ACOUSTIC PROPERTY CHARACTERIZATION OF A SINGLE WAFER MEGASONIC CLEANER

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The sound distribution for a single wafer megasonic cleaner was characterized by wafer cleaning tests, visual observations, sound measurements and modeling results. The cleaner consists of a horizontal wafer spinner and a megasonic transducer/transmitter assembly. Sound is transmitted from the transducer assembly to a horizontal quartz rod through a liquid meniscus to the wafer. The sound can travel in both radial and axial directions from the quartz rod. By varying parameters of the transducer and transmission components, the degree of radial and axial sound transmission from quartz rod can be controlled.

INTRODUCTION

Although megasonic cleaning is widely used in the semiconductor industry, the fundamental physical processes are not thoroughly understood. In addition to understanding the mechanism of particle removal, the distribution of sound within a cleaning chamber has been studied via experiments and modeling. Both flat and curved transducers have been investigated.[1]

A single wafer megasonic cleaning method was developed to address the semiconductor industry need for a single wafer cleaner that can be integrated with complementary process steps, such as dry-in/dry-out CMP processing.[2] To remove slurry and other particle contamination, a piezoelectric transducer assembly transmits sound energy along a quartz rod placed directly above the wafer. The sound is then transmitted to the wafer via a liquid meniscus between the quartz rod and wafer (Fig 1). Backside cleaning is accomplished by sound transmission through the wafer. In order to better understand how to optimize and improve cleaning performance, sound characterization investigation has been done. Impact of the quartz rod/wafer distance was previously reported.[3] This work concentrates on the sound distribution across the wafer, specifically the direction of sound transmission from the quartz rod.

EXPERIMENTAL

Cleaning Tool Details

Cleaning experiments were done in a *VERTEQ Goldfinger*, a single wafer, megasonic cleaner (Fig 1&2). The module includes: (1) a wafer chuck and spinner, (2) a megasonic transducer assembly and (3) a chemical delivery system. The megasonic assembly consists of a piezoelectric transducer assembly which is attached to a quartz rod. The transducer assembly consists of a circular piezoelectric material bonded to an aluminum cylinder. The sound (~830 MHz) is transmitted from the transducer through the quartz rod to the liquid meniscus and finally to the wafer. The quartz rod is only above the wafer; backside cleaning is done by sound transmission through the wafer. Chemicals are delivered to the wafer through spray nozzles above and below the wafer. The desired dilution is achieved by mixing H_2O with a concentrated chemical from a metering pump and reservoir in the module. For these experiments, 0.6% NH_4OH solution at 60°C was used. During standard cleaning processes, the chuck is rotated at approximately 20rpm. For characterization purposes, “static” wafer tests were run, where the wafer was not rotated during chemical processing. Afterwards, rinsing and drying (1500-2000 rpm rotation) were done on the same chuck.

Wafer Preparation

Slurry contaminated oxide wafers were prepared by (1) prewetting the wafers in water, (2) dipping for 10s in a bath of Cabot SS-25 slurry, (3) removing and placing in a dilute surfactant solution (Wako) for 10s, and (4) drying in a spin dryer prior to use. Wafer defects were measured on a Tencor 6400 (>0.20μm).

Sound Measurements

A megasonic cavitation meter (PPB-502) was used to measure the energy density of cavitation in liquids. The instrument consists of a sensing probe connected to the electronics case. The meter measures cavitation of the imploding solution bubbles and also the sound waves produced by a pressure transducer. The meter measures the energy twice per second. Experiments of interest include: (1) energy variations at a given point as a function of time, (2) energy distribution across the wafer, (3) energy changes with changes in operating parameters and (4) comparisons over the lifetime of a transducer assembly.

Modeling

Commercially available software (Wave2000) was used. The software uses a finite difference method to compute an approximate solution to a two-dimensional acoustic wave equation. The numerical solution is based on an algorithm published by Schechter.[4] The user defined parameters include geometries (of sound source, transmitter and receiver), physical properties of materials, boundary conditions, sound source conditions, receiver conditions, and parameters to control the simulation.

