Trimming Clean using SAPS Megasonic Technology on Xtacking 3D NAND

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Introduction. Xtacking 3D NAND process normally combines two wafers together. Firstly, one of the wafers needs to be trimmed and cleaned before bonding (as shown in Fig.1). The trimming process cuts the wafer directly by mechanical forces in the region of 1-2 mm width from the and 0.1-0.2 mm depth. During the trimming process, many particles will be generated. These particles are mainly distributed on the wafer surface and the wafers edge trench area. Particles are flat and range in size from 0.5 um to 10 um (as shown in Fig.2). These particles can result in a large number of bubbles being formed on the interface during the bonding process, that can seriously impact yield. Therefore, it is very important to choose an efficient cleaning method to remove these particles especially in the trench area.

At present, the industry uses conventional chemicals such as HF, SC1 (NH_4OH:H_2O_2:H_2O), SC2 (HCl:H_2O_2:H_2O) on single cleaning tools to remove these kind of particles. The conventional chemical uses a 2 fluid nozzle spray which can act on the wafer surface, removing the surface particles using both mechanical force and chemical reaction. However, the particles produced during the trimming process have strong adhesion to the wafer surface, requiring a longer process time to remove these particles. The conventional method is unable to remove particles in the trench area due to the limited mechanical forces and chemical saturation inside the trench area and at the interface. Researchers have been active in discovering more efficiently cleaning methods for removing the particles[1].

In recent years, the functional water (FW) incorporation with space alternating phase shift (SAPS) megasonic technology is widely applied for particle removal. The SAPS megasonic technology uses the high frequency (0.8~1.0MHz) alternating current to excite a piezoelectric resonator crystal to produce the megasonic wave, which makes a thin acoustic boundary layer near the wafer surface and forms pressure vibration and high energy of ultra-high frequency in the chemical[2].

In this paper, we combine the FW dissolving H_2 with SAPS megasonic technology to remove the particles created during the Xtacking 3D NAND trimming process and compared the particle removal ability with the conventional chemical cleaning mode.

Experimental. Tests were carried out on an ACM Research Ultra-C SAPS V single

In this test, FW containing 1.2 ppm H_2 and 39 ppm NH_4OH was compared to the conventional chemical cleaning method of 1:100 dilute HF, 30 ppm O3, SC1 (NH_4OH:H_2O_2:H_2O) 1:2:50 and SC2 (HCl:H_2O_2:H_2O)1:1:50. All tests are at room temperature.

Table.1 shows six (Mode 1 - Mode 6) different test conditions, and cleaned 10 trimmed wafers with each condition. All processed wafer post particle count (@40nm) can be measured on a KLA-Tencor Surfscan SP5. The surface morphology was obtained using the AMAT SEM.

Results. The post particle count after cleaning by the six different modes exhibited in Fig.4. The three modes of FW combination with megasonic with different power (Mode 1 (30W), Mode 2 (45W) and Mode 3 (60W)) show better particle removal ability than conventional chemical methods (Mode 4 (HF+O3), Mode 5 (HF+O3+SC1) and Mode 6 (HF+SC1+SC2)). Mode 2 (45W) shows the most efficient particle removal capability.

As shown in Fig.5, SEM images show trench particle removal efficiency (a) Mode 2 (best in FW Mega test group) and (b) Mode 6 (best in conventional chemical clean test group) . The trench area cleaned by Mode 2 shows almost no particle residue. However, as exhibited in Fig.5(b), the trench area cleaned by Mode 6 still shows particle residue.

During the particle removal < 100um) fluid boundary layer will be formed in the particle surface, because of the friction resistance between the particles surface and chemical layer. The existence of the fluid boundary layer, a barrier between the particle surface and fresh chemical liquid will hinder the wafer surface particle removal. Conventional spin clean mode is unable to weaken the fluid boundary layer. However, the thickness of the boundary layer can be reduced to less than 0.6 um when used with 0.8 MHz megasonic cleaning mode. At this time, the chemical liquid can directly act on the particles surface due the magasonic wave effect. Meanwhile, many tiny bubbles will be formed in the chemical solution because of the existence of H_2 dissolving in DIW, these bubbles can continuously take away the particles due to the effect of megasonic. Finally, according to Zeta potential theory, 39 ppm NH_4OH can provide p alkaline environment and ensure the particles and wafer surface takes a negative charge at the same time, which prevents particles re-adhering to wafer surface (As shown in Fig.6)[d].

For the wafer edge trench particle, which is very close to the wafer edge, only 1-2 mm, the conventional clean nozzle does not reach this area as this would cause splashing and impact the particle removal ability. The conventional cleaning using chemical dispense from the nozzle also has no physical impact for this trench area. The megasonic method is a more efficient way to cover the wafer trench area and therefore removes the particles and defects in this area by combination with the H_2 bubble and alkaline environment.

The use of FW with megasonic also decreases significantly the chemical usage which lowers the cost for this process as well as being beneficial for the enviroment.

