Novel CMP filtration technology application for critical size particles remove

Chloe Chen [1], Nate Chang , Volley Wang and Yi Wei Lu
[1] Entegris, Chloe.Chen@entegris.com

Chemical mechanical polishing (CMP) is a vital semiconductor manufacturing process to solve device performance challenges. As novel CMP slurry abrasive size trends to smaller particles, this will further challenge both cleanliness and defectivity. Control of the targeted particle size on the wafer can be accomplished utilizing both sieving and non-sieving particle removal functionality in one advanced particle reduction (APR) filter. In this study, functional CMP filtration has been studied to reduce large particle count (LPC) and small particle count (SPC) to better control slurry quality and reduce on-wafer defects. The experiment separates into two sections. In section one filtration of a functional APR filter is evaluated. In section two the filter is integrated with the polishing process of TEOS wafers as well as the pCMP treatment. This study presents the results of filter A (APR) for LPC and SPC reduction performance. Filtered slurry material remove rate (MRR) shows more consistent polish results. Wafer total defects at >90 nm show >10% reduction. The wafer-to-wafer variation was reduced. The APR filter not only improved total defect counts but also reduce pCMP loading of the ceria abrasive.

Keywords: *DMA, CMP, Small particle reduction, Filter, PP Filter, APR, Hybrid Media, pCMP, Polishing, Ceria, Slurry*

INTRODUCTION

The increasing number of various CMP (Chemical mechanical planarization) processes are applied for advanced nodes. More novel materials and new device architectures demand significantly greater performance from CMP, except for the specifically formulated slurries at different selectivity, rates for better topography, and planarization efficiency control to achieve new planarity requirements for different CMP applications, one of the biggest and most common challenges for IC scaling in CMP process is the scratch reduction. CMP slurry filtration is posed at a much more important role in defectivity reduction than ever.

Efficient filtration methods and greater filtration performance are investigated to well reduce or control the LPCs (large particle counts) in slurries in recent years for both bulk slurry manufacturers and chip manufacturing companies. However, fine particles can be detrimental in leading-edge semiconductor processes. An embedded abrasive could result in open failure defects after film deposition and etching. However, fine particles are more difficult to be removed. Therefore, fine particle identification and removal from CMP slurry systems are critical in advanced nodes, so fine particle removal is the key point in the future.

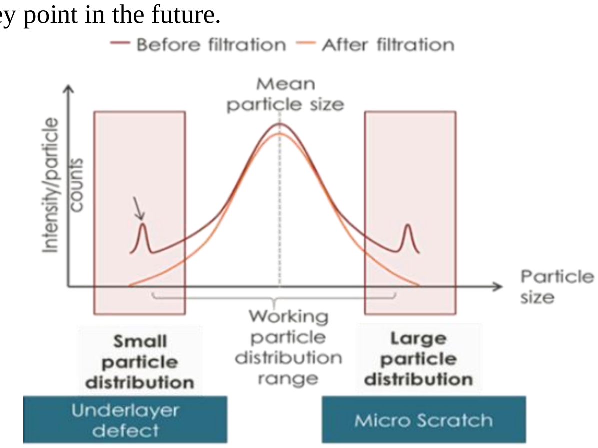

Figure 1. Schematic diagram of particle removal efficiency

Experimental

Ceria slurry preparation:

We prepare commercial Ceria slurry 0.25wt%. Before the testing, we check the PSD, and particle count was measured by DLS, and a DMA equipped with CPC. For the DLS test, the ceria abrasive D50 around 70nm, then the fine particle counts, ranging in size from 10 nm to 25 nm, were monitored by the DMA with CPC (Figure 2).

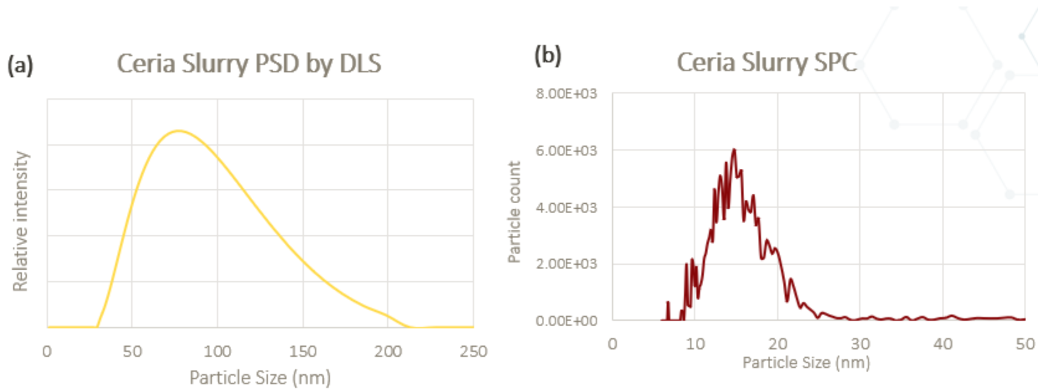

Figure 2. (a) PSD determined by DLS and (b) particles count measurement by DMA-CPC