RESULTS

During normal processing, the wafer is rotated while megasonic energy is applied. To better understand sound distribution, “static” wafer cleaning tests were performed, during which the wafer was not rotated. Shown in figure 3 are defect maps after slurry contaminated wafers were processed under this condition. The defect maps are representative examples of processing under three different transducer setup conditions. Figure 3 also shows the orientation of the quartz rod and liquid dispense. The different transducer conditions produce different sound patterns. The radial:axial component ratio can be altered considerably.

Sound measurements were performed using the probe described in the experiment section. Figure 4 shows the normalized intensity values for transducer conditions A and B from figure 3. There is strong correlation between the clean areas on the wafers and the areas of higher signal from the sound probe. As with the wafer cleaning tests, transducer condition A has a significantly higher axial direction component than condition B.

The transmittance of the sound through the quartz rod was also modeled (2D) using commercially available software. The grid schematic is shown in Figure 5. Geometry and physical parameters of the transducer, quartz rod, wafer, water layer and receivers are inputted. The quartz rod shape was approximated as a rectangle, without considering the curved portion attached to the transducer assembly. The transducer shape was also approximated. The length and width of the quartz rod, and thickness of the water layer and wafer are consistent with experimental values. Receivers were placed in the water layer under the rod and near the end of the quartz rod. This was done to help understand the different axial and radial components seen in the previous experiments. Normalized to a sound source magnitude of 1, transducer condition A produced a signal of 0.2 at receiver 1. Since this receiver was placed just inside of the rod, a low magnitude signal indicates very little sound reflection back into the rod. In other words, the sound is transmitted efficiently in the axial direction. This is consistent with the wafer cleaning tests. On the other hand, transducer condition B produced a normalized signal of 1.1 at receiver 1, indicating inefficient transmission in the radial direction. This is also consistent with wafer cleaning data.

The sound distribution of the transducer assembly without the quartz rod was also evaluated. The flat surface of the cylindrical transducer base was placed horizontally and covered with water. After the transducer power was turned on, the water pattern was observed. Figure 6 shows photos of transducer conditions A, B and C. There is clear correlation of the water vibration pattern with the cleaning tests. Condition A shows vibration in the axial direction; “static” wafer cleaning tests show the same. Condition B shows mostly radial vibration. Condition C shows both axial and radial distribution.

CONCLUSION

Control of sound distribution has been demonstrated for a single wafer megasonic cleaner. This is accomplished by varying the transducer assembly operating conditions. Wafer cleaning tests, sound probe measurements, visual observations and modeling showed qualitative correlation regarding the radial:axial sound intensity. The single wafer cleaner can be integrated with complementary process tools in both front and back end applications. Different operating conditions may be necessary for the cleaning challenges of specific applications.

REFERENCES

1. D. Zhang, U of Minn Ph.D. Thesis (1993); Y. Wu, U of Minn Ph.D. Thesis (1997); A Busnaina et al, *J. Electrochem. Soc.*, 142 (1995) 2812; R. Hall et al, *MRS Symp Proc.*, 477 (1997) 15.
2. G. Willits and B. Fraser, *Semiconductor Fabtech*, 10 (1999) 301.
3. C. Franklin, Y. Wu, M. Olesen, M. Bran and B. Fraser, *Semiconductor Pure Water and Chemicals Conf. Proc.* (1999.
4. R.S. Schecter, *Science*, 265 (1994) 1188.

FIGURES

Figure 1. Cleaning module showing the quartz rod projecting over the wafer.

