Utilizing Advanced Pad Conditioning and Pad Motion in WCMP

Sang-Yong Kim*, Hun-Sang Chung**, Min-Woo Park***, Chang-Il Kim****, Eui-Goo Chang****

Abstract

Chemical mechanical polishing(CMP) process has been widely used to planarize dielectrics and metal, which can apply to employed in integrated circuits for sub-micron technology. Despite the increased use of CMP process, it is difficult to accomplish the global planarization of free-defects in inter level dielectrics and metal. Especially, defects like (micro-scratch) lead to severe circuit failure, and affects yield. Current conditioning method - bladder type, orbital pad motion- usually provides unsuitable pad profile during ex-situ conditioning near the end of pad life. Since much of the pad wear occurs by the mechanism of bladder type conditioning and its orbital motion without rotation, we need to implement new ex-situ conditioner which can prevent abnormal regional force on pad caused by bladder-type and also need to rotate the pad during conditioning. Another important study of ADPC is related to the orbital scratch of which source is assumed as diamond grit dropped from the strip during ex-situ conditioning. Scratch from diamond grit damaged wafer severely so usually scraped. Figure 1 shows the typical shape of scratch damaged from diamond. We suspected that intensive forces to the edge area of bladder type stripper accelerated the drop of Diamond grit during conditioning, so new designed Flat stripper was introduced.

Key Words : ADPC, ADPM, Pad Life Time, Orbital Scratch

1. 서 론

To Increase pad life time and reduce orbital scratch during tungsten CMP utilizing ADPC and ADPM.(Advanced Pad Conditioning and Motion) on the Speedfam-IPEC 776 Polisher.[1] ADPM(Advanced Pad Motion) provides the Capability of a 180 degree rotation of the polish Platen in addition to the standard orbital motion utilized by the SFIP 776 polisher. ADPC(Advanced Pad Conditioning) provide an improved conditioning arm with a foam pad supporting the conditioner material instead of an inflatable bladder. The combination of ADPC with ADPM provides an more uniform conditioned surface and reduces the possibility of diamond loss from the stripper.[2] Figure 1 show the structure of ADPC and simple description of ADPM. (a) Bladder type conditioner ;The far edge area of pad (Figure1 #1) can not be conditioned well because of its structural limit. [3]

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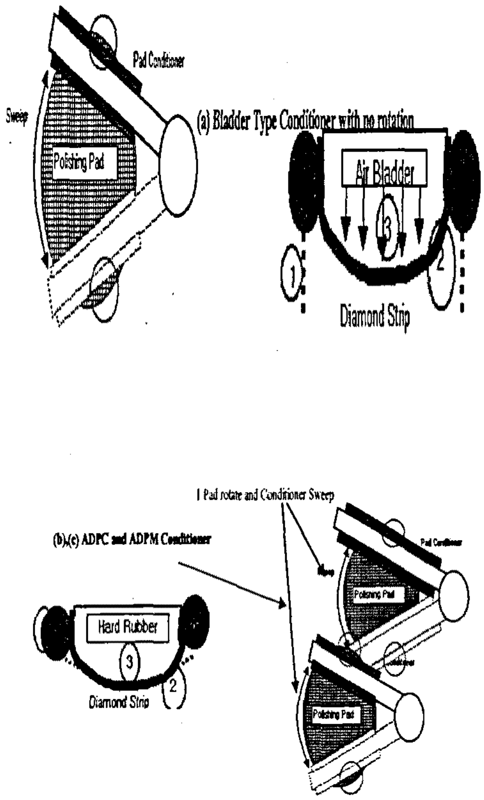


Figure1. Diagram of Pad Conditioner (a) Bladder type, (b) ADPC type,(c) APM Description.

