Stripping Process Development using SAPS Megasonic Technology

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***Abstract*-Integrated circuit(IC) design, IC manufacturing and IC packaging constitute the three pillars of IC industry. With the development of chip integration and high-density circuit packages, more photolithographic technology step were used in IC industry. As we all know, the purpose of photoresist stripping is to remove photoresist (PR) residues, particles and metal which come from the pattern structures. The photoresist (PR) stripping process is an important factor after photolithography technology which plays a key role in the yield of products. Residual photoresist can cause device layer failure or even damage the device layer.**

Conventional wet PR stripping, soaking and single chamber stripping is widely used for removal photoresist in advanced packaging. Wet PR stripping uses a specific chemical to dissolve the PR layer. During PR removal process, it will need 20~30min bench soaking method and 5~10min single chemical rinse to accomplish PR strip step which may lead to a low throughput.

In this work, the method of "space alternated phase shift (SAPS)" mega sonic was applied for the assistance of PR stripping. The mega sonic power could pass through the deep hole of patterns or other complicated patterns with sustained energy, facilitating the removal of photoresist completely. Moreover, the optical microscope was carried out to examine the results of PR removal effects in different pattern wafers and AOI was used to evaluate first pass yield (FPY). Mega sonic energy with different powers and different applied reaction time was rigorously investigated the removal effects of photoresist.

Keywords-Advanced packaging, Photo-resist, Wet stripping, Megasonic, Solvents

I. INTRODUCTION

Conventional wet PR stripping, soaking and single chamber stripping are the common strategies for removing photoresist in advanced packaging. However, the soaking and single chamber stripping strategies are greatly restricted by their time-consuming process. It has been accepted that mega sonic energy is conducive to remove particles from semiconductor devices during the cleaning process [1], [2]. Unfortunately, photoresist stripping technology with the assistance of mega sonic energy is not widely used to remove impurities of semiconductor. It should be buried in mind that the unsuitable applied mega sonic energy may cause great damage to sensitive semiconductor devices. [3] Hence, it's wisdom to regulate appropriate mega sonic power before extensive practical application.

The fundamental principles of mega sonic are based on high frequency (0.8~3.0 MHz) AC to excite piezoelectric resonator crystal, producing mega sound wave originated from vibration. Therefore, the thin acoustic boundary layers are formed near the surface of the wafer. A tremendous sound pressure gradient, particle velocity and acoustic streaming effect stemmed from ultra-high frequency and high-energy vibration produced in solution, are conducive to the cleaning and stripping process.

While the amplitude of the alternating sound pressure is lower than the liquid saturation vapor pressure at the current temperature, negative pressure will appear, and the gas dissolved in the liquid is precipitated present with the form of gas core. Under the negative pressure, the gas core grows rapidly with the size up to dozens of microns in the acoustic expansion phase with diameters ranging from several microns to dozens of microns, and the cavitation bubbles produce eventually. In the following compression phase, the cavitation bubble diameter decreases sharply under the effect of positive pressure. This leads to producing nonlinear oscillation (steady-state) cavitation, together with the sound pressure reaches a certain threshold (cavitation threshold) quickly. The cavitation bubbles collapse and burst instantaneously. The energy produced during this process is large enough to overcome the adhesion force between particles/PR and the wafer surface.

It is mainly used to clean the wafers with liquid film on the surface of the low-speed rotating wafers with a fan mega sonic generator (MegPie). Wafer rotation speed, liquid film thickness, and MegPie position and energy are key process parameters. Space Alternative Phase Shift (SAPS) mega acoustic wave technology is based on controlling the distance between the mega generator and the wafer to achieve cleaning and stripping function. The acoustic intensity at the same portion changes with the position of the substrate. When increasing the total half wavelength of sonic wave of the gap, the acoustic intensity varies in a full cycle. Each portion on the wafer receives full cycle of intensity due to the substrate moves a full distance. Therefore, the same amount of acoustic intensity (including the same average intensity, the same maximum intensity, and the same minimum intensity) can be achieved on each location of substrate. This plays an important role in the uniformity of the whole cleaning and stripping process. Vicelike, the mega sonic energy is evenly distributed on the wafer surface to avoid the damage of wafer pattern. The maximum working frequency of SAPS mega sonic can reach 3MHz and the maximum power can reach $3W/cm^2$.