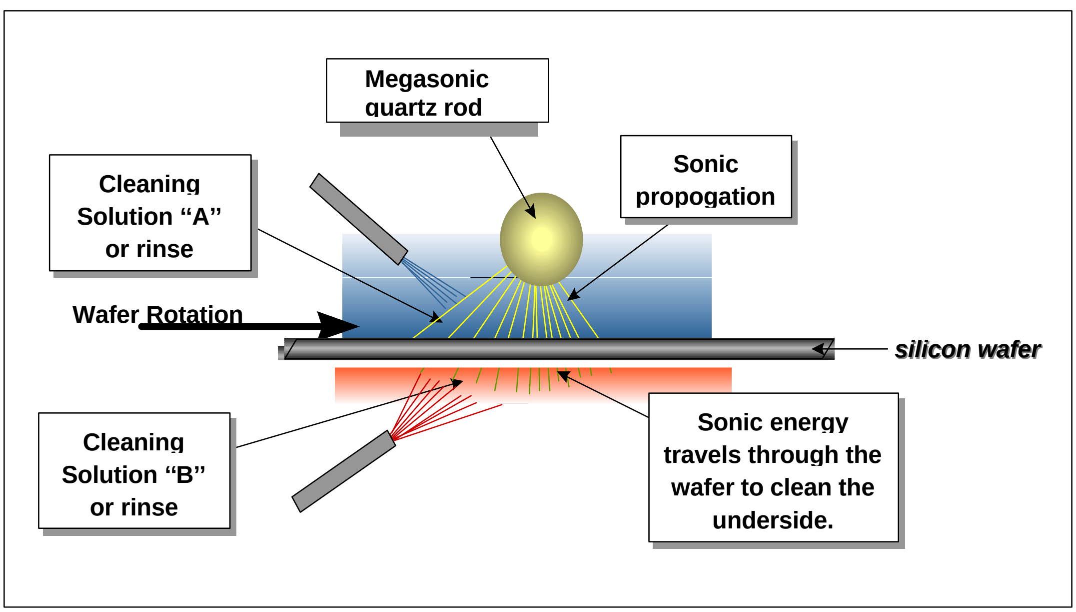
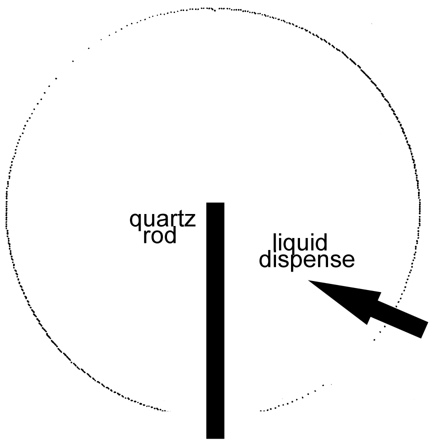
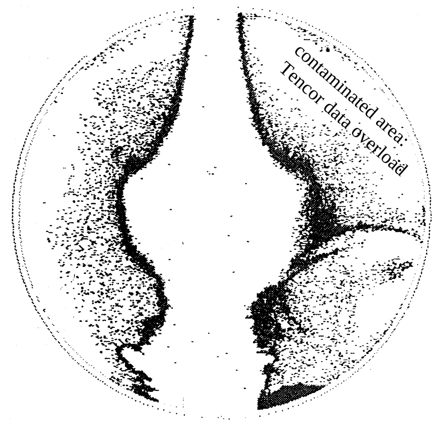


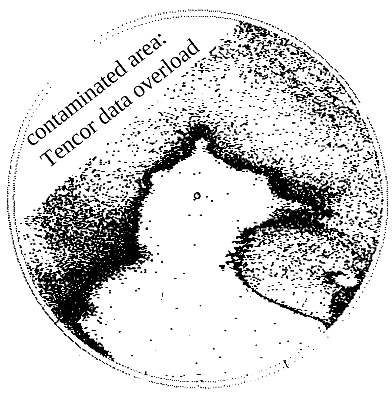
Figure 2. Schematic - megasonic energy propagation and liquid distribution.