And the Figure1 #2 point is suspected to the main source of diamond loss because of its inflatable contact to the pad.(b),(c) ADPC/ADPM type ; Edge area of stripper has more stable structure because hard rubber(Figure1 #3) prop up the strip sheet(Figure1 #2). No spicular point exist at ADPC structure. Figure1 #1 shows pad rotation and conditioner sweep. Non conditioned area of pad can be prohibited by this combined motion. [4,5]

2. 실 험

The polishing experiment was performed on an SPEEDFAM-IPEC 776 chemical mechanical polisher with optimized process conditions. The SPEEDFAM-IPEC 7700 cleaning system were used for the post CMP cleaning. Also, the polyurethane based polishing pad and silica based slurry were used for the polishing. The oxide thickness was measured before and after W CMP as polishing time using a film thickness measurement tool, NANO M8000. Initial Pad Life was studied based on the conventional concepts of removal rate, non-uniformity and particles. Second pad life study was performed focused on the defect density by pad counts. Defect density by conditioner count also was performed to decide conditioner life. Polish recipe and conditioning parameter is as Table1.

Table.1. Tungsten CMP Polish Recipe (wcmpapc.rcp) and ADPC parameter.

Step	Wafer psi	Delta Press.	Orbit rpm	Wafer Rpm	Pump1 ml/m	Pump2 ml/m	Pump3 Ml/m	DI H2O	Time/sec Sweep	Remark
1	0.25	0	100	100	100	0	0	OFF	7	Pad condition
2	1	0	0	0	0	125	0	OFF	10	Slurry prewet
3	3	0	100	100	0	125	0	OFF	4	Ramp up
4	4	0	200	200	0	125	0	OFF	4	Ramp up
5	5	0	260	260	0	125	0	OFF	Variable(EPD)	Main polish
6	4	0	200	200	100	0	0	OFF	4	Ramp down
7	3	0	150	150	100	0	0	OFF	4	Ramp down
8	1	0	100	100	100	0	0	ONE	4	Ramp down

3. 결과 및 고찰

3.1 Pad Life Study

Conventional pad life of bladder type, orbital polisher is less than 220 wafer counts.

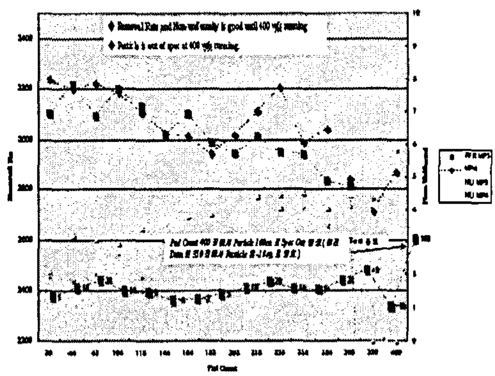


Fig.2. Analysis of removal rate, non-uniformity and particle by wafer count.

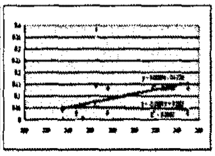
It's mainly because one-directional conditioner sweep and pad motions accelerate the wear of pad. By this reason, our first concern was pad life using ADPC and ADPM. Result is described in Fig.2. Removal rate started at 3200Å/min and continued to decline to 2800Å/min at the 400 wafer count, non-uniformity shows rising trend but maintained less than 5% and particle failed as 108ea(delta count ; (pre-post)) at the 420 wafer count. According to WCMP process spec ; (spec limit of removal rate is 2200Å, Non-uniformity is 8% and particle is less than delta 76) removal rate and non-uniformity gives a satisfying results. Particle also shows good result until 400 counts. As a result, we decided the initial pad life as 400 wafer-count.

3.2 Detailed Pad Life by Defect Density

We performed 9 detailed group test to decide pad life by a viewpoint of defect density. Total defect density and its reviewed counts (# of defects) were considered simultaneously. Fig.3 shows the result of each group test.

1.GROUP (a)

PAD COUNT	DEFECT DENSITY				
	#5	#10	#16	#19	#21
235	0.041	0.041	0.015	0.144	0.01
247	0.03	0.049	0.005	0.005	0.02
253	0.005	0.005	0.036	0.03	0.01
265	0.14	0.065	0.349	0.04	0.38
276	0.132	0.023	0.057	0.057	0.034
330	0.132	0.023	0.057	0.057	0.034



2.GROUP (b)

PAD COUNT	DEFECT DENSITY				
	#5	#10	#16	#19	#21
31	0.009	0.023	0.014	0.018	0.014
134	0.06	0.086	0.073	0.36	0.007
291	0.017	0.004	0	0.004	0.004

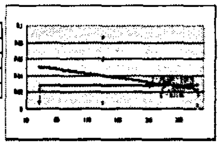


Fig.3-1.Test result of group (a) and group (b).

