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Particle removal, Functional water, SAPS megasonic technology

Introduction

Space alternated phase shift (SAPS) megasonic technology incorporating with functional water, with dissolving gases H_2 or N_2, was applied to remove fine particle in wet cleaning processes of semiconductor manufacturing in this study. The vha ... megasonic ... cleaning performance was further proved with significant yield improvement ... comparison with other main cleaning technology.

In semiconductor manufacturing, in order to removal impurities such as s... chemicals, and contaminations in trench and via, a wet cleaning step is nece... device manufacture node migrating to very integrated devices, it is important ... or de-ionized water only to reduce or eliminate the material loss. However ... de-ionized water usually is not efficient to remove fine particle from the surf...

Functional water was used for wet cleaning process in semiconductor manuf... cleaning due to its advantage of reduction in cost and environment pollution ... to those solutions dissolving specific gases, such as the hydrogen, oxygen, ... water containing a small amount of chemicals such as ammonia [1]. The radic... are generated in those solutions, and the radical generation is promoted by ... megasonic irradiation [2]. Furthermore, the mechanical force of bubble c... megasonic also improves the particle removal capability during the cleaning ... functional water can be used in cleaning process for metal film, such as t... material loss resulted from the addition of H_2O_2 in traditional SC1 solution.

In this paper, the method of space alternated phase shift (SAPS) megasonic technology incorporating with functional water is applied for fine particle cleaning, with dissolving gas H_2 or N_2, are under investigation. The influence of the process parameters, including dissolving gas concentration, dilute chemical concentration and megasonic energy, was studied and optimized. The results show that this technology has a high efficiency in fine particle removal, especially particle diameter less than 65nm, while with the minimal damage to the structures.

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Key Process Parameters Influence on Particle Removal Capability

The influence of the key process parameters on the Particle Removal Capability is important. The main parameters of the cleaning process are concentrations of functional water's dissolving gases, dilute chemicals and megasonic energy. A series of DOE tests (design of experiment) are done to analyze the parameters and further to optimize them.

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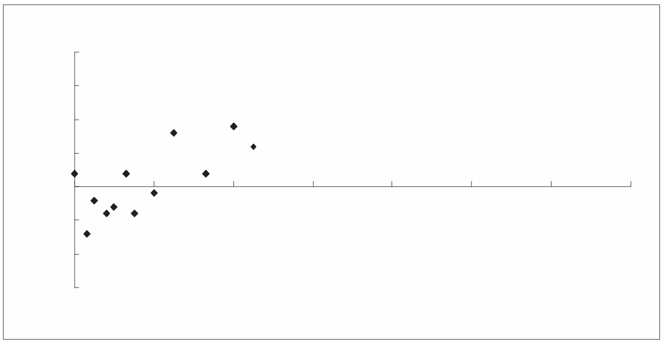
Table Ⅰ shows the parameters used in the DOE for a specific application of SAPS technology and function water. Here, the function water contains dissolving N_2 gas and very dilute NH_4OH. The megasonic intensity increases from P_1 to P_2, standing for the nominal power of megasonic, and $P_1<P_2$. The DOE is based on the cleaning process on the bare wafer with particle number less than 30. The particle size under the inspection is in the range of above 44nm.

Table I: Parameters Used in DOE

Parameters	Range
Dissolving N_2 concentration	3-14 ppm
Dilute NH_4	

assistant removal when megasonic power increasing from 0 to P_a; megasonic domination and chemical & gas assistant removal when megasonic power increasing from P_a to P_b; megasonic domination removal when megasonic power above P_b. Here the P_a, P_b are nominal power of megasonic, and $0<P_a<P_b<P$. The middle period with the megasonic power from Pa to P_b shows a good cleaning performance. This window is wide enough to be feasibly controlled and adjusted during the production.



