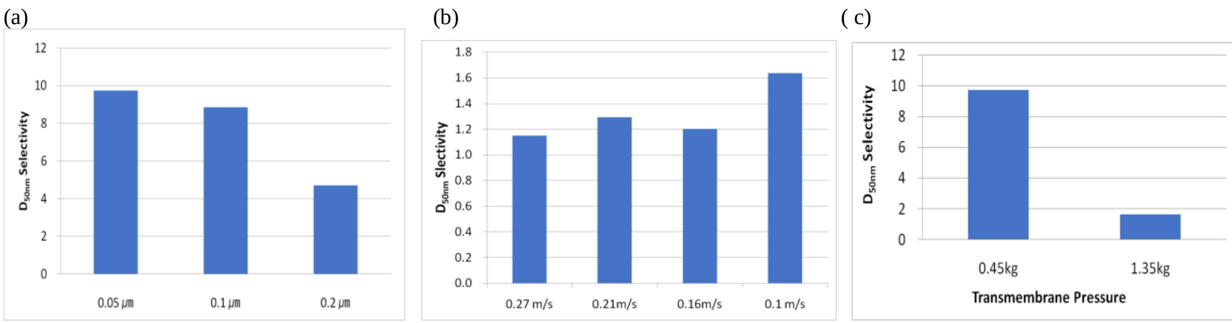

Fig.4 (a) D_{50nm} selectivity comparison by pore size (b)tangential flow velocity and (c)TMP

Figure 4 shows the selectivity comparison result by PES membrane pore size, flow velocity and transmembrane pressure(TMP). D50nm selectivity is calculated as (Sep. % of < 50nm) / (Sep.% of > 50nm) to figure optimal condition to keep the active abrasive particle as well as reduce small particle that is hard to be removed in cleaning process. As a result of the comparison, we could find higher separation condition as 0.05um, 0.1m/s and 0.45kgf respectively. TMP has more influence on selectivity than other operating parameters.

CONCLUSIONS

In conclusion, TFF technology utilized with flat sheet membrane can be one of solution for minimizing small particle that is hard to be removed in post CMP cleaning process. Through application of the TFF system, the total number of ceria particles in the slurry was decreased, however, the concentration and cleaning efficiency of the ceria slurry, which proving that small ceria particles (< 50 nm) can act as a contaminant after the CMP process.

Reference

[1] J. Seo, A. Gowda, S. Babu, Almost complete removal of ceria particles down to 10 nm size from silicon dioxide surfaces, ECS Journal of Solid State Science and Technology 7(5) (2018) P243.

[2] Speed, D., Environmental aspects of planarization processes, in Advances in chemical mechanical planarization (CMP). 2022, Elsevier. p. 257-320.

[3] Corlett, G., Targeting water use for chemical mechanical polishing. Solid State Technology, 2000. 43(6): p. 201-201.

[4] Y. El Rayess, C. Albasi, P. Bacchin, P. Taillandier, J. Raynal, M. Mietton-Peuchot, A. Devatine, Cross-flow microfiltration applied to oenology: A review, Journal of Membrane Science 382(1-2) (2011) 1-19.

Corresponding Author:
Taesung Kim
Tel: +82-31-290-7466
E-mail: tkim@skku.edu
School of Mechanical Engineering, Sungkyunkwan University Suwon, Gyeonggi-do 16419, Korea