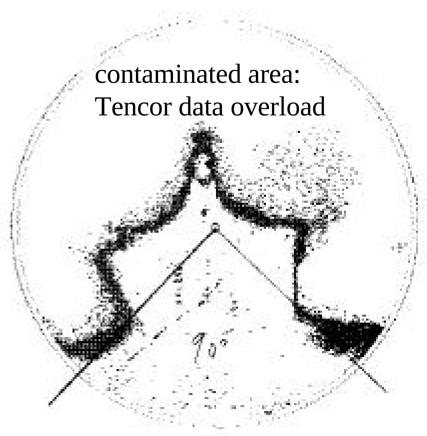
Transducer and liquid dispense orientation



Transducer setup A

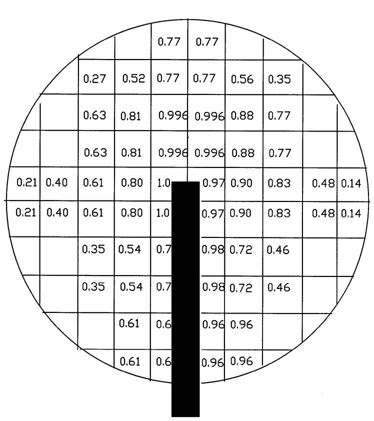


Transducer setup B

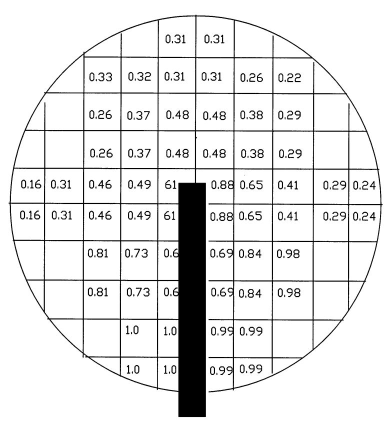


Transducer setup C

Figure 3. "Static" wafer tests - transducer and liquid dispense orientation; wafer defect maps for 3 different transducer setups.



Transducer setup A



Transducer setup B

Figure 4. Megasonic probe intensity measurements - normalized

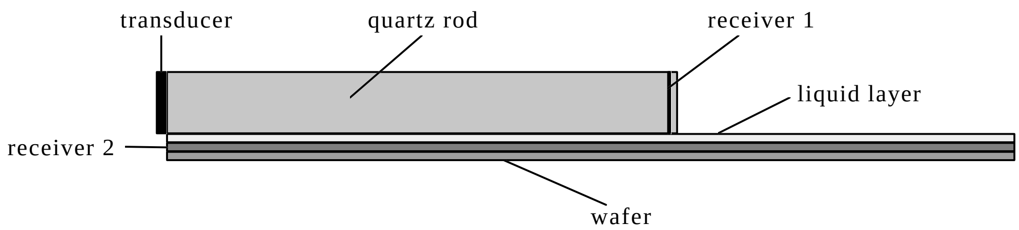
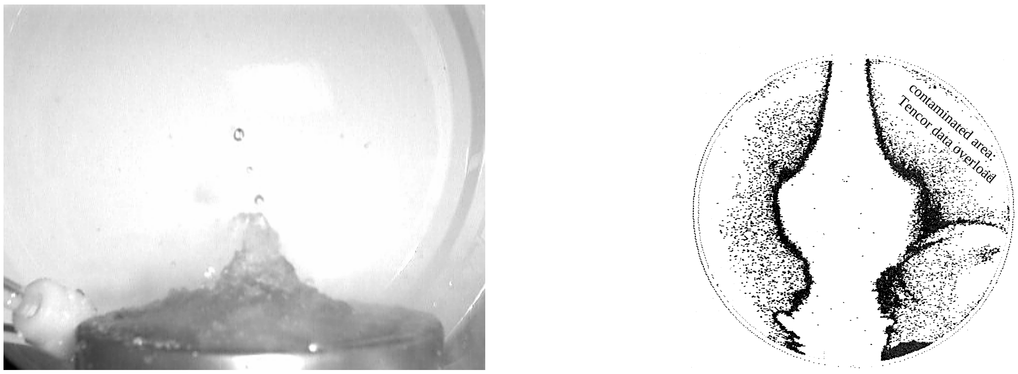


Figure 5. Schematic used for 2D simulation



Transducer Condition A

Transducer Condition B

Transducer Condition C

Figure 6. Photos - water placed on transducer assembly without quartz rod - transducer conditions A,B,C.