Conclusion. In this paper, we compared the wafer surface and trench area particle removal capability of the Xtacking 3D NAND process, between the conventional HF/SC1/SC2 chemical and FW megasonic clean methods. The test results prove that the FW megasonic clean mode shows increased sm0 g0 0 0.086 Tc[(OH)] TJETQ EMC /Span <</MCID 45/Lang (de-DE)>>BDC q0.000ph642 (

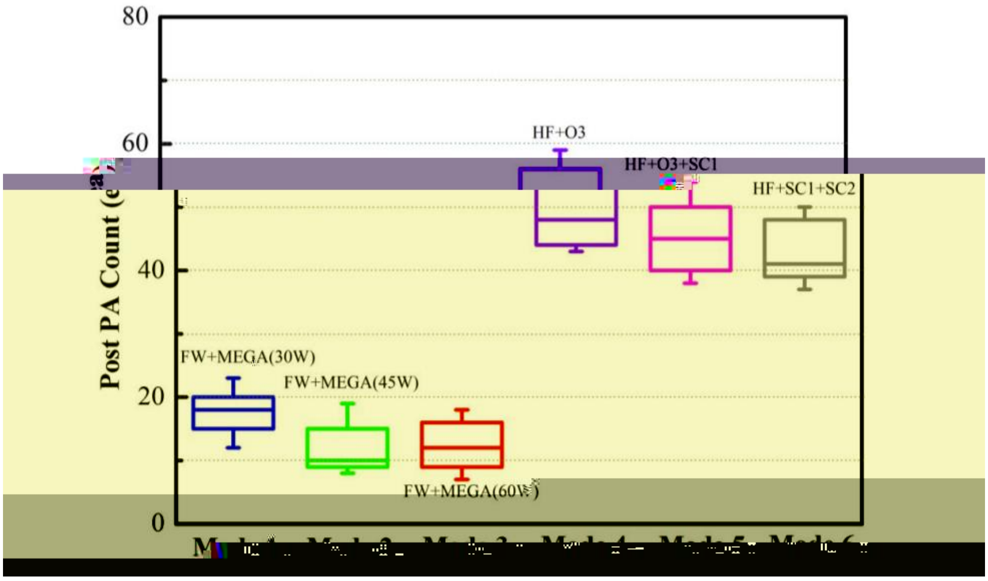

Fig. 4: Comparison of six clean mode (Mode1-Mode 6) to surface PA remove ability

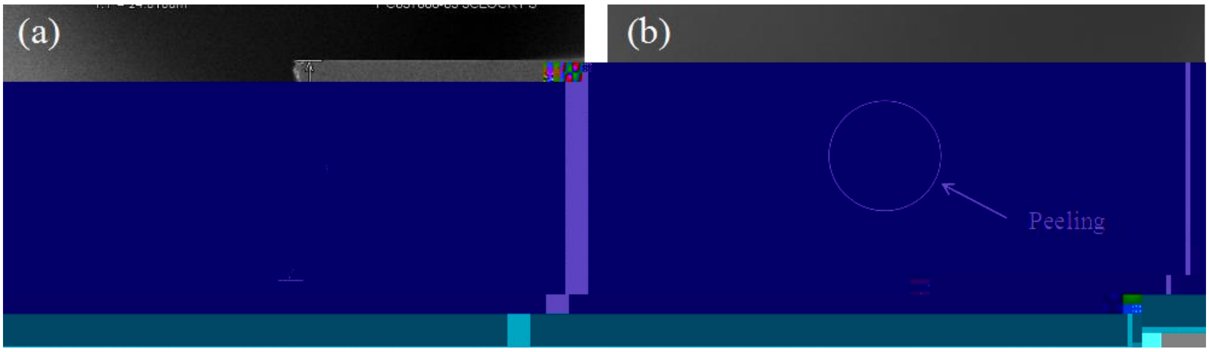

Fig.5: SEM image of wafer edge with (a) Mode 2 (FW Mega-45W); (b) Mode 6 (HF+SC1+SC2)

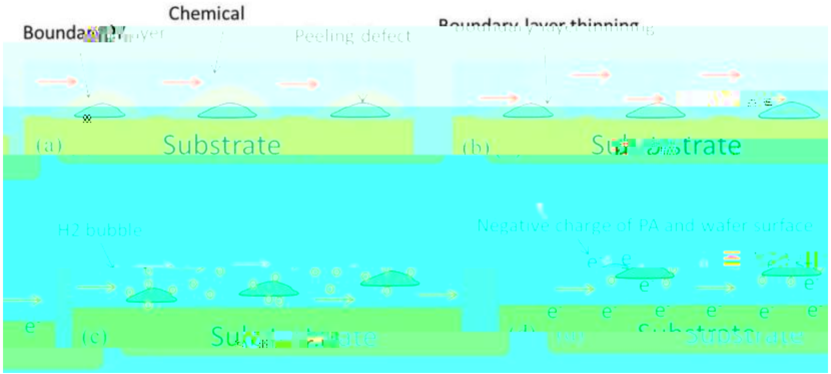

Figure 6: Schematic diagram of the FW megasonic clean mechanism: (a) PA wrapped within boundary layer ; (b) Boundary layer thinning with megasonic and chemical react to PA directly; (c) H_2 bubble remove PA; (d) Alkaline chemical (PH 10) prevent PA adhere back

Clean Mode	Mode 1	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6
Chemical	FW Mega-30W	FW Mega-45W	FW Mega-60W	HF+O3	HF+O3+SC1	HF+SC1+SC2

Table 1: Comparison of six different clean technology applications

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