Group (a) shows that DD (defect density) is slightly rising by wafer count. Correlation coefficient , R2 = 0.3999, is very low. It means that there exists no relationship between defect density and wafer count or is in very weak related condition within 360 wafer count. Group (b) shows similar result. R2=0.118. (Pad life of group (a) is 360, (b) is 300.) Group (c) shows upward trend, R2=0.5736. It seems like that there is somehow linear relationship between wafer count and defect density. To clarify this, we reviewed wafer #19, of which defect density is 1.642, and cannot find out any specific defect like scratch, particle,etc. Reviewed results showed us that all its defects are nuisance and under layer related one. So, we could concluded that also didn't have any linear relationship between defect density and wafer count within 341 pad life.

3.GROUP (c)

PAD COUNT	DEFECT DENSITY				
	#5	#10	#16	#19	#21
90	0.025	0.005	0	0.03	0
98	0.01	0	0.069	0	0.01
159	0.076	0.061	0.193	0.132	0.122
171	0.242	0.445	1.261	1.642	2.31

4.GROUP (d)

PAD COUNT	DEFECT DENSITY				
	#5	#10	#16	#19	#21
37	0.03	0.147	0.107	0.041	0.01
46	0.025	0	0.01	0.01	0.01
83	0	0.005	0	0	0
149	0.005	0	0.01	0	0.05
291	0.178	0.04	0.045	0.549	0.069
341	0.178	0.04	0.045	0.549	0.069

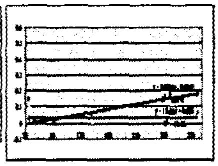
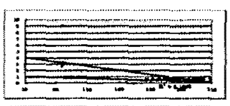


Fig.3-2.Test result of group (c) and group (d).

Group (E) through (H) showed inverse linear relationship. Correlation coefficient, R2 is 0.23, 0.18, 1, 0.99. All groups have low correlation coefficient except group (G). It's because of 1182120,wf#5,10 of which defects are proved as all nuisances. If we exclude this point, coefficient is near to 0. In detailed pad life test, section 3.2, we performed total 9 different sub group test to define the relationship between wafer count and its defect density. As a result, we could come to a conclusion that within 400 wafer count, there exist no uprising or downward trend between wafer count and D.D.

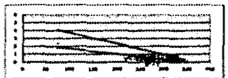
[illegible]

PAD COUNT	DEFECT DENSITY				
	#5	#10	#16	#19	#21
33	0.02	0.03	0.01	0.02	0.02
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0.037	0.053	0.018	[illegible]	[illegible]
	0.104	[illegible]	[illegible]	0.073	[illegible]
	0.014	0.123	0.014	0.189	[illegible]
172	0.035	0.043			
182	[illegible]	0.003	[illegible]	[illegible]	[illegible]
	[illegible]	0.149	[illegible]	[illegible]	[illegible]
[illegible]					
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]



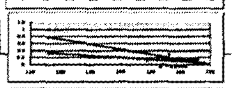
[illegible]

PAD COUNT	DEFECT DENSITY				
	#5	#10	#16	#19	#21
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]



[illegible]

PAD COUNT	DEFECT DENSITY				
	#5	#10	#16	#19	#21
[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]
[illegible]	[illegible]	[illegible]			[illegible]
[illegible]	0	0			0



[illegible]

PAD COUNT	DEFECT DENSITY				
	#5	#10	#16	#19	#21
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	0.014	[illegible]			[illegible]

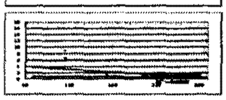


Fig.3-3.Test result of group (E),(F),(G),(H).

