Megasonic Enhanced Photoresist Strip with DiO_3

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Introduction

Twenty years ago dissolved ozone in DIW (DiO_3) found its way into the semiconductor industry as a cleaning agent. DiO_3 provides an effective replacement for Piranha (H_2SO_4, H_2O_2) cleans. The fundamental chemistry of ozone based cleaning is due to direct and indirect reactions of ozone and oxygen radicals (the so-called radical pathway). Due to its high oxidation rate the radical pathway can accelerate the reaction. Megasonic energy can act as an initiator for the radical pathway. At the same time, due to the creation of turbulence inside the boundary layer, the available ozone close to the surface is increased. In the present study this chemical physical combination was tested for improvement of photoresist strip rate.

Experimental Details

Apparatus Silicon wafers were processed on a POLOS™ Spin200 Advanced tabletop single substrate spin processor. Spin speeds, process step times and dispense functions were controlled by the Spin200 controller. A megasonic transducer and DiO_3 source were both integrated with the Spin 200 for these experiments.

A radially uniform, large area megasonic transducer, the MegPie® was used. [1, 2] This transducer couples a uniform field of acoustic energy into a fluid filled gap formed by the substrate and the single crystal sapphire face of the transducer. (figure 1)

The fluid introduction into the gap was optimized through the employment of a radial dispense manifold. In this configuration all of the process fluid was introduced through the manifold and directly into the acoustic field preventing changes caused by exposure of the process fluid to atmosphere. The radial dispense manifold facilitated an increased maximum operating spin speed and reduces the process fluid requirements. [3]

The ozonated DIW (DiO_3) was supplied by an MKS LIQUOZON® Single Ozonated Water Delivery System. (figure 2) This model is compact and suited to single substrate processing. It is specified to deliver concentrations from 5 to 95ppm at flow rates from 0.5 to 20lpm and has been well documented in other DiO_3 testing and production. [4]

Materials Five sets of 200mm silicon wafers were coated with different types and thicknesses of Photo Resist (PR) both positive and negative. Pre-strip process resist thicknesses ranged from 1um to 30um. (Table I)

Measurement PR film thickness was measured before and after the DiO_3 stripping process. Measurements were made using a Filmetrics thin-film measurement system. A 30 point pattern was used, 15 points across the wafer in x from notch, and 15 points across the wafer in y. The mean value of these readings was used for before/after comparison of the results and the difference divided by process time expressed in nanometers per minute (nm/min).

Results and Discussion

The initial tests in this experimental series were run to determine the baseline removal rate with DiO_3 alone, then DiO_3 with Megasonic enhancement. These initial tests indicated a definite improvement in removal rate through the addition of acoustic energy to DiO_3. A single test was also run with DIW and Megasonic enhancement, as anticipated no resist removal was observed.

Following these initial tests, a very wide scope of process variables was tested for the impact on removal rate with several types of PR.

Process times were determined for each PR thickness to avoid the complete removal of the PR, since a complete strip of the wafer would not allow a comparative thickness measurement. Process fluid temperature was 20°C for all tests.

Process variables tested included megasonic dosage expressed in watt density, or watts per square centimeter of the transducer active area (W/cm^2). Ozone concentration in DIW expressed in ppm, DiO_3 flow rate expressed in lpm, and substrate spin speed expressed in rpm.

Megasonic energy dosage values were one split; different power levels were applied to three wafers, all other process factors were held constant through the three tests. (figure 3) The measured results indicate a clear inverse relationship between higher megasonic dosage and PR strip rate in nm/min.

A series of wafers were run with and without megasonic energy and at two different flow rates. (figure 4) The clear difference in strip rate between megasonic and no megasonic was again demonstrated, and the balance of tests was moved to 1.4lpm.

A range of spin speeds were programmed for an additional set of wafers to determine effect of rpm on removal rate with all other parameters fixed. (figure 5) The results indicated that rpm is a very large factor in PR strip rate.

A small set of negative PR coated wafers were run, and results were mixed. The AZnLof 2070 material exhibited a reasonable strip rate (279nm/min $2W/cm^2$, 80ppm, 20c, 110rpm, 1.4lpm) while the JSR THD 126N did not respond with conventional boundary layer reaction type removal, but after extended process times, cracked into platelets of approximately 1-2 cm in diameter and then proceeded to lift off as with a standard lift of resist (LOR) process.

Conclusion

The combination of DiO_3 and a uniform Megasonic energy field in a conventional single wafer spinner significantly increases the strip rate of various positive PR coatings compared with DiO_3 alone. Improvements in strip rate of over 65% were measured. (figure 5) Variations in spin speed (rpm), flow rate (lpm), and megasonic dosage (W/cm^2) resulted in large effects on the measured strip rate. Further experiments are planned to investigate and optimize these process parameters. Improvements in mechanical and fluid flow mechanisms to allow for uniform fluid delivery at higher rpm are also being investigated. The performance with negative PR systems was of some interest and the scope of these tests will be expanded in the next experimental series.