Large particle counts measurement:

LPC was analyzed by the Entegris Particle Sizing System Accusizer® FX-Nano. Accumulated particle counts at channels > 0.5 µm, > 0.6 µm and > 0.8 µm were monitored.

Polishing setup and wafer defectivity:

Commercial Ceria slurry diluted to 0.25wt% before filtration. POU slurry was filtered by PP Filter/APR (Table 1) with a flow rate of 300 mL/min.

CMP experiments were carried out on a 200 mm Applied Materials MIRRA polisher. The commercial ceria slurry was used in the test. The details of polishing and conditioning parameters are listed in Table 2.

The wafers used in this test were 4000 A PE-TEOS wafers, the removal rate of TEOS were polished for 60 s were measured by ellipsometry (JA Woollam-M2000D). The defect monitor wafers were polished with the wafer's defect level measured with KLA-Tencor Surfscan® SP1. Each wafer was cleaned with PCMP solution after polishing process by OnTrak DSS-200. As to enhance the signals from the test set, the chemistry cleaning process has been tuned less efficient to increase the contributions from slurries to defectivities on wafers. For the investigation of the surface defect attributes, the films were examined using Applied SEM VisionTM G7.

Table 1 Filter composition

Filter	Media
PP	PP
APR	Hybrid media +PP

Table 2 Polishing and conditioning parameters

	Platen (rpm)	Head (rpm)	Head DF (psi)	Slurry flow (mL/min)	Process time (sec)
Ceria P1 process	93	87	2	150	30
Ceria P3 process	90	84	2.6	175	30

	Mode	Down force (lbf)	Disk head (rpm)
P1 conditioning	In-situ	6	111

DMA-CPC measurement:

Samples were diluted to a certain concentration before measurement. Liquid samples are passed through a nebulizer (Figure 3-A), followed by a heater (Figure 3-B). Particles with different sizes were separated by DMA after neutralization (Figure 3-C), and particle was measured by CPC.

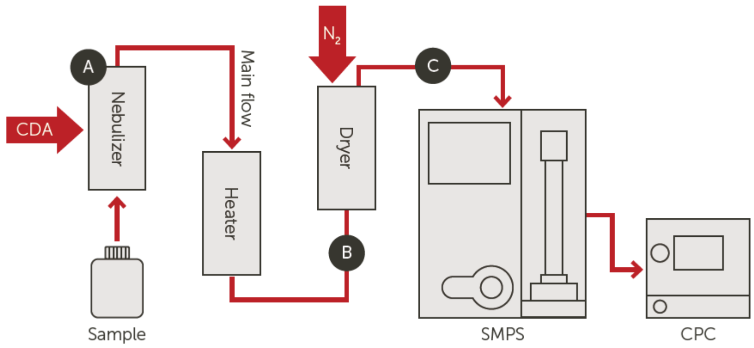

Figure 3. Particles count measurement by DMA-CPC

RESULT AND DISCUSSION

Comparison of filtration efficiency:

To compare the filter performance for different size ranges, large particles were divided into 3 intervals: > 0.5 μm, > 0.6 μm and > 0.8 μm. Fine particles were 6-30 nm. From the LPC retention result (Figure 4) both the PP and APR, the retention results of particles

APR showed better retention than PP, APR keep greater than 80% retention on 3 channels, PP > 0.5 μm retention keep greater than 40% on 3 channels. From the SPC retention result (Figure 5), we find that regular PP showed almost no retention of <30nm fine particles until filtration. For APR filters, APR showed better SPC retention than only PP filter reduce >40%.