Compared with conventional bench soaking and single rinse, mega sonic stripping reveals unique advantages for some complicated structure, such as TSV pattern. The active ingredients of chemical liquid are difficult to reach the bottom of TSV simply through the diffusion of the liquid with the general stripping method. Whereas the cavitation effect of SAPS is easily to make the liquid reach the bottom of TSV and evenly distribute throughout the deep hole structure with its oscillating stirring effect, which could effectively remove PR in the deep hole. Space Alternative Phase Shift (SAPS) mega acoustic wave technology can be applied for the stripping process of other complicated structures like PR after dry etch.

II. EXPERIMENTAL

In this study, space alternated phase shift (SAPS) mega sonic technology was used as an auxiliary strategy for the PR stripping. Space alternated phase shift (SAPS) mega sonic waves enhance the wettability of chemicals, resulting in a fast chemical migration in the corner of patterns or other complicated patterns with sustained and uniform energy during the process. (Fig. 1). Compared to conventional bench soak or single rinse methods, SAPS megasonic technology presents great photoresist removal efficiency. Besides, SPAS megasonic technology exhibits lower material etch rate, resulting in less damage to structures (1), (2) in Fig. 1.

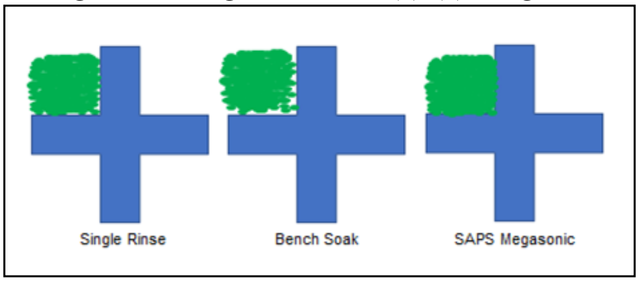


Fig.1. The chemical wettability for corner of pattern by single rinse, bench soak and SAPS megasonic.

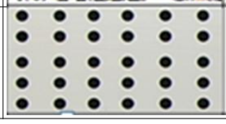
In this work, we have explored the influence of PR removal efficiency for megasonic and the removal efficiency of PR under different megasonic power. According to the experiment results of PR removal efficiency and first pass yield (FPY), chemicals with megasonic disclose superior performance for PR removal and good wettability to propagate to the corner of pattern. The 50pcs PR thickness 80um normal structural wafers were used for evaluating photoresist removal performance for experiment I, while the 50pcs PR thicknesses 12um complicated structural wafers were also used for evaluating photoresist removal performance for experiment II. The 50pcs PR thickness 2um normal structural wafers were applied for evaluating influence with different megasonic power for experiment III. In experiment I, normal structural wafers was split into two equitable groups: One group wafers are cleaned with conventional single-wafer rinse cleaning, and the other group wafers are cleaned with SAPS megasonic. In experiment II, complicated structural wafers were split into two equitable groups: One group wafers are cleaned by conventional single-wafer rinse cleaning, and the other group wafers are cleaned by SAPS megasonic. In experiment III, normal structural wafers are split into two equitable groups: One group wafers are cleaned with megasonic by power 15W, and the other group wafers are cleaned with megasonic by power 30W. In this work, OM inspection is executed to detect the presence of photoresist residue, while AOI is implemented to evaluate first pass yield (FPY).

III. RESULTS

In experiment I, OM inspection results confirm that no PR residues present on all wafers. The wafers cleaned with megasonic reveal the best first pass yield and fewer particles on the wafers. In experiment II, the wafers cleaned with conventional single-wafer rinse method emerge obvious PR, whereas the wafers worked with megasonic method present no PR on the wafers at the same experimental conditions. And AOI exploration further verifies that wafer cleaned by megasonic method exhibit excellent yield. In experiment III, higher megasonic power is conducive to improve the efficiency of PR removal.