3.3 Conditioner Life by Defect Density

One of the most important works of this project is to reduce the scratch from diamond drop. It is quite difficult to set the conditioner life because, in many cases, scratch from diamond didn't have any trend by the consumable life related. In addition, it didn't have any continuity; that is, for example, even though we continue to process without any corrective actions when scratch happened, scratch will not be shown up again. Property of ex-situ conditioning and non-continuity of diamond drop will be explained of this phenomenon. By above reason, randomized number of scratch cases is important than continuous trends. Fig.4 is the summarized result to set the conditioner life.It seems that DD trend is going upward as conditioner count increase. To clarify this relation, we analyzed each defect and specified it. Defect at the count 3500 proved as nuisance, from 4000 to 5000 is also proved all nuisance, 6000 is mainly under-layer defect. We found particles at the count 6200 and 7100 but both of this is proved as cleaner trouble, not polisher. We cannot find out any diamond scratches from above test, but defect density and defect cases are going upward together. So, we set the initial conditioner life as 6000 and performed detailed test to get a more reliable result.

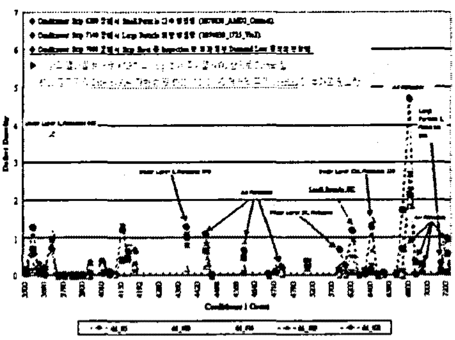


Fig.4.DD trend and number of defect cases using ADPC/ADPM.

3.4 Detailed conditioner life by Defect Density

Even though continuous DD trend cannot give us specified defect category, it is meaningful to analyze correlation effect of defect density by conditioner count combined with pad count together. It could be comprehensive result including all factors causing potential scratch.

Fig.5 shows the correlation effect when combined pad with conditioner. Lower parts of figure 5 describe the defect density by pad count. We could know that pad change have been done total 10 times during above period. So, We can divide above chart into 10 sub groups by convenient. If we analyze the effect of pad count to the defect density of each group, we could get easy conclusion that there exists no pad effect to the defect density. We already performed this test in section 3.2, from fig (a) to (h). But, just notify upper part of figure 5. It describes that defect density slightly go up as conditioner count increase. If we combine above two figures together, new alternative effect can be derived. ; There exist no correlation effect between DD and pad count, but average DD of each pad group is slightly dependent on conditioner count. If conditioner is in its initial state, DD is very low all over the pad life. If conditioner count is in more than 4000, DD will go up rapidly even pad count is in its initial state.

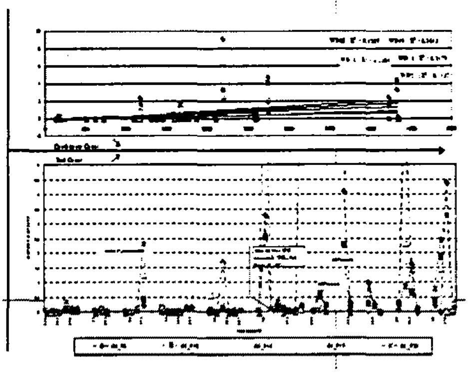


Fig.5. Describe defect density by pad count and conditioner count.

4. 결 론

After taking everything into consideration, we reached following conclusion.

The pad life study utilizing ADPC/ADPM during the conditioning process with baseline process and consumable set was successfully completed in experiment. Total 400 wafers processed on this experiment and all process capabilities were checked like R/R, NU, PC. After reviewing all relevant parameters, we could set a initial pad life as 400. Detailed pad life study was done to analyze pad count effect by defect density within 400 wafers- count.

Total 9 sub-group test were performed and we could get a conclusion that within 400 wafer count, there exist no correlation effect between pad count and defect density. Conditioner life and detailed conditioner life test were performed. Total 8000 patterned wafers were monitored and each correlation effect of pad, conditioner by defect density was analyzed. Particles were happened in 6200, so initial conditioner life was set as 6000. In detailed report, we could know that conditioner life could cause pad life with respect to defect density. A lot of various factors could be derived from Describe defect density by pad count and conditioner count. So it was quite ambiguous to set a, so-called, defect free conditioner and pad life together. After considering process margin, we decided to set a pad life as 350, conditioner life as 4000. Further study for the pad life between 350 and 400, conditioner life between 4000 and 6000 need to be continued in near future

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