A Multi-frequency Megasonic System for Nano-particle Removal

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1. Introduction

In semiconductor manufacturing, main processes can be classified as film deposition, photolithography, etching, ashing and cleaning. Among them, cleaning is a crucial step for preparing subsequent processes, providing reliable substrate surfaces without contaminated nano-particles. Traditionally, wet-bench type cleaning was dominant using such as standard cleaning 1 (SC-1) and standard cleaning 2 (SC-2) methods [1]. But as diameters of wafer substantially have increased, single-wafer cleaning has been adopted alternatively, and used in industrial fields [2]. In addition, even smaller particle size criteria has been demanded in cleaning process, so another effective method was needed in detaching nano-particles from substrates. Single-wafer megasonic systems have been proposed for these reasons and they are regarded as one of major potential cleaning tools [3, 4]. In megasonic cleaning, physical forces from a vibrating piezoelectric actuator are acting on contaminated particles with chemical activity in the sub-micron size range [5]. But there remains energy efficiency issue and complicated system structures to be improved. In this paper, a multi-frequency megasonic system for nano-particle removal was proposed. This system adopts both 1 MHz and 3 MHz operating frequencies in one system for raising energy efficiency. In designing the system, finite element analysis using ANSYS software was performed to predict anti-resonance frequencies. Based on these results, the megasonic system is fabricated and the performance is assessed by measuring acoustic pressures. In addition, particle removal efficiency (PRE) tests are preformed and compared with a conventional product.

2. Multi-frequency megasonic system

Schematics and working principle of the multi-frequency megasonic system are shown in Fig. 1. The megasonic is mainly composed of a cylindrically shaped quartz waveguide and lead zirconate titanate (PZT) actuators (1 MHz and 3 MHz) inside. When working, the waveguide is placed over a wafer and de-ionized (DI) water with chemical are supplied for removing particles. To design the multi-frequency megasonic wavegude, analysis was performed to predict impedance characteristic using finite element method (FEM) software ANSYS. As a result, the anti-resonance frequency of the quartz waveguide for 1 MHz actuating was 1000 kHz, which agreed well with the measured value of 995 kHz as 0.5% error. In addition, the predicted anti-resonance frequency of the waveguide for 3 MHz actuating was 2998 kHz, which coincided with the measured value. Reflecting these analysis results, the quartz waveguide was fabricated and acoustic pressures were measured. The measured pressure distributions are shown in Fig. 2. Relatively well-distributed acoustic pressures could be observed.

3. PRE test

For the assessment of the cleaning ability, PRE tests were processed using an experimental setup shown in Fig. 3. 60 nm particles were deposited on a bare wafer and the number of particles before and after cleaning, were counted using a particle counter. The PRE with different input powers was plotted compared with a conventional product as shown in Fig. 4. The result gave us 56.1% PRE improvement compared with the commercially available system.

4. Conclusion

In this work, the multi-frequency megasonic system for nano-particle removal was developed. In the design process, FEM analysis was performed and the anti-resonance frequencies were predicted well for 1 MHz actuating as 995 kHz with 0.5% error to the measured value of 1000 kHz, and for 3 MHz as 2998 kHz, which coincided with the measured value. To assess the cleaning ability, PRE tests were performed and the results showed that 56.1% PRE improvement was achieved compared with a conventional product. These results imply that the developed system can be applied to nano-particle cleaning process with higher efficiency.

References

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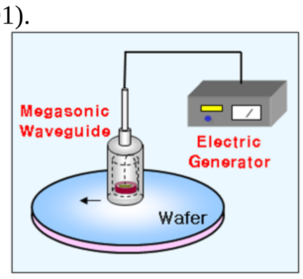

Fig. 1. Schematics and working principle of the multi-frequency megasonic system.

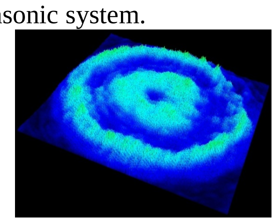

Fig. 2. Measured acoustic pressure distributions.

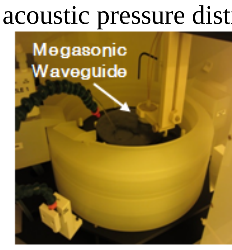

Fig. 3. Experimental setup for the PRE test.

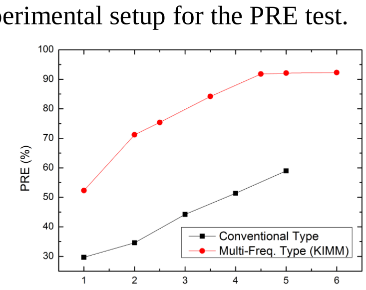

Fig. 4. PRE test results: PRE vs. input power.