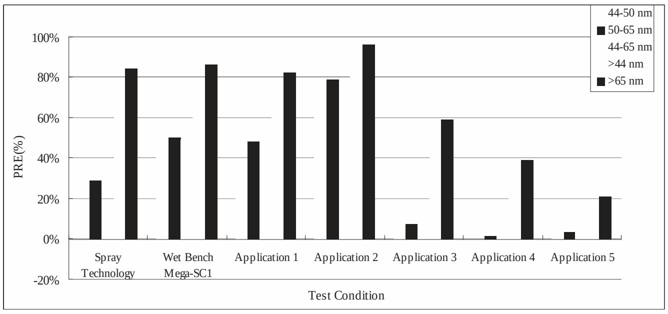


Figure 3a: Comparison of Particle Removal Efficiency between SAPS Technology Incorporating with Functional Water and Other Main Cleaning Technologies

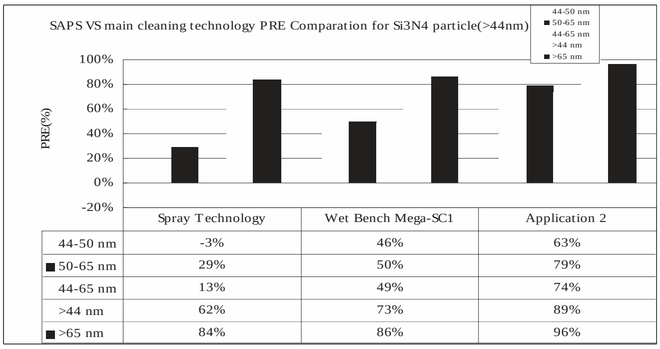


Figure 3b: Comparison of Particle Removal Efficiency between SAPS Technology Incorporating with Functional Water and Other Main Cleaning Technologies

Yield data Validation

To validate the SAPS technology with functional water in the production, the split tests are done to compare it with the base cleaning methods in different steps, such as pre mask, pre metal deposition, post CMP, post nitrite deposition, post TEOS deposition etc.. The yield data are obtained based on a certain number of production lots for the statistical accuracy.

Table Ⅲ shows the yield improvement in the split lots using SAPS megasonic technology incorporating with functional water instead of the corresponding base process for the specific steps. The results indicate the obvious yield improvements in the split lots with SAPS technology and functional water application.

Table III: Yield Improvement When Using SAPS Technology and Functional Water

Step	Base Cleaning Technology	Yield Improvement of Functional Water + SAPS Megasonic
A	Spray Technology 1	0.7%
B	No Cleaning	1.3%
C	Spray Technology 2	0.3%
D	Spray Technology 3	0.6%
E	Spray Technology 4	1.2%
F	Wet bench 1	0.5%
G	Wet bench 2	1.3%
H	Wet bench 3	1.0%

Figure 4 shows the defect inspection map of the wafer samples for a specific cleaning step post CMP. It illustrates that the split group using SAPS technology and functional water achieves higher particle removal efficiency, above 15% enhancement, than the base group using normal spray process.

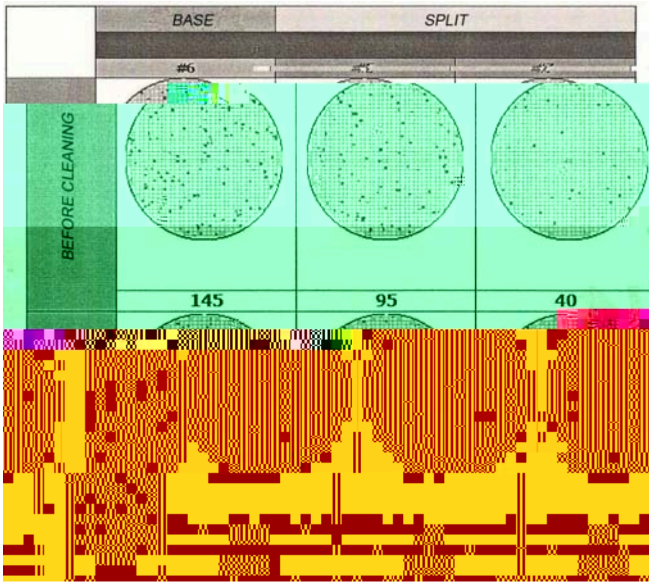


Figure 4: Inspection Map

Figure 5 shows the defect review image of the wafer samples in

The window of megasonic power is wide. The etch rate of the process, less than 0.4 ¡/min, meets the target of dilute chemical for TOX. The etch rate is less than 5 ¡/min for CVD tungsten wafer, which is very slight comparing to traditional SC1 solution.

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