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Sound pressure measurement of the waveguide type ultrasonic cleaning machine using fiber optic probe hydrophone

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1. Introduction

Sound pressure control in the high frequency ultrasonic cleaning machine is very important because the breaking cavitation bubbles cause the severe damage in the micro pattern on the semiconductor wafer. Therefore, the precise sound pressure measurement in the high frequency, such as 1 or 2 MHz, is requried in the cavitation occurring environment. The authors proposed the new waveguide type ultrasonic cleaning machine (WGUCM) which can produce the appropriate sound pressure distribution in the semiconductor celaing and which also has flexibility against the installation in the semiconducor manufacturing appratus[1,2]. However, accurate sound pressure measurement of the WGUCM is difficult since the conventional hydrophone which consists of PZT thin disk element cannnot be applied in the cavitation. As the new sound pressure measurement method, the fiber optic probe hydrophone (FOPH) has been already realized[3,4]. The principle of the FOPH is based on the index varition due to sound pressure at the fiber end. However, the cavitation noise reduces the accurary due to large difference of the reflection coefficient between water and cavitation bubbles. In this report, the FOPH is applied the sound pressure meaasurement of the WGUCM. And the elimination of the caviation noise in the measurenet is carried by the discrete wavelet transformation (DWT).

2. Configuration of FOPH and WGUCM

Figure 1 shows the WGUCM. The PZT disk vibrates in the thickness mode at 950kHz. The PZT disk is set apart from the end of the waveguide tube. The waveguide is created in a straight or curved shape. The cleaning solution is supplied through the waveguide. Ultrasonic wave generated are emitted together with the flowing solution and irradiate the substrate. It is possible to supply ultrasonic waves at a distance from the PZT disk; thus, only a narrow space is required for its use. Figure 2 shows the configuration of FOPH. A C-band amplified spontaneous emission (ASE) light source (ASE-C-10S, Fiber Labs Inc.) is employed where the wavelength is from 1530nm to 1570nm. The light is propagated through the single mode glass fiber(SMF) and is emitted from the fiber end. Reflection intensity depends on the index of the water in the front of the fiber end. Index of the water is proportional to the density of the water. The density is also proportional to the sound pressure at the fiber end. The propagation path of the reflected light is changed by the circulator and is incident on the photo diode(PD). The PD output is amplified and the output waveform is observed by the oscilloscope. The sensitivity of the hydrophone is 2.25×10^{-5} mV/Pa.

3. Measurement results

The sound pressure distribution inside the waveguide was measured in 15mm from the waveguide end. In Fig.3, the distribution of the fundamental component and the second harmonic of measurement waveforms are indicated. According to the previous papers[1,2], the harmonic components were also measured using the glass rod type hydrophone. In the glass rod type hydrophone, the output was saturated against the input power of the UCM since the adhesive layer between the PZT elements and the glass rod is softened due to ultrasonic vibration energy propagated through the glass rod. And also, the sound waves are incident on the side surface of the glass rod in the addition with

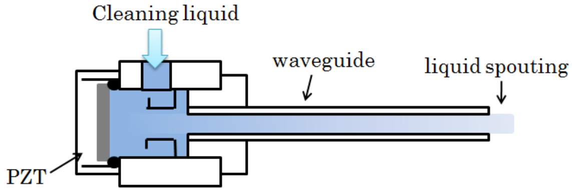

Fig.1 Configuration of the waveguide type ultrasonic cleaning machine (WGUCM).

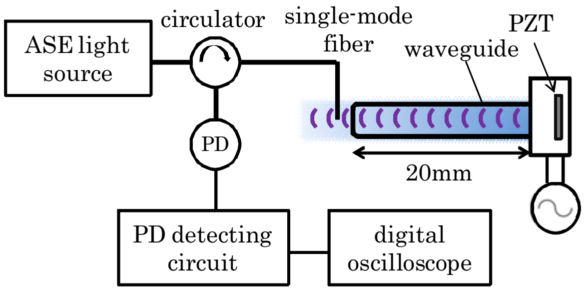

Fig.2 Configuration of the FOPH.