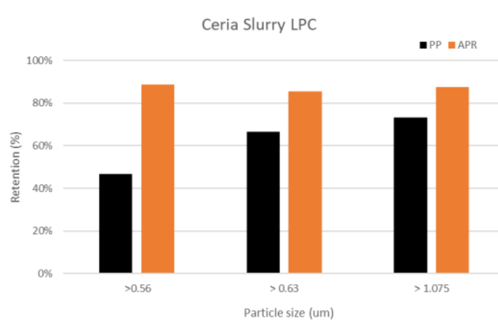

Figure 4. LPC retention

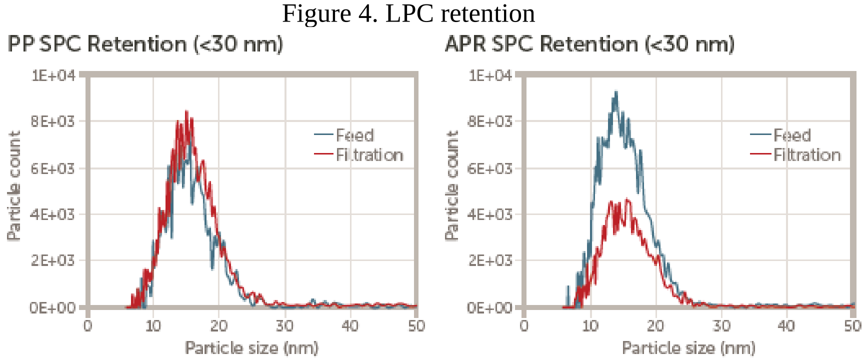

Figure 5. SPC retention (a) PP (b) APR

However, for the LPC/SPC retention result of APR, we find that hybrid media can be effective in the interception of the small particle. For the particle size distribution (PSD) result, we can examine all PSD candidates without significant shift (Figure 6).

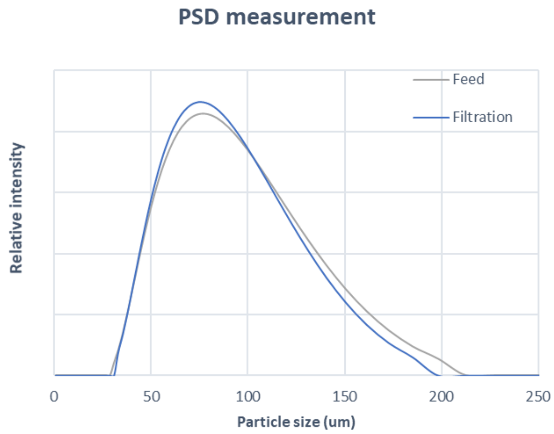

Figure 6 Ceria slurry particle size distribution of APR feed/ filtration

Wafer polishing experiment:

We design some conditions for the wafer polishing test (Table 3). DOE1 is no filter + no pCMP, DOE2 is no filter + pCMP, DOE3 is PP + pCMP, and DOE4 is APR+ pCMP. For the total defect result, we can see the DOE1 showed the 0% performance, DOE2 we can know the pCMP only improve total defect >7%, DOE3 showed the PP filter filtration + pCMP improved >12%, DOE4 APR filter filtration + pCMP shows good performance overall >18%.

We test the multiple wafer data to check the filter effect, we can clearly see have filtration the MRR (Figure 7(a)) is more stable and smaller deviation. Then from the TEOS defect counts @ SP1 >90nm data (Figure 7(b)), DOE3 and DOE4 data, DOE4 show the better and positive stability than DOE3.

Table 3 Experiment DOE

DOE	Filter	pCMP	Mean	Performance
1	X	DIW only	1	0%
2	X	pCMP	0.9316	7%
3	PP	pCMP	0.8805	12%
4	APR	pCMP	0.8159	18%

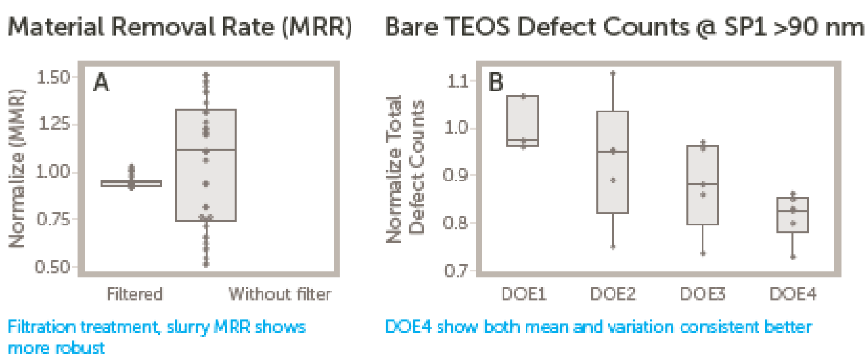

Figure 7. Material remove rate and bare TEOS defect counts @ SP1 >90nm (a) Filtration treatment, slurry MRR shows more robust (b) DOE4 show both mean and variation consistent better

For the total defect counts, we used a KLA-Tencor Surfscan® SP1 to confirm the distribution (Figure 8) of the different DOE polishing wafer defects. We classify the total defect at 0.09 µm~0.1 µm and 0.1 µm~0.2 µm with the total defect count being similar. This is larger than the 0.2 µm defect background noise. We observe (Figure 9) the pareto chart of the defect type summary of the after filtration + pCMP treatment demonstrate both large/small particle are reduced. The use of no filter results in a smaller PA of >40% and the big PA shows >25% (Figure 10-a). For the filtration result, we see the small PA and big PA total defect counts are down to 9%.