Throughput is an important indicator for fab. Experiment I demonstrates that both conventional single rinse and megasonic rinse can remove the PR completely. However, it takes only 186s (Fig.2 a) to remove all PR via megasonic method, and it takes almost twice the time of 350s (Fig.2 b) to remove all PR. According to AOI exploration, megasonic method discloses better first pass yield (FPY) compared to single rinse recipe method (Fig. 3). Benefiting from the megasonic high efficiency of removing particles, fewer impurities present on the sample surface.

a)

Chemical time	Picture	Remark
Megasonic: 62s		PR not removed
Continue to megasonic 62s, total 124s		PR not removed
Continue to megasonic 62s, total 186s		PR removed at all

b)

Chemical time	Picture	Remark
Normal rinse: 150s		PR not removed
Continue to rinse 150s, total 300s		PR not removed
Continue to rinse 50s, total 350s		PR removed at all

Fig.2 PR residue and chemical rinse time for normal structural wafer: a): clean with megasonic, b): clean with conventional rinse.

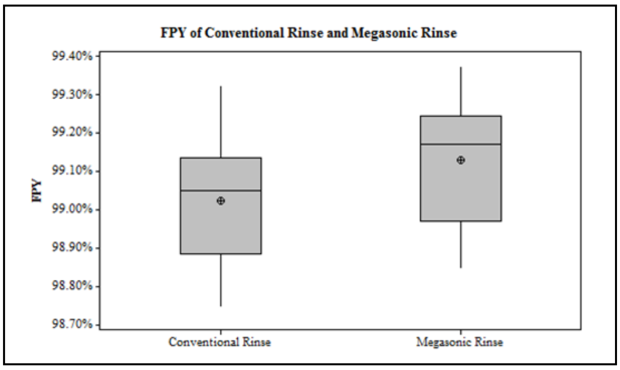


Fig.3 First pass yield of conventional rinse and mega sonic rinse.

In experiment II, the wafers reveal obvious PR on the corner of the patter after 240s processing time, indicating that the PR cannot be removed through conventional single rinse. However, it takes only 62s to remove PR completely via megasonic method (Fig.4), and megasonic method exhibits excellent yield.

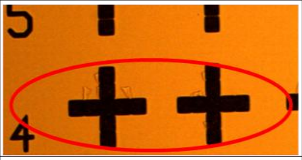
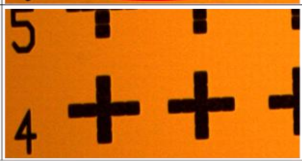
Chemical time	Picture	Remark
Normal rinse: 240s		corner of pattern PR residue
Megasonic rinse: 62s		PR removed at all

Fig.4 Normal rinse and megasonic rinse comparison for complicated structural wafers.

In experiment III, higher megasonic power is conducive to improve the efficiency of PR removal. It takes 175s and 235s to remove 2 um PR by the megasonic method at the power of 30 W and 15W, respectively(Fig.5).

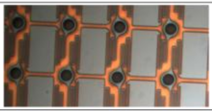
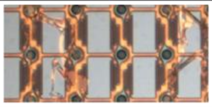
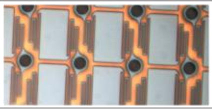
Megasonic power	Chemical time	Picture	Remark
30W	Normal rinse 55s + megasonic rinse 120s, total 175s		PR removed at all
15W	Normal rinse 55s + megasonic rinse 120s, total 175s		Edge of wafer PR residue
	Continue megasonic rinse 60s, total 235s		PR removed at all

Fig.5 Megasonic rinse at power of 30W and 15W , different process times consumed.

IV. CONCLUSION

In this paper, a new SAPS megasonic technology was applied for PR stripping. For normal structural wafer, SAPS megasonic technology improves removed efficiency and product yield greatly. Compared to the conventional single wafer rinse strategy, the SAPS technology presents the uniform megasonic energy distributed on the wafer surface, verifies implying a significant capability for photoresist removal and a perfect first pass yield. Thence, SAPS megasonic technology provides a feasible method to solve the indelible PR issue for the complex pattern.

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