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the glass rod end which is measured point. And, hence, the sound pressure inside the waveguide is measured accurately using FOPH. The difference of the fundamental components and the second harmonic components distributions are appeared. As the intensity of the second harmonic increases, the fundamental component decreases in the distance of 20mm from the guide end. The measured waveform includes higher harmonic components. When the diameter of the cavitation bubbles is almost same as or larger than the diameter of the optical fiber core, the output is a waveform as shown in Fig.4. And, hence, the micro cavitation bubbles of which diameter is less than the fiber core gives influence on the output .

4. Elimination of the cavitation noise using DWT

Figure 4 shows the measured waveform in 20mm from the glass guide end. Impulse noise which corresponds to cavitation noise, often appeared unlike inside the glass guide. As inside cavitation is almost vaccum, these noise pulses occur due to the difference of the index between 1.32 of water and 1.00 of air. In order to reduce the cavitation noise, the DWT is applied. The DWT is suitable for the detection of the impulse noise in the periodic waveform. Figure 5 shows the elimination signal process using DWT. After application of the DWT to the original waveform, the high level magnitude data are extracted. The high level magnitude data in the WT corresponds to the impulse noise which includes the high frequency components. After inverse DWT process, the impulse noise waveform in the time region is obtained. Next, the impulse noise waveform subtracts from the original waveform. And, then, the output waveform which reduces the cavitation noise can be obtained. Figure 6 shows the spectrums of the waveform without the signal process and with the signal process. It is confirmed that the cavitaion noise components with the process in the high frequency noise reduces in the comparison with the spectrum without the signal process. And the sound pressure with the process in the fundamental component is lower than that without the process because cavitation noise also has the fundamental components. And, hence, it is considered that the elimination of the cavitation noise reduces the fundamental components.

Our future plan is to increase the precision of the measurement using multiple FOPHs.

References

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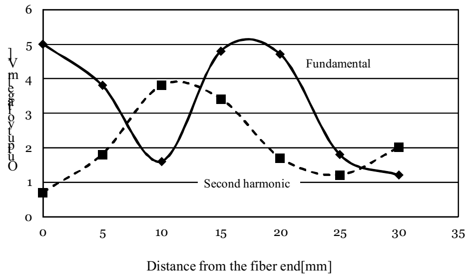


Fig.3 Sound pressure distribution inside the wave guide of WGUCM.

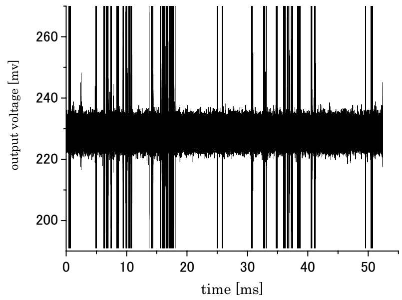


Fig.4 Output waveform of the FOPH at 20mm from the glass waveguide end.

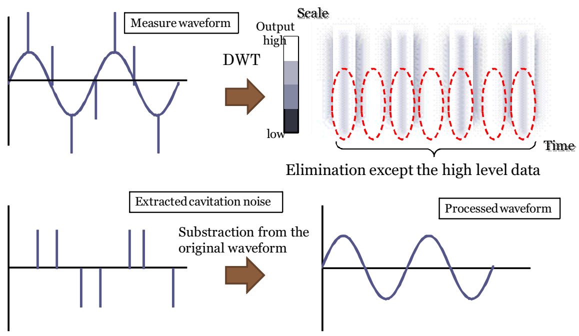
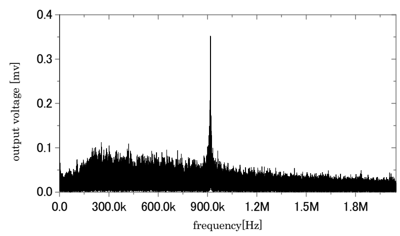
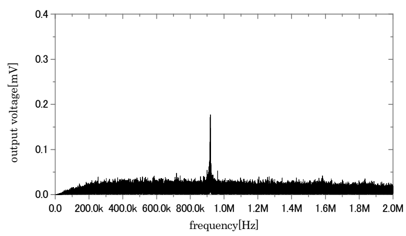


Fig.5 The process sequence of the reduction of the cavitation noise using DWT.



(a) without process



(b) with process

Fig.6 The comparison of the spectrums between without process and with process.