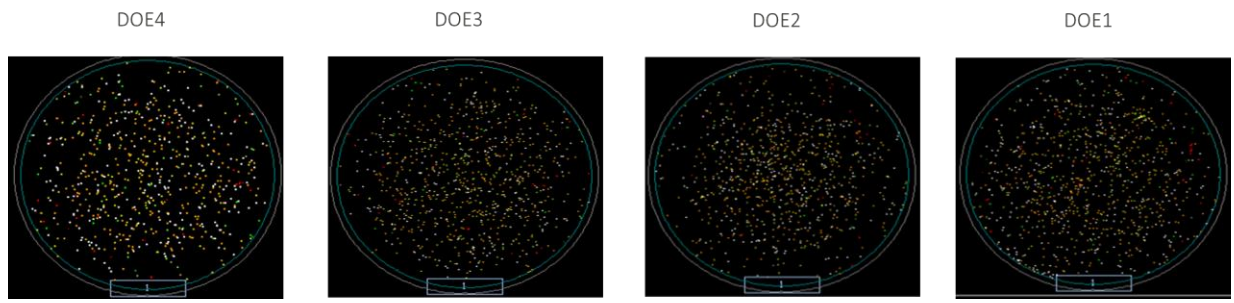

Figure 8. Total defect counts were measured by KLA-Tencor Surfscan® SP1

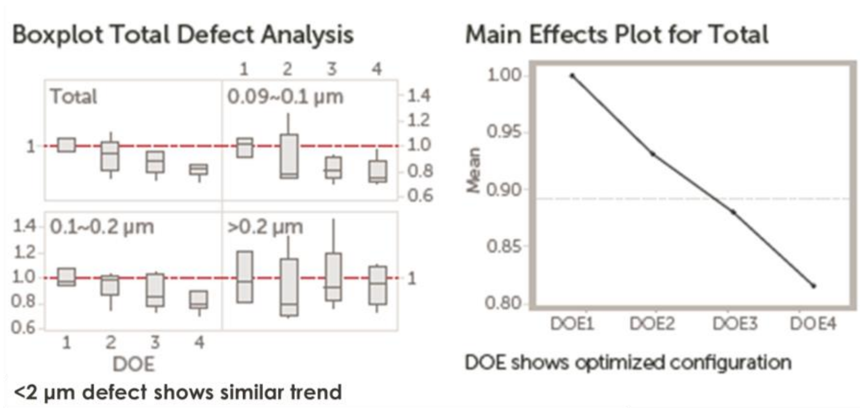

Figure 9. (a) Classify the total defect (b) DOE configuration

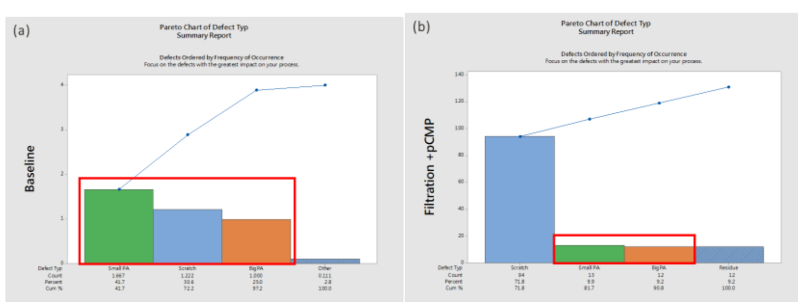

Figure 10. (a) Baseline total defect count distribution (b) Filtration defect count distribution

SEM inspection of used filter media:
For the wafer result, the DOE4 APR filter showed a better result, so From SEM inspection, we found that hybrid media to further understand the retention mechanism, we analyzed the media by SEM to determine the particles type (Figure 11).