Acknowledgements

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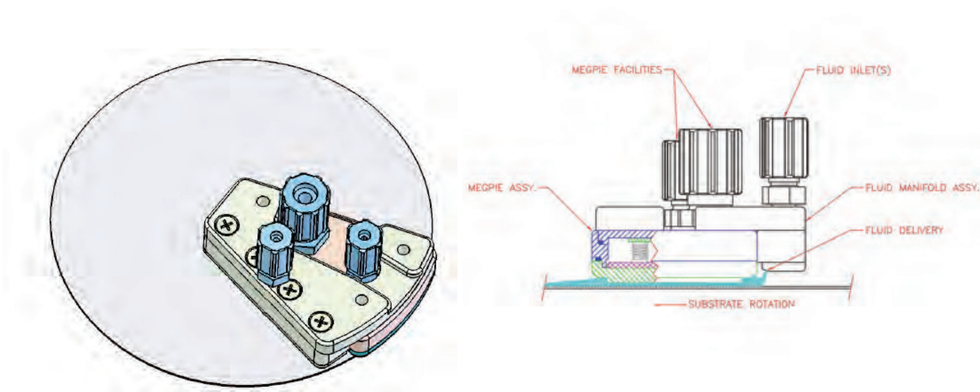

Figure 1. 200mm Sapphire MegPie® megasonic transducer in process position over a wafer, and cross section of MegPie® with Radial Dispense Manifold.

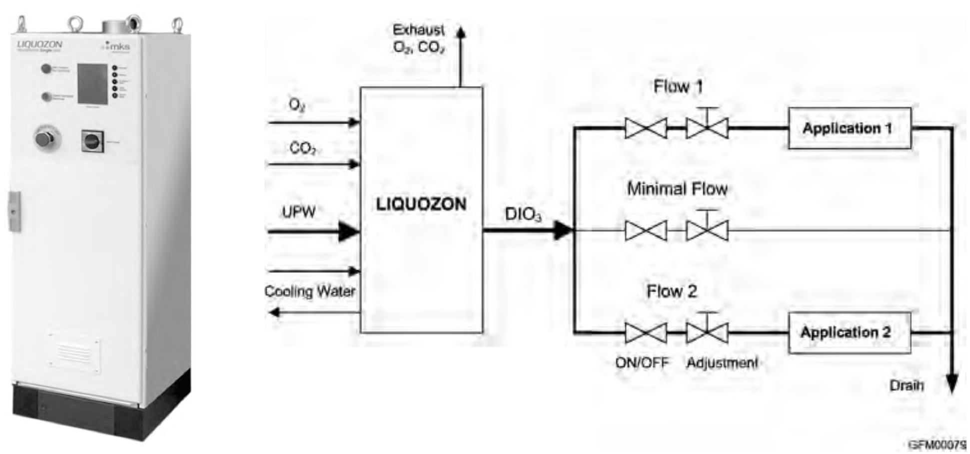

Figure 2. LIQUOZON® Single: Ozonated Water Delivery System and application schematic.

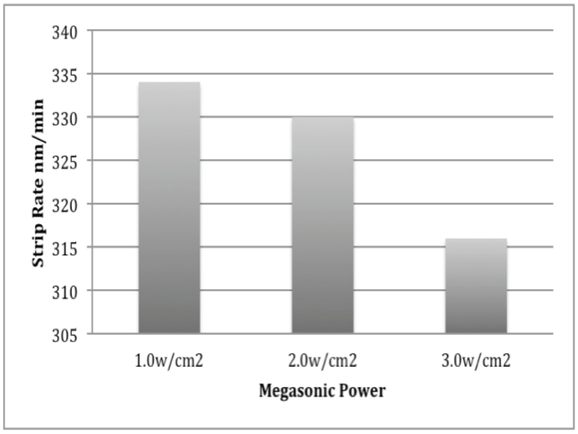

Figure 3. AZ MIR701 PR, 80ppm, 20c, 110rpm, 1.4lpm

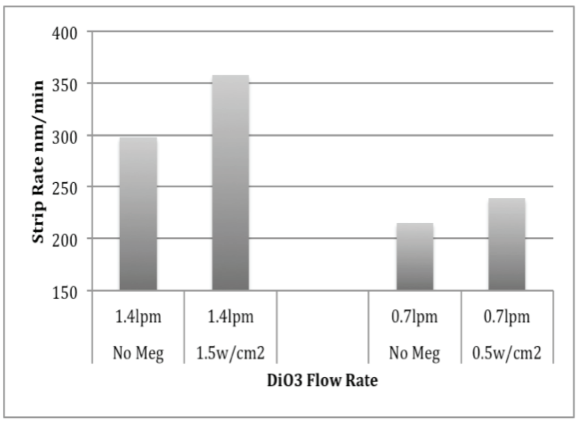

Figure 4. Comparison of flow rates, AZ9260 PR, 80ppm, 20c, 50rpm.

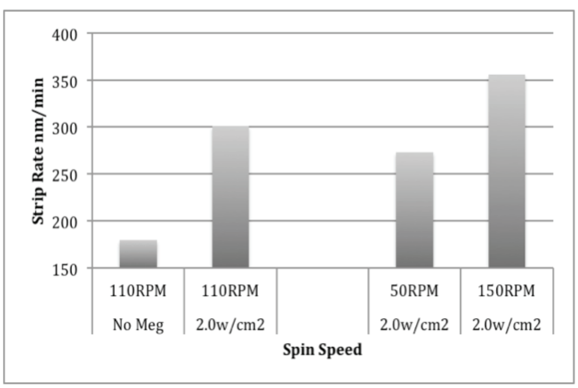

Figure 5. Comparison of spin speeds, AZMIR701 PR, 80ppm, 20c, 1.4lpm.

Table I, listing of wafers, PR, and thickness used in experimental series.

PR Type	Tone	Thickness	Process	Wafers Processed
AZ MIR 701	Positive	1um	Coated	15
AZ MIR 701	Positive	1um	Coat/exp/dev	5
AZ 9260	Positive	8um	Coated	10
AZ nLof 2070	Negative	7um	Coated	3
JSR THB126N	Negative	30um	Coated	2