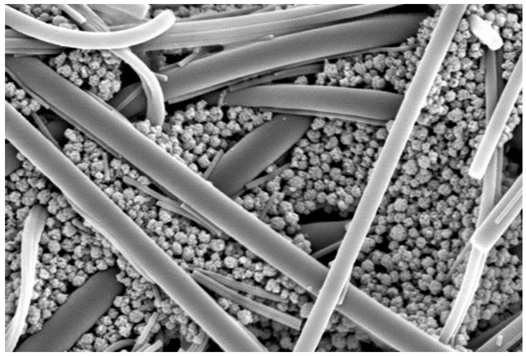

Figure 11. SEM images of hybrid media

From SEM inspection we found that hybrid media showed many particles of various sizes that were captured on fibers. This result confirmed the hypothesis of the particle removal behavior.

From the AMAT G7 defect review (Figure 12), we can see the wafer typical defect classify, have scratch defect, large particle defect, small particle defect, and residue defect. For testing purposes, we want to improve the generation of these defects.

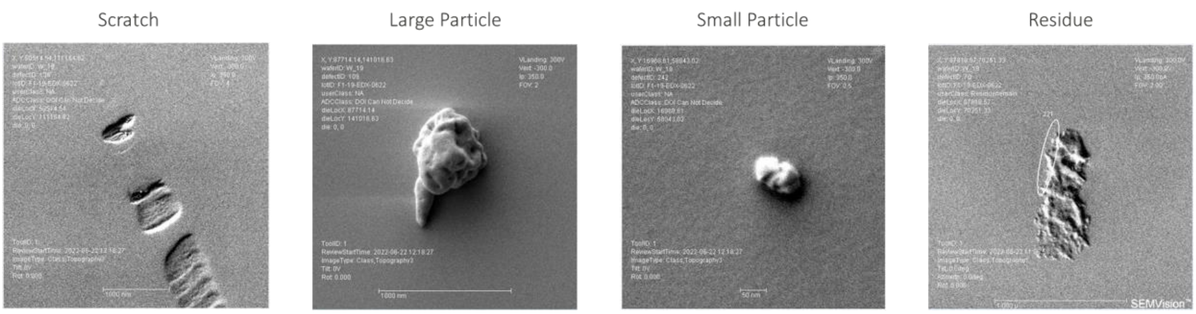

Figure 12. AMAT G7 Defect Review

CONCLUSIONS

In this study, the DOE4 shows the better test result (Figure.13), for the LPC channels >0.56um shows greater than 80% retention. For the SPC test result, 6-30nm shows > 40% retention. In the PSD result, we can see the remained the same without shift. From SEM inspection we found that hybrid media shows consistent fine particle adsorption. Filtered slurry material remove rate (MRR) shows more consistent polish results. Wafer total defects at >90 nm show >10% reduction. The wafer-to-wafer variation was reduced. The APR filter not only improved total defect counts down to 9%, but also reduce pCMP loading of the ceria abrasive.

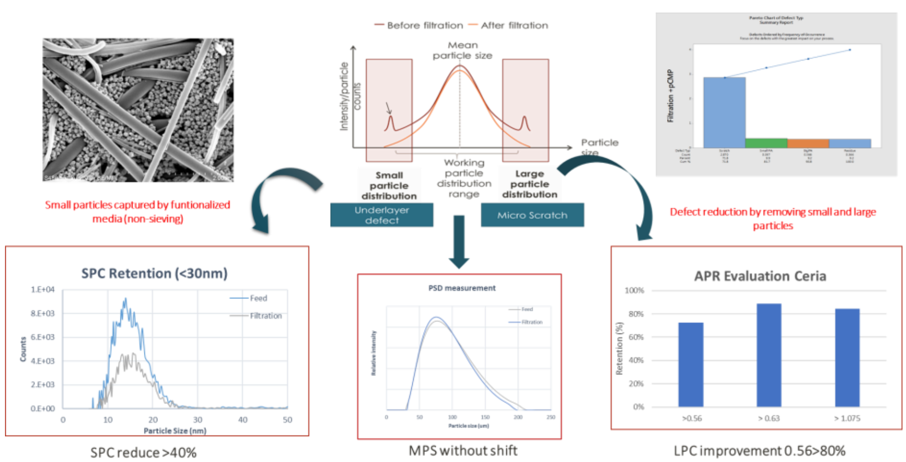

Figure 13. Schematic diagram of the test result

Acknowledgments:
The authors would like to acknowledge the assistance provided by Darren Deng and Eric Lai from Entegris TTC Polish Center, Roger Lou as consultant.

Corresponding Author:
Chloe Chen
Tel: +886 3 688 3939
E-mail: Chloe.Chen@entegris.com
Entegris Ltd., 4F., No. 669, Sec. 4, Zhongxing Road, Chutung Town, Hsinchu County 31061, Taiwan